DESALINATION AND DEVELOPMENT: THE SOCIOECOLOGICAL AND TECHNOLOGICAL TRANSFORMATION OF THE GULF OF CALIFORNIA

by

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DEDICATION

To my family, Glenn, Darcy and Aron, for their love and support

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ABSTRACT

The provision of freshwater, particularly in urbanizing arid regions facing increased variability in precipitation patterns due to climate change, is one of the greatest challenges. Desalination—the conversion of seawater or brackish water to potable water—offers a potentially “limitless” supply of this vital resource. The preference for desalination, as an innovative, supply-side water augmentation option is gaining traction worldwide, including in northwestern Mexico. In arid regions, where water is a limiting factor to increased production and growth and nearly every drop of water is contested, a new technology that augments water supplies is likely to engender vast social, economic, institutional, and environmental transformations. Through an in-depth study of water management in the context of global climate change in northwestern Mexico, this dissertation examines the factors that lead to the adoption of desalination technology and assesses how the technology affects the communities where it is implemented. In seeking to understand the (potential) transformations and complex imbrications of this technology within the socioecological system in which it operates, four themes have emerged, including: 1) The best path towards improved water management is through investments in both infrastructure and institutions (i.e., governance); 2) Despite the real and urgent need to address the negative impacts of climate change on water resources, desalination should be considered as a “last resort”; 3) While desalination can increase water security at certain scales, it also introduces new vulnerabilities; and 4) While discursively, Mexico’s water policy embraces principles of contemporary environmental governance (i.e., decentralization, public participation, and sustainability), these principles have yet to

be fully implemented in practice. Policy recommendations include integrating land use and water planning, improving monitoring and regulation of groundwater extraction, increasing capacity building within water and planning agencies, and pre-conditioning desalination (or other supply-side water infrastructure projects) upon the successful implementation of a range of water conservation and system efficiency measures. Without such measures, increased water availability is likely to encourage additional growth, rather than resource conservation. Specific findings and contributions of this dissertation to the field of human-environment geography are discussed at the end of chapter two and in the appended articles.

INTRODUCTION

In 1965, U.S. President Lyndon B. Johnson imagined that one day we would “free mankind from Nature’s tyranny” by converting limitless saline water to freshwater through the use of desalination technology (Johnson, 1965: 865). In 1965, President Johnson and Mexican President Gustavo Díaz Ordaz signed an agreement to explore the feasibility of a joint U.S.-Mexico nuclear powered desalination and energy production facility (UMIAEA, 1968). A U.S.-Mexico-International Atomic Energy Agency study (UMIAEA, 1968) concluded that, “large dual purpose plants using nuclear energy are technically feasible means of providing power and fresh water to the [northeastern Mexico and southwestern U.S.] area studied.” (p. v). However, during this same time period, a dispute between the U.S. and Mexico in the 1960s regarding the quality of the water being delivered to Mexico, strained the relationship, particularly in regards to collaboration on water resources projects between the two countries and the desalination project was abandoned.

Fast forward forty years and continued growth, along with prolonged drought conditions and the specter of climate change impacts on water resources have prompted water managers on both sides of the border to reconsider this technology as a drought-proof solution to meet current demands and buffer against future water variability (Water Education Foundation, 2010). The International Boundary and Water Commission (IBWC), the institution responsible for settling issues related to boundary and water treaties between US and Mexico has established a core working group dedicated to finding new water resources, including proposed binational desalination projects in

Ensenada, Baja California, Rosarito, Baja California, and Puerto Peñasco, Sonora (McEvoy and Wilder, 2012; López Pérez, 2009; Salmón, 2009). As part of the 2007-2012 National Infrastructure Program, the Mexican federal government has identified eight priority desalination projects in northwestern Mexico (Conagua, 2012a) (figure 1). These plans illuminate the role that desalination plays in the imaginaries of water managers, planners, and developers in achieving the modern dream of making the desert bloom and overcoming water scarcity as the limit to growth and development.

1. Tijuana, BC
2. Guaymas, SON
3. Ensenada, BC
4. Ensenada, BC (La Misión)
5. La Paz, BCS
6. Los Cabos, BCS (Expansion)
7. Puerto Peñasco, SON
8. Loreto, BCS

Figure 1. National Infrastructure Program’s priority desalination projects (Conagua, 2012a)

In addition to these proposals, in Baja California Sur, there are two large-scale private desalination-dependent projects planned for the Gulf of California region which, if constructed, could have significant socioecological implications. The first is Cabo Cortés, a mega-resort proposed by a Spanish development company, with 27,000 hotel rooms, 2 golf courses, a marina, various commercial areas and a desalination plant that would produce 750 liters of water per second (lps) to supply part of the water needed for the development (Hernández, 2012). Cabo Cortés would be located just outside Cabo Pulmo, a National Marine Park, which is one of the most robust marine preserves in the world (Hernández, 2012; Aburto-Oropeza et al, 2011). The Park contains a productive and diverse coral reef, which is the only living coral reef in the Gulf of California, and one of the few reef ecosystems found in the eastern Pacific Ocean (Arizpe Covarrubias, 2008). However, the development of the mega-resort Cabo Cortés has been put on hold because of concerns about the discharge from the desalination plant and other impacts.

A second desalination-related development is an open-pit gold mining operation, located just outside the Biosphere Reserve of La Sierra La Laguna. The mining operation, proposed by a Canadian company, would require an estimated 3.8 million liters of water a day (Agua Vale Mas Que Oro, n.d.). The company plans to build a seawater desalination plant that could produce 7,500 m^3 per day (equivalent to 87 lps) and transport the produced water via aqueduct to the mining operation (Entre dos Mares S. de R.L. de C.V., 2011: 6). Environmental groups and local businesses have expressed opposition to the mining operation due to concerns about arsenic pollution that could contaminate the aquifer – the major source of water for region (Agua Vale Mas Que Oro, n.d.).

Research Questions

In arid regions, where water is a limiting factor to increased production and growth and nearly every drop of water is contested, a new technology that augments water supplies is likely to engender vast social, economic, institutional, and environmental transformations. This dissertation aims to understand the (potential) transformations and complex imbrications of this technology within the socioecological system in which it operates. Due to the very recent emergence of desalination as a preferred water policy strategy, this dissertation examines the factors that lead to the adoption of desalination technology as a climate change adaptation and development strategy and assesses how the technology affects the communities where it is implemented. The broad research questions that guided my fieldwork include:

1. What is the legal, political, and economic context in which desalination is adopted?
2. How does the adoption of desalination technology affect:
    a. water provision and management?
    b. the creation of new institutions to manage and regulate the emerging industry?
    d. vulnerability, adaptive capacity, and water security at various scales?
3. How do socio-environmental drivers shape the implementation of desalination technology?

My dissertation research addresses these questions through an in-depth study of desalination and water management in the context of global climate change in northwestern Mexico (see description of case study contexts and methods below).

Contributions of the Dissertation

My critical examination of how desalination technology transforms and is transformed by social and environmental relations contributes new knowledge and understanding to the fields of human-environment geography; water resources management; climate change adaptation; technological risk; political ecology; and science and technology studies. By using a grounded case study approach, my research details how, why, and under what conditions the choice to adopt desalination technology was implemented, or considered. Such grounded research helps to improve our theoretical understanding of the technology-society-nature relationship. It also provides insights into issues of equity and fairness in water management decision-making by examining the distribution of the costs and benefits of desalination technology at various scales. The multi-scalar case study approach allows for a nuanced understanding of the degree to which desalination can be used to reduce water supply vulnerabilities and improve water security, as well as the implications of relying on desalination as a climate change adaptation strategy. It also considers the ways in which desalination might be a 'maladaptive' strategy. Lastly, the regional focus on water management in Mexico provides an in-depth analysis of four key issues in contemporary environmental governance (i.e., decentralization, private sector involvement, public participation and environmental sustainability). A summary of the major research findings and contributions to the area of research is discussed in more detail in the final section of chapter two and the appended articles.

Explanation of the Problem

The provision of freshwater, particularly in urbanizing arid regions facing increased variability in precipitation patterns due to climate change, is one of the greatest challenges. Water resources, are not only a necessity for human life, but also a vital input into agricultural and industrial production, as well a crucial element of many ecosystem functions. Many regions are facing water scarcity, where demand for the resource outstrips natural supply. This has led to the over extraction of groundwater aquifers and complex interbasin transfers that have significant social and environmental costs (Postel and Richter, 2003).

In addition to the challenges posed by population and economic growth, climate change is expected to have deleterious impacts on scarce water supplies in many regions. In the southwestern U.S. and northwestern Mexico climate models project increased temperatures, increased evaporation, increased length in dry spells, intensified droughts, and greater variability in rainfall patterns – all of which will negatively impact water resources (Garfin et al, 2013; Magaña et al, 2012; Wilder et al, 2010; IPCC, 2007; see also Milly et al, 2008).

In light of these changes, desalination is being promoted by various local, state, and regional decision-makers as an adaptation response that can allow the arid west to meet increased water demands driven by increasing population and economic growth, as well as buffer the region's water supply against climate change. Desalination as a "drought-proof" solution to water scarcity and future climate change (Cooley, Gleick, and Wolff, 2006: 2) has appeal worldwide. According to the International Desalination Association's 24th Worldwide Desalting Plant Inventory, worldwide there are nearly16,000 desalination plants with the capacity to produce over 71 million cubic meters (MCM), equivalent to 57,500 acre-feet (AF) of water per day (IDA, 2011). The capacity to produce desalinated water has grown by 57 percent in the last five years (GWI, 2012).

There are several reasons for the increased interest in desalination including growing water demands, conflicts over limited clean water supplies, and concerns about future water availability due to climate change impacts on water resources. Desalination is considered to be less politically divisive than some water management options (e.g., water transfers or conservation measures). Kuhlhoff and Roberts (2007) suggest that the move to desalination in the US-Mexico border region is less politically divisive than rural-to-urban transfers that pit powerful irrigation districts against municipal bureaucracies. A technological fix does not call into question the growth paradigm that drives regional water policy, nor does it require policy-makers to address the long-run trade-offs between different values and uses of water (Waterstone, 1992). A final factor that has contributed to the increased appeal of desalination is that improvements in membrane technology and energy recovery devices have resulted in a dramatic reduction in the cost of desalinating water. So while desalination is an energy intensive (and hence expensive) water supply option, it is becoming an increasingly attractive augmentation option.

But desalination is not a benign technology. A National Research Council (2008) analysis of desalination technology found that there is a “limited amount of long-term research” and a “considerable amount of uncertainty” about the environmental impacts of desalination (p. 144). The limited research conducted on the impacts of seawater desalination has mainly focused on the direct environmental impact of the saltwater concentrate or brine discharge on marine ecosystems (NRC, 2008). Findings from existing studies are inconclusive, with some studies indicating minor to major impacts on marine ecosystems, while others found no significant impacts (NRC, 2008: 130). My research does not provide an in-depth study on the direct environmental impacts of the discharge management, but rather builds a comprehensive framework for assessing the full range of risks and impacts of the technology (see appendix A). My research also seeks to understand how environmental impacts are being considered and evaluated in the planning process, as well as to assess the current institutional and regulatory arrangements for the management of desalination technology in northwestern Mexico. While much of the existing research is focused on the direct impact of the brine discharge on marine ecosystems, my research focuses on the potential *indirect* environmental impacts of the technology. Desalination technology has embedded processes of development and environmental transformation within it, including, for example, development of hotels and tourist attractions in undeveloped coastal areas. On one hand, developing a new source of freshwater could protect aquifers and provide more water for in-stream environmental uses (Sax et al, 2006). On the other hand, an increased supply of freshwater would likely encourage urban growth, which is associated with a range of environmental impacts (e.g., air and water pollution, habitat fragmentation, and loss of biodiversity) (Sax et al, 2006; Johnson, 2001). Previous research on efficiency and conservation, suggests that, according to Jevons Paradox, technological progress and increased efficiency, actually increases (rather than decreases) the rate of consumption of the resource (Alcott, 2005). Some residents in arid regions are hesitant to conserve water because they fear that increased conservation will simply allow for further growth (Ormerod, 2010). As Smith (2009) notes, desalination can allow arid regions to “have limitless development ‘cake’ and eat it too” (p. 77). My research examines the indirect environmental impacts of desalination in northwestern Mexico.

Literature Review

Water Resources Governance: From Supply Management to Demand Management

In analyzing the social, political, economic, and environmental conditions under which desalination technology is adopted, it is important to consider literature regarding water resources management challenges and trends. Three key challenges facing water managers in arid regions are: 1) urbanization and increased demands for limited water supplies 2) climate change, which is expected to negatively impact water resources by prolonging droughts, increasing temperatures and evaportranspiration rates, and making rainfall patterns more variable and 3) lack of investment in water infrastructure (IPCC, 2007; Ray et al, 2007; Pineda, 2006; Gleick, 2000). Historically, water managers and engineers have relied on large, state-led infrastructure projects to provide subsidized water for irrigation, and increasingly urban development (Kallis and Coccossis, 2003; Saurí and del Moral, 2001). This technocratic approach, referred to as the "hydraulic paradigm" or "hard path planning," focused primarily on increasing water supply. But, as Ingram, Whiteley, and Perry (2008) note, this paradigm largely ignored issues of equity, which resulted in an uneven distribution of costs and benefits, with marginalized social groups and the environment typically incurring the greatest costs of water projects.

Due to a growing recognition of the negative environmental and social impacts of many of these projects, along with the high financial costs of constructing and maintaining large-scale infrastructure projects and the broader political-economic restructuring that undermines the foundation of this paradigm, some scholars have declared "the end of the hydraulic era" (Gleick, 2000; World Commission on Dams, 2000; Gleick, 2003; Kaika, 2003; Kallis and Coccossis, 2003; Postel and Richter, 2003; Ingram, Whiteley, and Perry, 2008; see also Glennon and Pearce, 2007; Saurí and del Moral, 2001). In the last 25 years, a new paradigm, often referred to as Integrated Water Resource Management (IWRM), has emerged to replace the state-led, supply-focused hydraulic paradigm. This market-led approach to water management has the twin goals of achieving neoliberal efficiency (often through privatization or decentralization) and environmental sustainability (Conca, 2006). It is characterized by a move from government (centralized) to governance (decentralized) (Kaika, 2003), the application of economic principles to encourage rational use, market rationale (Saurí and del Moral, 2001), inclusion of environment as a recognized water "user" (i.e. laws for in-stream flows), increased stakeholder participation (Kaika, 2003), use of efficient technologies (e.g., drip irrigation, fix leaky pipes, line canals) (Gleick, 2003; 2000), and a re-allocation of water among competing interests (Glennon and Pearce, 2007; Gleick, 2003). In sum, this paradigm marks a shift from a focus on supply management to an emphasis on demand management.

Mexico, following Chile's example, was one of the early adopters of the efficiency and sustainability paradigm, closely observing the World Bank's prescriptions for development of water markets, privatization of rights and services, decentralization, and elements of public participation when it adopted a new National Water Law in 1992 (Wilder, 2010). Mexico became a model for the rest of Latin America with its modernized water policy, and showcased its progress by hosting the World Water Forum in 2006. Nevertheless, today water is still inequitably distributed and centrally controlled especially in water-scarce, arid regions of the country (Wilder, 2008a; Castro, 2007). Despite the push to move away from expensive, large-scale, supply-driven water infrastructure projects, desalination is becoming the preferred water augmentation strategy in northwestern Mexico.

Science, Technology and Society: A Dialectical Relationship

STS scholars, political ecologists, and assemblage theorists are not only interested in examining the social conditions that shape the adoption of certain policies and technologies, but also seek to understand how technology itself spawns the creation of new social institutions (Jasanoff, 1990), the degree to which technology should be considered an “autonomous” object with the agency and capacity to determine the developmental path of society (Winner, 1977), how technology changes people’s perception of the normal state of affairs (Robbins, 1991; Winner, 1977), and how technology shapes the production process and livelihoods (Marx, 1976).

In studying the emergent social institutions that are created during the process of technological adoption, Winner (1977) uses the term “reverse adaptation” to describe “the adjustment of human ends to match the character of the available means” (Winner, 1977: 229). Birkenholtz (2009) uses this concept to examine how the proliferation of tubewell technology in Rajasthan, India fosters the formation of new social institutions. He defines this as a process, “where daily production activities are reverse adapted to meet the demands of the object” (p. 133). He shows how tubewells not only “intensify and extensify production” but also “demand the further creation of new social institutions” such as cooperative tubewell partnerships (p. 128). Birkenholtz drew theoretically from Robbins' (1991) study of how GIS and remote sensing technologies affected the classification and management of forests in Rajasthan in a process of reverse adaptation. Robbins also examined how the technologies "changed the perceptual apparatus of development professionals and local people" (p. 162). Jasanoff (1990) focused on the formation of institutions, specifically regulatory institutions, through the interactions of policymakers and science advisers. Shivelbusch's (1977) history of trains shows how the advent of modern transportation changed both institutions (e.g., by requiring the creation of new laws and political-economic arrangements that would allow the new industry to function and grow), as well as human perception and consciousness (e.g., the speed of rail technology created new ways of perceiving the landscape and motion). White (1995) suggests that the construction of hydroelectric dams in the Pacific Northwest drove the demand for electricity and local growth (rather than the other way around). Even Marx (1976) observed how technology creates new needs and desires. Furthermore, Marx noted the important role that technology plays in shaping development trends, production processes, livelihoods, and social relations (Marx, 1976). In arid regions, where water is often a limiting factor to increased production and growth, a new technology that augments water supplies is likely to change development patterns, livelihoods, and social relations. This study examines these changes, as well as what types of agencies and institutional arrangements (i.e., organizations and agencies, as well as rules and norms) develop to manage the newly produced resource.

Climate Change, Vulnerability, and Adaptation in the Water Sector

Within the social sciences, and particularly among geographers, there is an emerging field of study related to climate change vulnerability and adaptation. Ribot (2010) and Ribot and Agrawal (2010) emphasize that vulnerability is "the risk of damage in the face of a climate trend or event" (Ribot and Agrawal, 2010: 1), but these climate trends or events are "transformed into differential outcomes via social structure" (Ribot, 2010: 49). As such, vulnerability is produced by "on-the-ground" inequalities and political economic conditions, rather than "falling from the sky" (Ribot, 2010: 49). This conception of vulnerability as a socially produced phenomenon fits with Adger et al.'s (2006) view that vulnerability is conditioned by socioeconomic, institutional, and political, as well as environmental factors, including climate. Assessing vulnerability requires consideration not only of exposure to climate change, but also of the risk associated with that exposure and the capacity of an individual, community, or nation to adapt to impacts of climate change (Adger et al, 2006).

Adaptation is therefore a policy or practice that reduces vulnerability to the negative impacts of climate change. Conversely, maladptation, as defined by the Intergovernmental Panel on Climate Change (IPCC, 2010) refers to "any changes in natural or human systems that inadvertently increase vulnerability to climatic stimuli" (p. 378). Ribot (2010) and Mearns and Norton (2010) emphasize the need to evaluate adaptation strategies at multiple scales, and among different sectors within society. They observe that adaptive strategies are likely to have uneven impacts, making some members of society better off and more resilient to climate change, while (inadvertently) making other members more vulnerable. This literature suggests that in evaluating desalination as an adaptive strategy, it is important to consider the distributional equity of costs and benefits. This research examines the embedded social implications of desalination technology for reducing or increasing social vulnerability in the context of climate change.

Technological Risk: The Unintended Consequences of Modernity

Empirical and theoretical research on modernity, technology, and risk suggests that technologies often have unintended consequences that can harm society and the environment (Beck, 2009; Perrow, 1999; Beck, 1992; Winner, 1977). According to cultural theorist Mary Douglas (1992) the dominant view that nature is robust and able to withstand unlimited growth encourages “bold, individualistic experimentation, expansion, and technological development” (p. 263). Yet Beck’s theory of the “risk society” – in which the very “triumphs” of modernity bring about new, and often uncontrollable risks – should give us cause to question what the unintended consequences of technological developments might be. This research incorporates insights from the field of risk and hazards to analyze desalination as a water augmentation strategy.

Case Study Context

Case Study Description: Puerto Peñasco, Sonora

Puerto Peñasco is a burgeoning coastal resort community located on the Gulf of California. Just a four and half hour drive from Tucson, Arizona, Peñasco is a favorite beach and retirement destination for landlocked Arizonans. The depleted groundwater aquifers can no longer support the growth that has recently been the economic engine of

Peñasco, so water managers are searching for new ways to augment local water supplies. Peñasco's municipal planners and officials have pinned their hopes on the construction of a major desalination plant to serve municipal needs (figure 2). The desalination proposal has significant binational implications, since both Arizona and Nevada water authorities have plans to potentially utilize desalinated water from the Peñasco plant to provide water for urban dwellers in Phoenix, Tucson and Las Vegas, or farmers in Yuma.

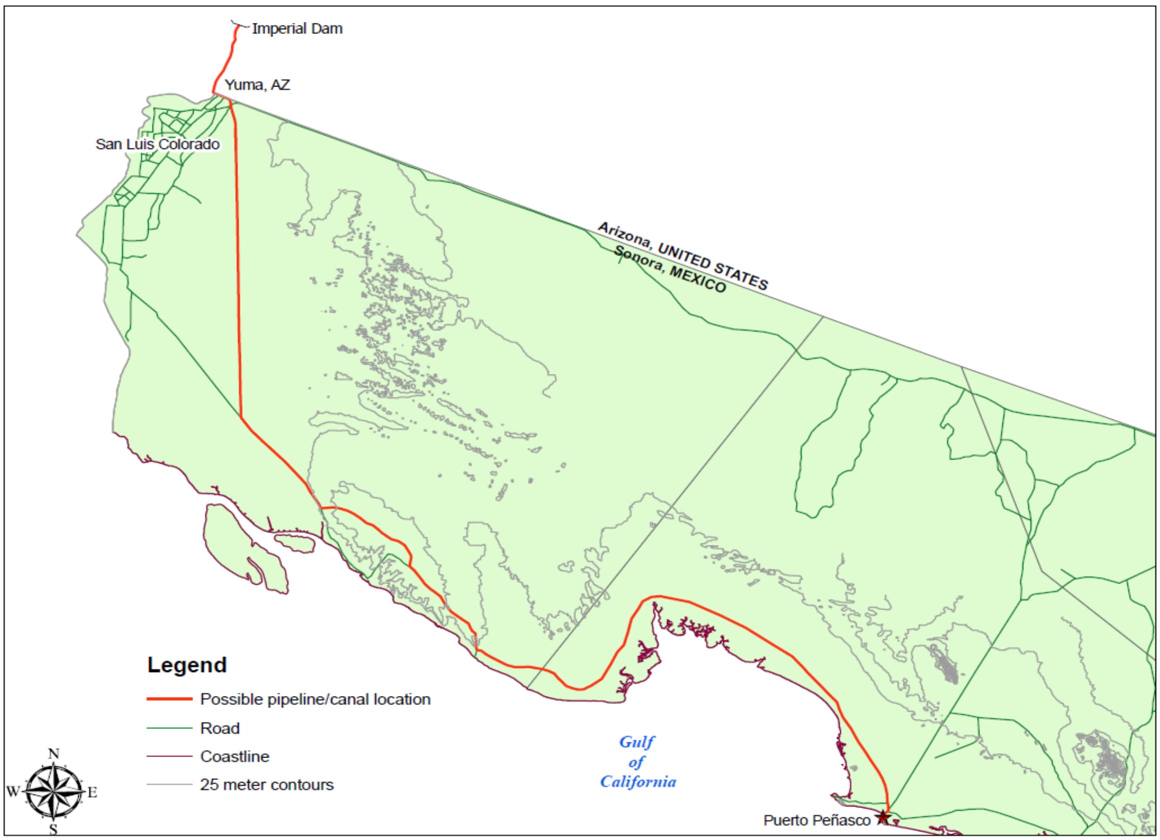


Figure 2. Proposed Binational Desalination Plant in Puerto Peñasco, with canal to transport water northward to Imperial Dam near Yuma, Arizona (Carpenter, 2008)

Case Study Description: Los Cabos, Baja California Sur

Los Cabos is one of Mexico's most well-known tourist destinations. With vast white beaches and over 300 days of sunshine per year, this arid coastal region attracts over a million visitors each year, many of whom come to recreate on one of the more than 10 golf courses (H. XI Ayuntamiento de Los Cabos, 2011: 179; IMPLAN, 2011). It is also home to 251,871 residents, most of who are employed in the service sector (INEGI, 2010; IMPLAN, 2011). Los Cabos refers to the city of San Jose del Cabo, the city of Cabo San Lucas, and the 18-mile tourist corridor that stretches between the two urban centers. The *municipio* of Los Cabos (equivalent to a U.S. county) is the local administrative unit, and consists primarily of these two urban centers, along with a few smaller outlying towns. Most data is reported at the level of the *municipio*.

The transition of Los Cabos from a quiet fishing community to a tourist mecca began in 1976 when it became part of the federal government's *Fondo Nacional de Fomento al Turismo* (FONATUR), or the National Tourist Development Fund. FONATUR is part of a regional development strategy to create economic centers that attract businesses, industry and foreign investment (Borja Santibáñex, Cruz Chávez, Juárez Mancilla, and Rodríguez Villalobos, 2006). It is responsible for fomenting the development of major tourist destinations in Mexico, including Cancún. Growth in Los Cabos exploded in the 1990s, with the number of hotels rooms growing from 1,524 in 1982 to 9,663 in 1998, with 21,857 new jobs being added to the *municipio* from 1988 to 1998 (Borja Santibáñex et al, 2006). The growth in the tourist economy attracted migrants from Guerrero, Sinaloa and other parts of Mexico in search of jobs. Currently, tourism is the principal economic activity in the *municipio,* with the service sector accounting for 83 percent of the *municipio's* gross domestic product (GDP) (H. XI Ayuntamiento de Los Cabos, 2011: 89). The population of the *municipio* of Los Cabos grew from 19,117 in 1980 to 71,031 in 1995, nearly quadrupling in just fifteen years (Borja Santibáñex et al, 2006) (figure 3).

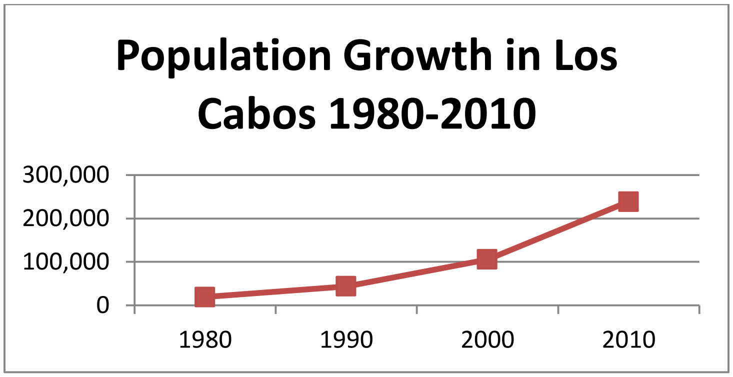
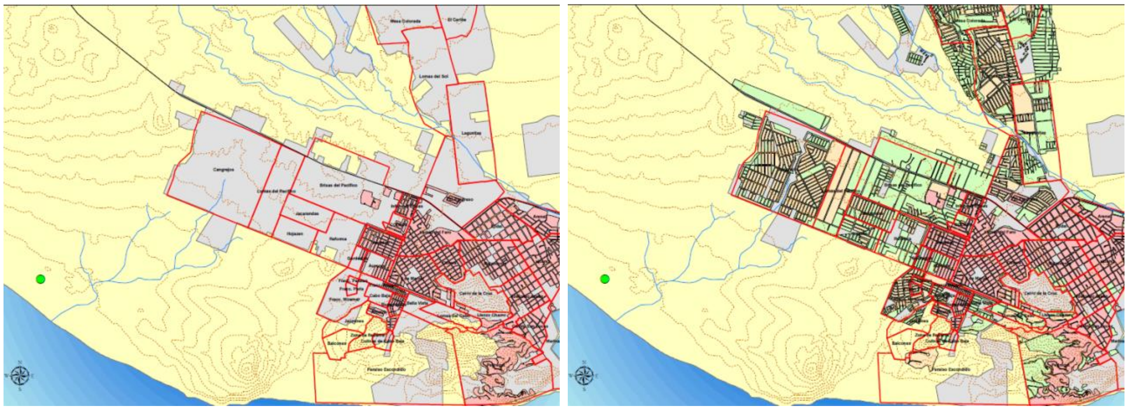


Figure 3. Population growth in Los Cabos, 1980-2010 (INEGI, 2010)

With limited housing options for workers and their families, a politically led social movement began in 1994 to establish the *colonia popular*, or working-class neighborhood, of Los Cangrejos on the outskirts of Cabo San Lucas (personal communication, 2012). Los Cangrejos grew from 3,451 residents in 2005 to 10,948 in 2010 (INEGI, 2005; Valdez Aragón, 2006). Several other *colonias populares*, both formal and informal, including Mesa Colorado (13,823 residents), 4 de Marzo (4,673 residents), and Las Palmas (8,654 residents) (INEGI, 2010), have grown on the outskirts of Cabo San Lucas to accommodate the continued growth (figure 4).

The *municipio* has struggled to provide infrastructure, including electricity, potable water and sewerage, to the growing population of Los Cabos. In 2004, the *municipio's* potable water supply network reached only 74% of the households, leaving 26% of the residents to rely on water trucks for water provision (Implan, 2011) (see appendix B).



2000 2010

Figure 4. Map of urban growth around the center of Cabo San Lucas, 2000-2010

The challenge of providing a clean, reliable supply of water to residents and businesses is due to both biophysical and socio-political factors. With an average annual rainfall of less than 16 inches (404 mm), an average temperature of 73ºF, and temperature extremes of up to 104 ºF, Baja California Sur is one of Mexico's most arid regions (Conagua, 2009). In 2008, 101 of Mexico's 653 aquifers were in overdraft, with 21 of these located in the northwest and Baja Peninsula (Conagua, 2010a: 43) (figure 5). Water is a scarce resource and the San José aquifer, the primary source of water supply for Los Cabos, already has a deficit.[1] The amount of water extracted from the aquifer (26 Mm^3) exceeds the amount of average annual recharge (24 Mm^3) (IMPLAN, 2011: 74-75). Climate change is expected to negatively impact water resources and reduce water availability in the region. Downscaled models of climate change scenarios project that by 2070, precipitation in this region will decrease by 10 to 20 percent, and annual temperatures will increase on the order of 4.5 ºF (Magaña et al, 2012) (figures 6 and 7).

[1] Conagua does not consider an aquifer to be "overdrawn" until extraction exceeds ten percent of recharge (Valdez Aragón, 2006: 66)

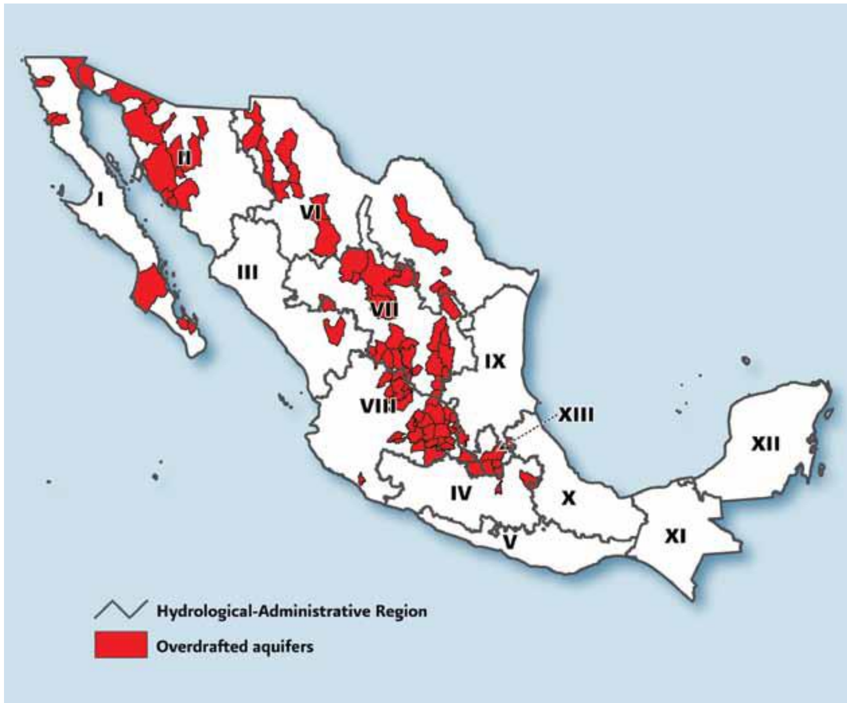


Figure 5: Overdrafted aquifers in Mexico by Hydrological-Administrative Region, 2008 (Conagua, 2010a: 44)

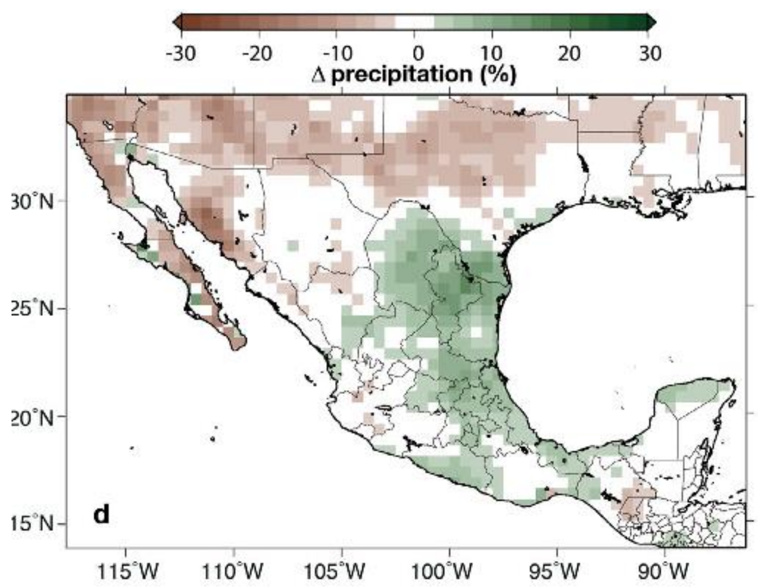


Figure 6. “Climate change projections for the HADCM3 for the 2040−2069 period under the A2 emission scenarios,” precipitation change (%) (Magaña et al, 2012: 180)

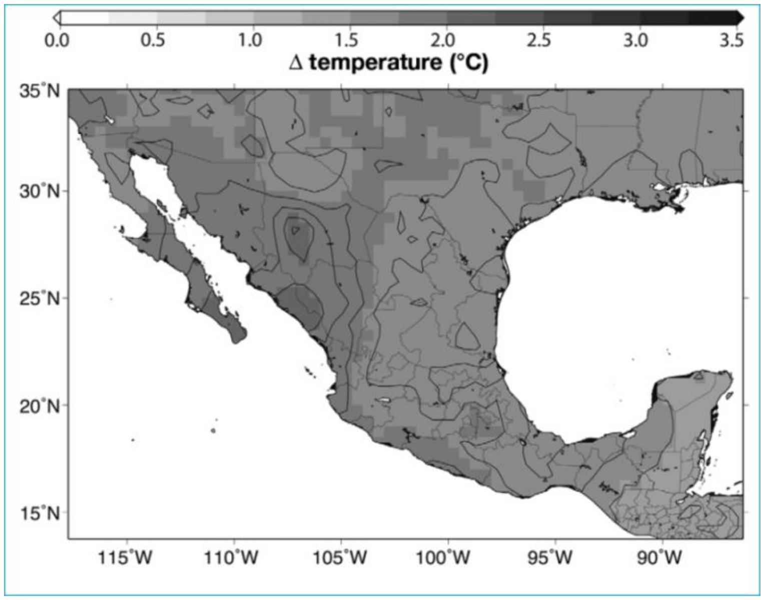


Figure 7. “Median values of the multi-model ensemble of downscaled changes of surface temperature (°C) (shading) for the 2040−2069 period with respect to the 1971−1999 climatology under the A2 emission scenario” (Magaña et al, 2012: 178)

Besides the San José aquifer, which provides 459 liters per second (lps) of water, Los Cabos also receives water from the Cabo San Lucas aquifer (36 lps), the San Lázaro dam (47 lps), and most recently, the Los Cabos desalination plant (179-200 lps) (Implan, 2011: 74). Reclaimed water is also used for some golf courses and green spaces (Valdez Aragón, 2006).

But beyond the biophysical water scarcity, there are socio-political factors that limit water availability. As in many parts of Mexico, the water distribution system operates inefficiently due to deteriorating infrastructure and/or lack of reinvestment and repair. Conagua (2008) estimates that most water systems in Mexico lose 30 to 50 percent of their water due to leaks (p. 37). Although in Los Cabos, much of the network in the recently established *colonias* is new, there is still an estimated 19 to 30 percent of water loss due to system inefficiencies (H. XI Ayuntamiento de Los Cabos, 2011; Valdez

Aragón, 2006). However, the water system is not completed metered (including metering at the extraction wells, as well as meters at the individual user connections), so it is not possible to calculate exactly how much water is lost in the system (Valdez Aragón, 2006).

In contrast to water demand worldwide, in Los Cabos it is the urban sector that is the largest water user (not the agricultural sector). The majority (69%) of water concessions in Los Cabos are for public-urban use (Valdez Aragón, 2006). From 1997 to 2004, during the period of rapid urban growth, the consumption of water by the domestic sector rose from 5.2 Mm^3 to 9.4Mm^3, an 80% increase (*ibid*). Interestingly, during this same period of time, water use in the industrial sector, which includes hotels, did not increase. This is due, in part, to an increased use of reclaimed water by many hotels, for their golf courses and green areas. Additionally, the 1995 Los Cabos master plan recommended that new hotel developments "self-supply," or provide their own source of water (H. Ayuntamiento de Los Cabos, 1995). Without an assured water supply from the *municipio,* new hotels had an impetus to build their own small-scale desalination facilities. Some older hotels also built their own desalination facility to ensure a reliable water supply. There are now 22 private, small-scale desalination plants in Los Cabos (Pombo, Breceda, and Valdez Aragón, 2008).

In addition to these private, small-scale desalination plants, in 2006, the *municipio's* water utility, in partnership with the state and federal water authorities, and a private firm (INIMA), built Mexico's first-ever municipal-scale desalination plant for public water supply. The desalination plant is financed, constructed, and operated through a Public-Private Partnership (PPP). Since 2001, through the federal *Programa para la Modernizacion de los Organismos Operadores* (PROMAGUA) (Program for the Modernization of Water Utilities), Mexico has had limited success in attracting private sector investment in municipal water supply systems that supply cities of 50,000 inhabitants or more (Conagua, n.d.: 6). PROMAGUA receives federal funding through the *Fondo de Inversión en Infrastructura* (previously FINFRA, now FONADINA) (Infrastructure Investment Fund), which is under the management of Banobras (the national development bank of Mexico) and assists in water infrastructure projects that are attractive for investment by the private sector. In this case, the federal government invested 30 percent of the cost of the Los Cabos desalination plant through FINFRA/FONADIN (OOMSAPASLC, 2013). The private Spanish-based company, INIMA, won the bid to build and operate the Los Cabos desalination plant for a period of 20 years.

The plant is located in the *colonia* of Los Cangrejos and began operation in 2006 (figure 8). The plant was designed to produce 200 liters of water per second and was planned to meet the water needs of 40,000 residents in various *colonias* in Cabo San Lucas. Since the construction of a new desalination plant potable water supply coverage has increased to 96%. However, for 44% of the water users in Cabo San Lucas, this service is intermittent (Implan, 2011) (see appendix B). The *municipio* has a scheduled *tandeo*, or water-sharing schedule, that directs water to different *colonias* every three to fifteen days.

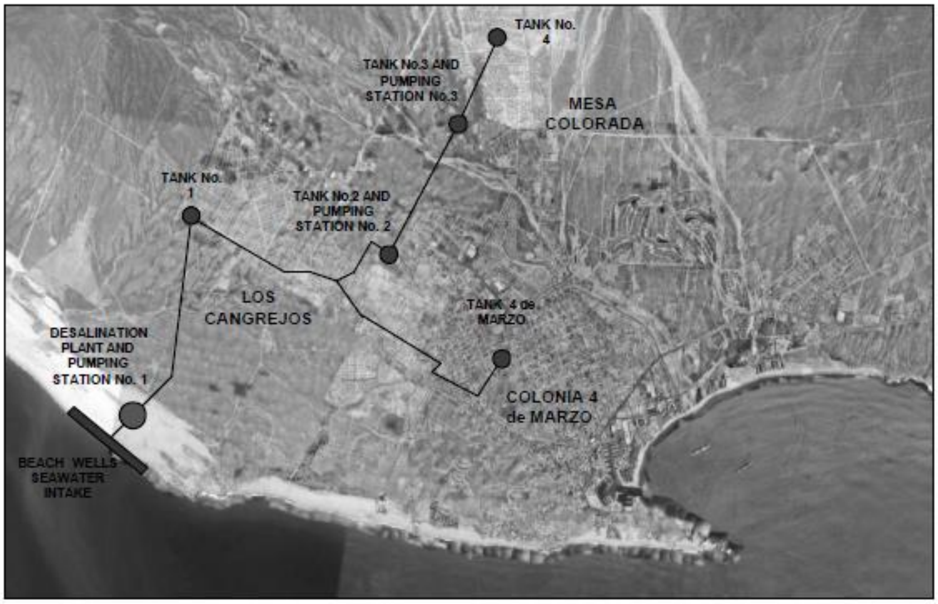


Figure 8. General plan of the Los Cabos desalination plant

To cope with the intermittent service, residents use a variety of water storage containers to maintain a water supply when the municipal piped water service goes out. These containers range from very basic *tambos*, or plastic jugs, to *tinacos*, or rooftop water storage containers, to more elaborate underground cement *cisternas,* or cisterns, which fill-up automatically when the municipal water is on, and then use a pump to deliver water to the house when needed. A cistern with a 10,000 liter capacity costs around $50,0000 pesos ($4,167 USD). *Tinacos* range in price, depending on size and brand, but cost around $1300 pesos ($108). A set of three *tambos* can cost $1,600 pesos ($133 USD) (personal communication, April 18, 2012). While a cistern provides the greatest degree of water security, the cost is prohibitive for many households.

The *municipio* has a public water truck service, or *pipas*, which delivers water to neighborhoods that are not connected to the public network or experience an extended *tandeos.* However, the public service is insufficient and private entrepreneurs have filled the market, providing water at a high cost. A full water truck delivery of 10,000 liters of water typically costs $500 pesos ($40 USD) (personal communication, April 27, 2012). But households that do not have the capacity to store that much water at once are charged for a portion of water, at the discretion of the private vendor (see appendix B).

Case Study Description: La Paz, Baja California Sur

In 2001, La Paz was listed among the 100 cities in Mexico that is most likely to experience a “severe water crisis” (Cruz Falcón, 2007: 2). The scenario of growth and water availability in the *municipio* of La Paz, which includes the state’s capital city of La Paz, along with a few smaller towns, is even more acute than that of Los Cabos. The primary source of water supply for the city of La Paz, the La Paz aquifer, is overdrawn (Carrillo Guer, 2010). While Conagua estimates that the deficit (i.e., the difference between the amount average annual extraction and recharge) is only 0.58 Mm^3, other studies have concluded that the average annual recharge is significantly less, resulting in much greater deficits, ranging from a deficit 8.98 Mm^3 annually to 20 Mm^3 annually (Cruz Falcón, 2007: 103). The aquifer has experienced saline intrusion since the 1960s (Cruz Falcón, 2007: 3). In the 1980s, nearly all the groundwater wells within the city limits were closed and relocated, due to saline intrusion (Cruz Falcón, 2007).

Conagua has issued a *veda*, or moratorium on new water concessions (Conagua, 2009). Existing water concessions are used primarily for public-urban water supply, which accounts for 62 percent of all water use, and agriculture, which accounts for 30 percent of water use (Carrillo Guer, 2010: 10). The distribution system for urban water supply is old and inefficient, with an estimated water loss rate of 44 percent (*ibid*, p. 20).

Despite these challenges, the water utility offers piped water service to 93.3 percent of all households (H. XIV Ayuntamiento de La Paz, 2011a). But only 60 percent of the users receive a continuous water supply and 20 percent have water 12 hours per day (PDUCP La Paz, n.d.: 66). The remaining 20 percent of users experience a *tandeo*, with water being directed to specific *colonias* every three to fifteen days. Households in La Paz rely on a variety of water storage containers and water trucks to make-up for the lack of reliable, continuous water service. However, in La Paz, the public water truck service is more extensive than it is in Los Cabos. This public service is free, though residents say that the truck drivers often ask for a *propina*, or tip, for service. The current mayor of La Paz is promoting a county-wide program (*Tinacos para Todos*) to distribute water storage containers to residents in marginalized neighborhoods at a subsidized price.

The economy of La Paz is more diverse than Los Cabos, with more government sector jobs, the state university (UABCS), and various NGOs. It is also an important port city and the largest employment sector is retail, followed by jobs in construction, hotels, manufacturing and other services (H. XIV Ayuntamiento de La Paz, 2011a: 59). But increasingly, national and international tourism is gaining importance. There are several major new hotel and condominium developments. Currently, there is just one golf course in La Paz, but there are proposals for nine new golf courses (H. XIV Ayuntamiento de La Paz, 2011b) (figure 9). The population has grown steadily from 111,310 in 1980 to 251,871 in 2010 (INEGI, 2010) (figure 10).

Figure 9. Golf course in La Paz (author's photo)

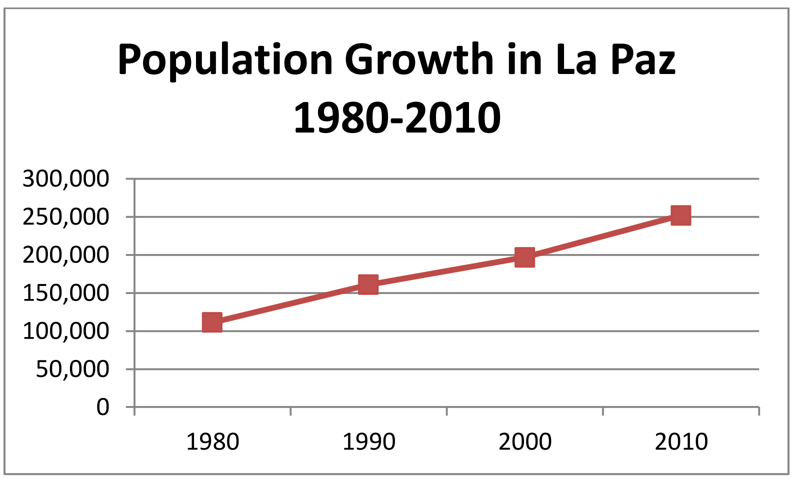


Figure 10. Population growth in La Paz, 1980-2010 (INEGI, 2010)

Despite the limited water resources, the federally imposed moratorium on new concessions, and increasing water demand from the burgeoning tourist sector, La Paz has not adopted a similar recommendation in its master to plan that new developments must "self-supply." However, two of the newer developments do have their own desalination facilities to guarantee supply to their residents. There is interest among some water managers and urban planners to build a large municipal-scale desalination plant, like the one in Los Cabos. A feasibility study for such a facility has already been conducted (IIUNAM, 2010). The state's long-term water plan identifies desalination as the principal means by which La Paz will overcome the increasing water deficit projected by 2030 (Conagua, 2012b). The administration of the recently elected President Enrique Peña Nieto identified the La Paz desalination plant as one of the nation's top infrastructure projects (Cortés, 2012).

Explanation of the Dissertation Format

This dissertation consists of three appended articles. Appendix A, entitled "Discourse and Desalination: Potential Impacts of Proposed Climate Change Adaptation Interventions in the Arizona-Sonora Border Region" (co-authored with Margaret Wilder) examines a proposed Arizona-Sonora binational desalination project and uses insights from risk and hazards literature to analyze how, why, and to what effect desalination is emerging as a preferred climate change adaptation response. This article was published in *Global Environmental Change* as part of a special issue titled "Adding Insult to Injury: Climate Change and the Inequities of Climate Intervention," which focuses on how the interventions and discourses surrounding climate change are creating new stressors on vulnerable communities (Marino and Ribot, 2012). This raises questions about issues of equity and fairness in the process of adapting to and mitigating climate change. My research, which includes a critical risk assessment of desalination, contributes to this nascent area of research by considering a broader range of desalination-related risks and impacts than previous studies have done. It concludes that while desalination may reduce some vulnerabilities (e.g., future water supply), it also introduces new vulnerabilities (e.g., compounding the water-energy nexus, increasing greenhouse gas emissions, inducing urban growth, producing brine discharge and chemical pollutants, shifting geopolitical relations of water security, increasing water prices, increased reliance on technical expertise, less opportunity for participatory decision-making and reduced flexibility in future planning). As such, it engages with the concept of maladaptation. It also contributes to the study of equity in water management decision-making by focusing on the distribution of the costs and benefits of desalination technology. This critical risk assessment highlights the need for a fundamental change in human-environment relations and intends to spur discussion of alternatives and enrich the options for policy interventions.

Research for this paper was funded by National Oceanic and Atmospheric Administration (NOAA) grant, on which I was a research assistant, and Margaret Wilder was the Deputy Principal Investigator. The paper presented in appendix A uses data that was collected as part of this research project. I was responsible for the majority of the data collection, analysis, and writing of the paper. The theoretical framework that shapes this article was inspired from readings and discussions in Marv Waterstone's seminar on Risk and Society. In addition, the paper benefitted from the comments and insights from organizers and participants of Initiative on Climate Adaptation Research and Understanding through the Social Sciences (ICARUS) workshops.

Appendix B, “Desalination and Water Security: The Promise and Perils of a Technological Fix to the Water Crisis in Baja California Sur, Mexico” uses empirical evidence from household surveys, semi-structured interviews, and planning documents that I collected as part of my dissertation research in Los Cabos and La Paz, BCS. This article examines how the introduction of desalinated water into the municipal water supply portfolio has affected water security in Cabo San Lucas, BCS. It also analyzes proposals for a similar desalination plant in the city of La Paz, BCS and discusses alternative water management options for achieving water security. This article challenges the discourse of desalination as an appropriate and sufficient technological solution for arid regions. This article will be submitted to *Water Alternatives*.

Appendix C, "Deviating from the Mainstream? The Discourse and Practice of Desalination and Environmental Governance in Coastal Northwestern Mexico" will be submitted to *Environment and Planning C: Government and Policy.* This article examines how desalination, as a water augmentation strategy, fits within the contemporary water governance framework which emphasizes the key policy principles of implementing a comprehensive and coordinated water policy framework, decentralization, private sector involvement, public participation, and environmental sustainability. Additionally, it provides policy recommendations for creating explicit mechanisms or institutional arrangements that could help to ensure that the technology contributes to sustainable water management. Data for this article was I collected as part of my dissertation research in Los Cabos and La Paz, BCS.

The following chapter provides an overview of the research methods and data collected for the three appended articles. It also provides a summary of the general themes that emerged from the research as well as the specific research findings in each article.

PRESENT STUDY

The details of the research are presented in the three appended papers. This chapter provides a description of the methods used and a summary of the key themes and conclusions of the research.

Methods

This dissertation uses a mixed methods approach that combines qualitative and quantitative techniques, as described below. The research for the three appended articles was carried out in three phases. Phase one involved research conducted while working as a research assistant at the Udall Center for Studies in Public Policy at the University of Arizona (UA) on a binational water, climate and vulnerability project (2008-2011). Phase two involved six-weeks of preliminary dissertation research in Baja California and Baja California Sur to identify a research site and make contacts to further examine desalination technology and water management in northwestern Mexico (July-August 2010). Phase three involved nine months of dissertation fieldwork in La Paz and Los Cabos, BCS. Approval through the UA Institutional Review Board's (IRB) Human Subjects Protection and Research was obtained for all phases of the research. I describe the methods used below.

Phase I (August 2008-May 2011)

As part of a larger study on climate change and water vulnerability in the Arizona-Sonora border region, I worked with an interdisciplinary team of researchers and water managers in the rapidly urbanizing areas of Tucson, Az; Nogales, Az/Nogales, Son and Puerto Peñasco, Son. (figure 11). The research was funded by the National Oceanic and Atmospheric Administration (NOAA) Sectoral Applications Research Program (grant NAO80AR4310704) and aimed to identify water-related vulnerabilities and assess current and future adaptive management strategies in the context of growth and climate change. Over a two-year period (2008-2010), the research team, of which I was a part, conducted 75 semi-structured interviews, attended 10 binational water planning meetings and hosted four binational workshops with water managers, emergency preparedness planners, decision-makers and local water users. Additionally, for the case study presented in appendix A, I consulted archival documents such as municipal development plans, water agency reports, aquifer assessments, feasibility studies and newspaper reports to understand development trends, water supply, water availability and the context in which desalination, as a water management strategy, arose.

Figure 11. Map of urban hotspots in the Arizona-Sonora Border Region, including Puerto Peñasco (figure created by Rolando Diaz-Caravantes)

Phase II (July-August 2010)

Preliminary dissertation research was made possible with funding by UA Social and Behavioral Research Institute Graduate Summer Research Grant Development Award. During six-weeks of preliminary research in BC and BCS (July-August 2010), I conducted six semi-structured interviews with various stakeholders (table 1) and identified two primary research sites for dissertation fieldwork (i.e., La Paz and Los Cabos, BCS).

ID	Sex	Position, Affiliation	Type of Organization	Location	Date	Length (Min.)
1	M	Employee, Defensa Ambiental del Noroeste	Env. NGO	Ensenada, BC	7/16/10	90
2	F	Professor, CICESE	Academic	Ensenada, BC	7/16/10	90
3	M	Employee 1, Niparajá	Env. NGO	La Paz, BCS	7/22/10	60
4	M	Journalist	Independent	La Paz, BCS	7/10	60
5	M	Operator, INIMA, Los Cabos Desalination Plant	Private firm	Los Cabos, BCS	7/28/10	30
6	M	Lawyer, CEMDA	Env. NGO	La Paz, BCS	8/2/10	60

Table 1. List of interviews conducted during phase II (July-August 2010)

Phase III (August 2011-May 2012)

The majority of the data presented in appendices B and C come from research conducted in the third phase of doctoral research. This included nine months of fieldwork on La Paz and Los Cabos, BCS, along with short research trips to Mexico City, Federal District and Jiutepec, Morelos to interview officials with the Comisión Federal del Agua

(Conagua), Instituto Mexicano de Tecnología del Auga (IMTA), academics at the Universidad Nacional Autónoma de México (UNAM), and a representative from Green Peace. Dissertation field research was funded by a National Science Foundation Doctoral Dissertation Research Improvement grant, a Fulbright-García Robles award, and a UA Water Sustainability Program Fellowship. Additional monies were available through the Arizona-Baja California Sur Partnership for Water Sustainability for research activities.

Question	Data Collection Method	Method of Analysis
1. What is the legal, political, and economic context in which desalination is adopted?	- Semi-structured interviews - Short survey - Participant observation - Focus group - Archival data (newspaper, government reports)	- Content analysis - Critical discourse analysis
2a. How does the adoption of desalination technology affect water provision and management?	- Semi-structured interviews - Short survey - Participant observation - Household survey in Los Cabos - Archival data (government reports, water agency data)	- Descriptive statistical analysis - Content analysis - Critical discourse analysis - Institutional analysis
2b. How does the adoption of desalination technology affect the creation of new institutions to manage and regulate the emerging industry?	- Semi-structured interviews - Short survey - Participant observation - Archival data (government reports, water agency data)	- Content analysis - Critical discourse analysis - Institutional analysis
2c. How does the adoption of desalination technology affect vulnerability, adaptive capacity, and water security at various scales?	- Semi-structured interviews - Short survey - Participant observation - Focus group - Household survey - Archival data (government reports, census, municipal data)	- Content analysis - Critical discourse analysis - Descriptive statistical analysis
3. How do socio-environmental drivers shape the implementation of desalination technology?	- Semi-structured interviews - Short survey - Focus group - Archival data (newspaper, technical reports, water agency reports)	- Content analysis - Critical discourse analysis

Table 2. Summary of dissertation fieldwork framework

Data was collected using six methods, including semi-structured interviews, short surveys, household surveys, participant observation, a focus group and review of secondary sources (i.e., government reports, newspaper articles, and scholarly articles). Each data collection method, and the associated method of data analysis, is described above in table 2.

Semi-Structured Interviews

At total of 79 semi-structured interviews were conducted with 71 different individuals during phase III (tables 3 and 4). Of these interviews, 46 were conducted in La Paz, 27 in Los Cabos and 6 in other locations. Interviews ranged from 5 minutes to 4 hours in length. Interviews were recorded when information was technical, detailed, and/or lengthy; and when it seemed comfortable to ask permission to do so.

Respondents were selected using a combination of purpose, snowball, and convenience sampling. Neuman (2006) defines purpose sampling as “selecting cases with a specific purpose in mind” (p. 222). Occasionally, I used a snowballing technique to ask previous respondents if they could recommend someone else I might talk to for additional information. Since water service was fairly standard within *colonias*, I conducted brief (5-15 minute) interviews using convenience sampling to rapidly assess differences in water service in various *colonias* in Los Cabos.

For the purposive sampling approach, my primary purpose was to select respondents who represented different interests, perspectives and opinions regarding water management, desalination and development were recruited to participate in interviews. My goal was to interview representatives from the following sectors: 1) federal, state and local water managers, 2) other governmental departments that manage water, urban planning and environmental protection 3) developers and realtors 4) environmental groups and 5) residents of various *colonias*. I conducted a total of 79 interviews with 71 different interviewees (some interviewees were interviewed more than once). Interviewees included representatives from the federal water commission (3), federal government (6), state water commission (2), state government (2), La Paz municipal water utility (3), La Paz municipal government (3), Los Cabos municipal water utility (2), Los Cabos municipal government (3), environmental NGOs (5), academics or researchers (6), private development, architecture, or real estate firms (9), private desalination operator (1), *colonia* residents (16), *colonia* leaders (4), expat residents (3), other (3).

The semi-structured format was selected because it allows the researcher to begin with some predetermined questions, but also move and/or digress from the interview schedule through probes and new insights that emerge during the interview (Berg, 2007). Also, the interview schedule varied depending on the interviewees' area of expertise.

Interviews were designed to 1) elicit perceptions of desalination as a solution to the region's water scarcity issue 2) understand the legal, political, economic and environmental context within which desalination technology was considered or adopted 3) understand what new institutions (i.e., rules, regulations, organizations) have been, or should be, created to manage the newly produced water resource and 4) understand how desalination technology has, or could, affect water provision, water management and access to water.

The transcripts and notes of interviews were analyzed and coded using content analysis to identify key themes. A critical discourse analysis (CDA) was also used to examine how certain discourses about water management and development become naturalized, who emphasizes the benefits of desalination, who expresses concern about the potential negative environmental or socio-economic impacts of desalination, who favors alternatives to desalination, and how the trade-offs between the pros and cons, and desalination and alternative management strategies are discussed.

Short Surveys

With 28 of the interviewees, I also administered a short, standardized survey on perceptions of desalination technology to enable a comparison of perceptions of desalination across groups of stakeholders. Questions on the short survey asked respondents the level to which they agreed or disagreed with various statements about desalination, water management, and urban development (see appendix B). Responses were entered into an Excel spreadsheet and analyzed using a basic count function to determine how many respondents agreed or disagreed with each statement.

ID	Sex	Affiliation	Type of Organization	Location	Date	Length (Min)
1	M	Employee 1, Ecologia, Educacion y Gestión Ambiental	Municipal Government	La Paz	9/27/11	45
2	M	Employee 2, Niparajá	Env. NGO	La Paz	10/3/11	90
3	F	Resident 1	Public Citizen	La Paz	10/2/11	20
4	M	Employee 1, COTAS	State Government	La Paz	10/6/11	60
5	M	Employee 1, COTAS	State Government	La Paz	10/8/11	60
6	F	School teacher and	Teacher	La Paz	10/8/11	30

		Project leader 1, CBTIS				
7	M	Employee 1, SAPA	Municipal Government	La Paz	10/14/11	30
8	M	Employee 1, Housing Department	Municipal Government	La Paz	10/18/11	90
9	M	Graduate Student 1, Ag Sciences, UABCS	Public Citizen	La Paz	10/18/11	60
10	M	Employee 1, ProNatura	Env. NGO	La Paz	10/20/11	180
11	M	Former employee 1, Biosphere Reserve Sierra La Laguna	Federal government	La Paz	10/21/11	90
12	M	Professor 1, CIBNOR	Academic	La Paz	10/27/11	120
13	M	Professor 2, CIBNOR	Academic	La Paz	10/27/11	30
14	M	Professor 2, CIBNOR	Academic	La Paz	11/8/11	180
15	F	Employee 1, CEA	State Government	La Paz	10/10/11	20
16	M	Employee 2, Niparajá	Env. NGO	La Paz	10/11/11	20
17	M	Employee 1, SAPA	Municipal Government	La Paz	11/26/11	150
18	M	Architect 1, DECOPE	Private firm	La Paz	11/29/11	30
19	M	Architect 1, DECOPE	Private development firm	La Paz	12/1/11	90
20	F	Employee 1, DMarc	Private development firm	La Paz	12/2/11	30
21	M	Employee 1, Peninsula Sur	Private development firm	La Paz	12/2/11	30
22	M	Operator 1, Private Desalination Facility, Impel Costa Baja	Private desalination firm	La Paz	12/6/11	60

23	M	Architect 2, DMarc	Private development firm	La Paz	12/8/11	60
24	M	Employee 2, SAPA	Municipal Government	La Paz	12/10/11	30
25	M	Employee 1, SAPA	Municipal Government	La Paz	12/10/11	240
26	M	Employee 1, CEMDA	Env. NGO	La Paz	12/13/11	60
27	M	Employee 1, SEMARNAT	Federal Government	La Paz	12/13/11	20
28	M	Employee 1, CONAFOR	Federal Government	La Paz	12/13/11	60
29	M	Employee 2, CONAFOR	Federal Government	La Paz	12/13/11	30
30	M	Employee 2, SEMARNAT	Federal Government	La Paz	12/13/11	30
31	M	Architect 1, DECOPE	Private development firm	La Paz	12/14/11	90
32	M	Employee 1, ProNatura	Env. NGO	La Paz	1/3/12	180
33	M	Ex-pat Resident 1	Public citizen	La Paz	1/5/12	120
34	F	Ex-pat Resident 2	Public citizen	La Paz	1/6/12	20
35	M	Employee 1, Andes Consultaria Ambiental	Private Env. Consulting firm	La Paz	1/30/12	45
36	M	Resident 2	Public citizen	La Paz	1/30/12	45
37	M	Employee 1, COTAS	State Government	La Paz	1/30/12	45
38	M	Professor 1, ITSON	Academic	Hermosillo, Sonora	1/31/12	15
39	M	Employee 1, Conagua BCS	Federal Government	La Paz	1/31/12	Email only
40	F	Employee 3, SAPA	Municipal Government	La Paz	2/1/12	30
41	M	Employee 1, Ecología, Educación y Gestion Ambiental	Municipal Government	La Paz	2/3/12	60
42	M	Employee 1, CFE	Federal Government	La Paz	2/7/12	30
43	M	Employee 1,	State	La Paz	2/7/12	30

		Dirrecion de Planeacion Urban Y Ecología,	Government			
44	M	Employee 2, CEA	State Government	La Paz	2/9/12	60
45	F	Employee 1, Asientamientos Humanos	Municipal Government	La Paz	2/10/12	30
46	M	Employee 1, Banker's Realty	Private real estate firm	La Paz	2/1/12	25
47	M	Employee 1, South Baja Properties	Private real estate firm	La Paz	2/12/12	20
48	M	Researcher 1, IMTA	Federal Government	Juitepec	2/20/12	120
49	M	Former professor 1, UNAM	Academic	Mexico City	2/22/12	90
50	M	Employee 2, Conagua	Federal Government	Mexico City	2/23/12	Email only
51	F	Resident 3	Public citizen	Los Cabos, colonia Los Cangrejos	3/12/12	30
52	M	Resident 4	Public citizen	Los Cabos, colonia Los Cangrejos	3/12/12	10
53	M	Resident 5	Public citizen	Los Cabos, colonia Los Cangrejos	3/12/12	10
54	F	Resident6	Public citizen	Los Cabos, colonia Los Cangrejos	3/12/12	5
55	F	Resident 7	Public citizen	Los Cabos, colonia Los Cangrejos	3/12/12	15
56	M	Resident 8	Public citizen	Los Cabos, colonia Los Cangrejos	3/12/12	30
57	M	Employee 1, OOMSAPASLC	Municipal government	Los Cabos	3/15/12	30
58	M	Employee 1, Green Peace	Env. NGO	Mexico City	3/21/12	30
59	M	Employee 3, Conagua	Federal Government	Mexico City	3/21/12	90
60	M	Resident 9	Public citizen	Los Cabos,	3/23/12	5

				colonia Mesa Colorado		
61	M	Resident 10	Public citizen	Los Cabos, Fracc. Las Palmas Homex	3/23/12	5
62	F	Resident 11	Public citizen	Los Cabos, Fracc. Las Palmas	3/23/12	5
63	M	Resident 12	Public citizen	Los Cabos, colonia Las Palmas	3/23/12	5
64	F	Employee 1, Los Angeles del Estero	Env. NGO	Los Cabos	3/24/12	20
65	M	Employee 1, Desarrollo Urbano y Ecología	Municipal government	Los Cabos	3/26/12	30
66	M	Employee 1, IMPLAN	Consultancy for municipal government	Los Cabos	3/28/12	45
67	M	Employee 1, Ecologia y Medio Ambiente	Municipal government	Los Cabos	3/30/12	N/A
68	M	Resident and colonia leader 1	Public citizen	Los Cabos, colonia Mesa Colorada	4/18/12	45
69	NA	Resident 13	Public citizen	Los Cabos, colonia Vista Hermosa	4/22/12	10
70	NA	Resident 14	Public citizen	Los Cabos, colonia Zacatal	4/22/12	10
71	NA	Resident 15	Public citizen	Los Cabos, colonia Zacatal	4/22/12	10
72	NA	Resident 16	Public citizen	Los Cabos, colonia Santa Rosa	4/22/12	10
73	M	Resident and former colonia	Public citizen	Los Cabos, colonia	4/25/12	45

		leader 2		Mesa Colorada		
74	M	Resident and former colonia leader 3, former OOMSAPASLC employee, real estate developer	Public citizen, former municipal government, private firm	Los Cabos, colonia Los Cangrejos	4/27/12	45
75	M	Expat and Employee 1, Cape Real Estate	Private real estate firm	Los Cabos	4/27/12	45
76	M	Employee 1, Gubasa Real Estate	Private real estate firm	Los Cabos	4/30/12	15
77	M	Employee 1, Portiles/Bella Vista	Private development firm	Los Cabos	4/30/12	15
78	M	Resident and informal colonia leader 4	Public citizen	Los Cabos, colonia Caribe Baja	5/1/12	30
79	F	Researcher 1, NA	NA	Los Cabos	5/24/12	60

Table 3. List of semi-structured interviews and short surveys conducted during phase III (August 2011-May 2012)

Affiliation	**# of Interviewees**
Federal water commission (Conagua)	3
Federal government (other)	6
State water commission (CEA)	2
State government (other)	2
La Paz municipal water utility (SAPA)	3
La Paz municipal government (other)	3
Los Cabos municipal water utility (OOMSAPASLC)	2
Los Cabos municipal government (other)	3
Environmental Non-Governmental Organization	5
Academic/Researcher	6
Private development, architecture, or real estate firm	9
Private desalination operator	1
Colonia residents	16
Colonia leaders	4
Expat residents	3
Other	3
Total # of interviewees	71

Table 4. List of interviewees by affiliation type

Household Surveys

I conducted household surveys in La Paz (N=160) and Los Cabos (N=154). Due to the fact that a municipal-scale desalination plant had already been built in Los Cabos, whereas it is in the planning stages in La Paz, the survey instrument varied slightly between the two research sites. In both locations, the survey consisted of a mix of closed and open-ended questions designed with the overall goal of assessing household water supply, vulnerability to water scarcity, and perceptions of desalination as a new water supply strategy. The survey instrument was designed based on insights from initial interviews.

La Paz: In La Paz, stratified random sample of 160 household surveys were conducted in eight *colonias* that the municipality had identified as having a "high" level of marginalization by the municipal government. I trained five research assistants in the survey protocol and solicited UA IRB approval for each research assistant. Over a five day period (January 23-27, 2012), we surveyed approximately ten percent of the households in eight marginalized *colonias* (table 5). The survey was designed to assess: 1) general household characteristics and public service provision 2) household water supply and water use 3) extreme weather events and disruption in water supply 4) perceptions of the water issue in La Paz and desalination as a water supply strategy and 5) socioeconomic data. The survey consisted of 78 questions to be answered by the respondent, including both closed and open-ended questions. An additional six questions regarding gender and construction material of the house were filled out by the researcher, independently. Survey time averaged 20-30 minutes per survey. Because water supply in

La Paz is on a *tandeo*, or water-sharing system, *colonias* only receive water once every three to fifteen days. Therefore the survey instrument was designed to illuminate the strategies that households employ to cope with water insecurity, particularly during extreme weather events (i.e., cyclones and high temperatures). Responses were entered into an Excel spreadsheet for analysis.

Colonia	**# of surveys conducted**	**# of households**	**Total population**	**Level of Marginalization**
La Escondida	11	120	350	High
Lazaro Cardenas	33	337	1305	High
Marquez de Leon	17	136	483	High
Vista Hermosa	9	75	279	High
Villas de Guadalupe	11	97	368	High
El Cardonal	19	181	748	High
Agua Escondida	32	327	1198	High
Calafia	28	280	1060	High
Total	160	1553	5791	High

Table 5. La Paz household surveys (Data was obtained from the municipalities report for their social program *Tinacos para Todos*).

Los Cabos: In Los Cabos, I conducted a systematic random sample survey of 154 households in one particular *colonia*. I chose to conduct surveys in the *colonia* of Los Cangrejos in Cabo San Lucas because it is the neighborhood that has benefitted the most from the construction of the Los Cabos Desalination Plant that was built in 2006. Los Cangrejos is known as a "*colonia popular,"* which refers to the lower socio-economic status of the majority of the residents (equivalent to a lower-income neighborhood, or working-class neighborhood, in the United States). Los Cangrejos was one of the first *colonias populares* to be established on the outskirts of the Cabo San Lucas city center in the 2000s. Los Cangrejos grew from 3,451 residents in 2005 to 10,948 in 2010 (Alvarez, 2006; INEGI, 2010).

Several other *colonias populares*, both formal and informal, including Mesa Colorado (13,823 residents), 4 de Marzo (4,673 residents), and Las Palmas (8,654 residents) (INEGI, 2010), have also been established on the outskirts of Cabo San Lucas to accommodate the continued growth. While the operator of the desalination plant, who is employed by the private company INIMA, is not in charge of the distribution of the water (that falls to the municipality's water utility), the operator indicated that when the plant began operations, initially 100 lps were sent to Los Cangrejos, while 40 lps were sent to 4 de Marzo, 20 lps to Las Palmas, and 20 lps to Mesa Colorado (personal communication, 2010).

Given that Los Cangrejos is the *colonia* that is located nearest to the desalination plant, many respondents assumed that this *colonia* received the most desalinated water because of its proximity to the desalination plant. It is the only *colonia popular* that has a nearly continuous supply of water. The other *colonias* still experience a *tandeo*, or water-sharing system, where water is directed to the neighborhood once every three to fifteen days. Since the purpose of the survey in Los Cabos was to assess the impact of the desalination plant on water security and vulnerability to water scarcity at the household level, I elected to conduct all surveys in the neighborhood that had benefited the most from the desalination plant.

The survey was designed to assess: 1) household characteristics and public services 2) household water supply 3) household water use 4) perceptions of water issues and desalination and 5) socioeconomic data. The survey consisted of 66 questions to be answered by the respondent, including both closed and open-ended questions. An additional six questions regarding gender and construction material of the house were filled out by the researcher, independently. Survey time averaged 20-30 minutes per survey. I trained three new research assistants and received IRB approval to have the research team conduct 160 household surveys (April 9-14, 2012).

According to INEGI census data (2010), Los Cangrejos has 10,984 residents and 2,728 households. While, ideally, I would like to have surveyed ten percent of the households (273) in Los Cangrejos, this was not possible due to limited time and financial resources. Instead, I chose to conduct the same number of surveys as had been conducted in La Paz (160). A map that showed the individual blocks within Los Cangrejos was used to randomly select one house from each block in the *colonia*, following a selection of end house, middle house, then end house (figure 12). There were approximately 155 blocks within the *colonia*. Of the 154 respondents, 53% were male and 47% were female. When possible, researchers tried to conduct the survey with the head-of-household. Sixty-one percent of respondents considered themselves the head-of-household, while the remaining 39% did not identify as head-of-household. Six surveys ended up being unusable, so I entered data from 154 usable surveys into an Excel spreadsheet. I analyzed the data using descriptive statistics (i.e., frequencies and central tendencies).

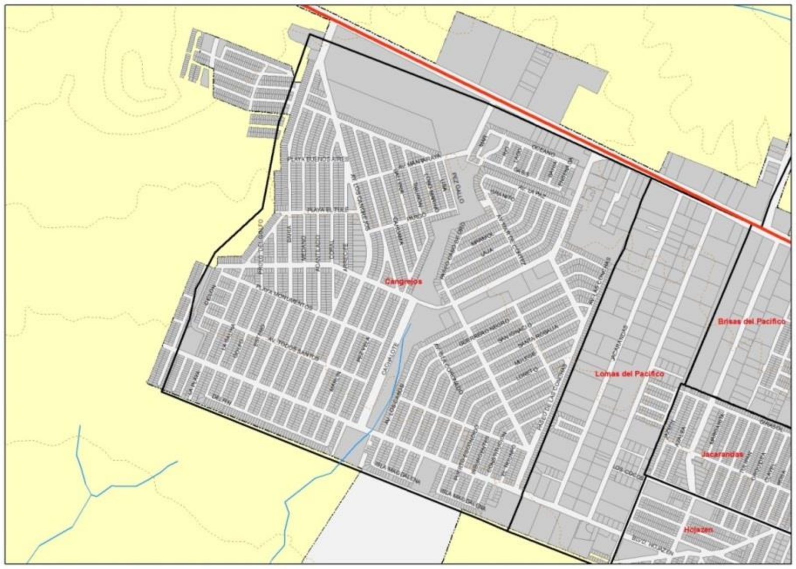


Figure 12. Map of neighborhood blocks in the *colonia popular* Los Cangrejos, Cabo San Lucas (INEGI, 2010)

Participant Observation

I attended as many workshops, presentations, meetings, and events related to water, climate change, urban planning, and economic development as I could. This provided an opportunity to learn more about the legal, political, economic, and environmental context in which desalination technology is adopted. A complete list of events attended is listed in table 6.

ID	Event Name	Event Description	Location	Date
1	COPLADES	Event to solicit public input for the 2011-2015 State Development Plan	La Paz	9/12/11 – 9/13/11
2	Presentation of State Development Plan	Presentation of the final 2011-2015 State Development Plan as developed by the recently elected state governor	La Paz	9/30/11
3	IMECOCAL Conference at CICIMAR	Academic conference on marine biology	La Paz	9/21/11

4	Forum on Tourism	A series of talks on regional tourism as part of the university degree program in tourism	La Paz	9/27/11
5	Presentation of Tourism Book at UABCS	Presentation of new tourism textbook written by a professor at the local university	La Paz	9/28/11
6	Water Footprint Workshop (Conagua and IMTA)	A workshop organized IMTA and held at Conagua offices in La Paz to discuss the concept of virtual water and water footprint	La Paz	10/6/11 – 10/7/11
7	Seminar on Water Management in Arid regions at UABCS	Five-day mini course on water economics by a professor from UNAM	La Paz	10/10/11 – 10/14/11
8	PEACC – presentation of research at UABCS	Presentation of research on climate change and vulnerability being conducted by researchers for incorporation into the state climate action plant	La Paz	10/13/11
9	Workshop on Small Dam Construction and Water Recharge	Workshop to build small dams and water catchment features in the upper portion of the La Paz watershed. The project is organized and carried out by a high school teacher, students and COTAS representative	El Ciruelito	n.d.
10	Forum on Water and Arsenic	sponsored by Niparaja, Agua Vale mas que Oro, Sociedad Civil and Guardianes del Agua	La Paz	12/9/11
11	Urbanería, Participatory Workshop on Alternative Water Management and Urban Development Options for La Paz	Planned intervention to showcase the potential for the construction of linear parks that would provide flood protection, water recharge and bicycle routes.	La Paz	5/11/12- 5/12/12

Table 6. List of participant observation activities

Additionally, using funding available through the Arizona-Baja California Sur Partnership for Water Sustainability, I was able to help co-organize and finance a participatory workshop on urban development and water management in La Paz. The *Urbanería* event was co-organized by three residents who are interested in designing linear parks that could be used as bike paths across the city, as well as provide flood control and aquifer recharge opportunities (rather than channelizing and paving the principal arroyos). The event was based on principles from an emerging approach within New Urbanism and participatory urban planning known as “guerrilla” urbanism or D.I.Y. (Do It Yourself) Urbanism (Hou, 2010), in which citizens stage “interventions” and temporarily reconstruct an area of public space. The goal is to inspire the social imaginary of what that space could look like or be used for. The 2-day *Urbanería* event began with presentations on water issues, green infrastructure, and permaculture. Participants then broke into small groups to analyze a map of La Paz and identify areas where linear parks could be constructed. On the second day, an “intervention” was carried out in a small section of the arroyo (figures 13-15).

Figure 13. Photo 1 from *Urbanería* event

Figure 14. Photo 2 from *Urbanería* event

Figure 15. Photo 3 from *Urbanería* event

Focus Group

A focus group typically consists of a small number of unrelated individuals (usually up to seven participants) (Berg, 2007). The goal of a focus group is to bring together people of different opinions and allow multiple perspectives to be discussed, encouraging a rich conversation and eliciting comments and ideas that might not arise during a one-on-one interview. Such conversations "allow researchers to see the complex ways in which people position themselves in relation to each other as they process questions, issues, and topics in focused ways" (Kamberelis and Dimitriadis, 2008: 397-398). I conducted a focus group style interview with 36 individuals who were participating in a week-long seminar on water management in arid regions at the UABCS (October 10-14, 2011). The seminar was given by a professor of water economics from UNAM. I was asked to give a formal presentation of my research to the group. After gaining informed consent form all participants, I administered a survey to 36 individuals to solicit opinions and perceptions of water supply, climate change vulnerability, water management and desalination in La Paz with this group of individuals. The results of the survey were entered into an Excel spreadsheet and analyzed using a basic count function to determine which factors were perceived to contribute most to water vulnerability in La Paz, the number of respondents who agreed or disagreed with statements about water management, desalination, and urban development. The results were anonymously presented the next day for discussion in a focus group format. The presentation and discussion of results lasted 1.5 hours. With informed consent, the discussion was recorded. The course facilitator agreed to take notes while I conducted the focus group. Participants in the focus group included, marine biologists, students, government employees, professors, water-related NGOs and others (table 7).

Affiliation	**# of participants**
Marine biologists	7
Students (marine biology, sustainable development, ecology, and unspecified)	7
Government employee (federal, state and local)	5
Professors (marine geology, agronomy, economy, unspecified)	4
Water-related NGO representatives	2
Other (geologist, economist, environmental consultant, system engineer)	4
No answer	7
Total	**36**

Table 7. Participants in focus group

<u>Review of Secondary Sources and Archival Data</u>

I collected as many relevant secondary sources that provided data on urban development and growth, water management planning, planning for desalination, and aquifer levels as I could obtain. These sources include government reports and planning documents, census statistics, NGO reports, archived thesis and dissertations at UABCS, archived reports at IMTA, and newspaper articles. The data were used to understand the context in which desalination is discussed as a water augmentation strategy, the role that desalination plays (or could play) in water provision, as well to assess the drivers and constraints on the adoption of the technology. These sources were analyzed for their content and usable data. However, some of the documents, particularly the water planning documents, were also analyzed using critical discourse analysis to assess how discourses about water management and development were presented, how the discourse of climate change was (or was not) addressed, how the benefits of desalination, as well as the concern about desalination were presented, and how desalination was discussed in relation to alternative management strategies.

Research Summary and General Research Themes

In seeking to understand the (potential) transformations and complex imbrications of desalination technology within the socioecological system in which it operates, four general themes have emerged from this dissertation research, including:

1) **The best path towards improved water management is through investments in both infrastructure and institutions (i.e., governance).** This research shows that simply investing more money in technical supply-side water augmentation infrastructure is unlikely to solve the issue of water scarcity. This is especially true in a developing country context where there remains a great need for institutional development and capacity building within the agencies responsible

for water management and land use planning. Furthermore, if aquifer recovery is a central goal of water management, then specific institutional mechanisms must be identified to ensure that the adoption of desalination technology contributes to sustainable water management. Without such mechanisms, it is likely that desalination will result in "business as usual" development in which increased water availability encourages additional growth, rather than resource conservation and environmental sustainability.

2) **Despite the real and urgent need to address the negative impacts of climate change on water resources, desalination should be considered as a "last resort."** This research shows that even in an arid region like northwestern Mexico, there are many water management measures that can be implemented before large-scale desalination systems are built. There is considerable interest in adopting "soft-path" alternatives, including fixing and replacing old and inefficient water delivery infrastructure, installing micro and macro water meters, incentivizing the installation of water-saving devices, and increasing agricultural efficiency. A key observation is that implementing a technical fix on top of water management system that is plagued with more systemic and structural problems does little to improve long-term water management and likely to foreclose or forestall other water management options. Furthermore, desalination, as a technical fix, masks the need to address more difficult social questions and address the long-term trade-offs between different values and uses of water. One of the goals of my critical assessment of the technology is to spur discussion of

alternatives and enrich the options for policy interventions. There remains a need to redefine the goals of modern development and reassess our human-environment relationships with the goal of re-orienting our fundamental institutions in more sustainable and equitable directions.

3) **While desalination, as a technical, supply-side water augmentation strategy, can reduce some vulnerabilities and increase water security at certain scales, it also introduces new social, economic, and environmental vulnerabilities, making it a potentially maladaptive strategy.** Echoing a key insight from geographical research on risks, hazards, and vulnerability, this research has shown that vulnerability to water scarcity and water security are determined by a range of factors, including biophysical, social, political, economic, and technological variables. There is concern about the equitable distribution of the costs and benefits of the technology. While working-class residents have benefitted from the municipal desalination plant in the Los Cangrejos neighborhood, it is unclear whether this model is viable in the long-term, and in other cities. In La Paz, there is concern that the expensive technology will not be used to meet the needs of the most marginalized residents, and instead further contribute to the 'archipelagic' nature of urban water infrastructure that primarily benefits the tourist sector and wealthier residents who are perceived to be able to pay the higher cost of desalinated water. It is important to ensure access to the most basic technologies (i.e., water storage containers, especially cisterns), since this is currently one of the most important ways in which households reduce their vulnerability to water

insecurity and intermittent water supply. There is also concern about the environmental impacts of the technology. While most research has focused narrowly on the impact of brine discharge on marine ecosystems, this research provides a framework that takes broader impacts, such as the coupling of the water-energy nexus, carbon emissions, and urban growth inducement, into consideration.

4) **While discursively, Mexico's water management strategy embraces principles of contemporary environmental governance (i.e., decentralization, public participation, and sustainability), these principles have yet to be fully implemented in practice.** While desalination facilitates democratic decentralization by offering a local solution to water scarcity, most of the financing, permitting, and regulation for desalination remains in the hands of federal-level institutions, which reinforces the state-led hydraulic paradigm. While there is strong support for increasing public participation in water management as part of a new constitutional provision that guarantees access to water and sanitation as a human right, there is little evidence that such participation is occurring in a meaningful way. In the case of planning for desalination in BCS, stakeholder input has not been adequately incorporated into the evaluation and prioritization of water management alternatives. And while desalination has the potential to redress negative environmental impacts associated with the overpumping of aquifers, existing institutional arrangements are insufficient to achieve the purported environmental benefits of the technology

It is my hope that this critical examination of how desalination technology transforms and is transformed by social and environmental relations contributes new knowledge and understanding to the fields of human-environment geography, water resources management, climate change adaptation, technological risk, political ecology, and science and technology studies. This research has aimed to provide insights for advancing a more equitable and sustainable nature-society-technology relationship. It also provides insights into issues of equity and fairness in water management decision-making by examining the distribution of the costs and benefits of desalination technology at various scales. The multi-scalar case study approach also provides a nuanced understanding of the degree to which desalination can be used to reduce water supply vulnerabilities and improve water security, as well as the implications of relying on desalination as a climate change adaptation strategy. Lastly, the regional focus on water management in Mexico provides an in-depth analysis of contemporary environmental governance.

Final Reflections and Conclusions

The discourse around desalination often presents it as an appropriate technological fix to ensure future water supply in arid, water-stressed regions. On the ground, however, desalination systems introduce a complex set of issues and questions. As in most research projects, the broad research questions that I developed at the outset (table 2) changed based on new questions and insights that emerged during fieldwork and data analysis. The specific research questions that are addressed in the three appended articles are related to the original research questions as shown in table 8.

Broad Research Questions	**Specific Research Questions**
1. What is the legal, political, and economic context in which desalination is adopted?	- What leads to production of risks related to water scarcity and the adoption of desalination technology in the Arizona-Sonora border region? (appendix A) - To what degree does the planning and implementation of desalination technology facilitate or deviate from the key principles of contemporary water governance? (appendix C)
2a. How does the adoption of desalination technology affect water provision and management?	- How much do residents pay each month for public potable water service provided by the Los Cabos Desalination Plant? How does this compare to how much they paid for household water supply prior to the construction of the desalination plant? (appendix B) - How satisfied are residents with water provision via the desalination plant? (appendix B) - Do residents consider desalination to be a suitable strategy for augmenting water supplies in the region? (appendix B) - How do residents use the desalinated tap water? (appendix B) - Is the Los Cabos ‘model’ of municipal-scale desalination financially viable in the long-term? And is it a viable model for other cities in BCS? (appendix B) - What are the alternative options for augmenting or improving water supply in La Paz and Los Cabos? (appendix B) - How does the implementation of new desalination systems at the municipal-scale affect alternative water management options? (appendix B) - What are the challenges to improving water management in BCS? (appendix B)
2b. How does the adoption of desalination technology affect the creation of new institutions to manage and regulate the emerging industry?	- What new institutions have developed to regulate the construction, management, and use of desalination technology? - What institutional mechanisms might be needed to ensure that the purported environmental benefits of desalination are realized? (appendix C) - To what degree have explicit mechanisms been designed and/or implemented to achieve aquifer recovery with the adoption of desalination technology? (appendix C)
2c. How does the adoption of	- What are the anticipated risks and potential vulnerabilities associated with the adoption of desalination technology?

desalination technology affect vulnerability, adaptive capacity, and water security at various scales?	(appendix A) - Who is likely to win and lose with the adoption of desalination technology? (appendix A) - Is desalination an adaptive strategy for reducing vulnerability to water scarcity and increasing water security? (appendix A and B)
3. How do socio-environmental drivers shape the implementation of desalination technology?	- How can risks be reduced if desalination technology is adopted as a water augmentation strategy? (appendix A) - What are stakeholders' perceptions of the Public-Private-Partnership model for financing and managing desalination facilities? (appendix C) - How are environmental impacts considered and evaluated in the planning process for desalination? (appendix C) - How does the discourse of climate change affect the adoption of desalination technology (appendix A and B)

Table 8. Relation between broad and specific research questions

There were some limitations and challenges that I encountered during fieldwork and data collection that shifted the direction of and emphasis of my research and the write-up of the final results. Gathering data about the inner-workings of the local water utilities was difficult. It was hard to obtain interviews with key personnel within the water local water utilities, especially in Los Cabos. For the interviews that I was able to conduct, respondents seemed guarded in their responses (probably because of the political nature of their appointments) and typically provided a narrow, technical explanation of issues and problems. I also encountered difficulty in obtaining data about the distribution of desalinated water in Los Cabos, the history of the decisionmaking process that led to the construction of the Los Cabos desalination facility, financial data on how the desalination plant is subsidized, and how the incorporation of desalinated water into the *municipio's* water supply portfolio has affected the water utility's budget.

Given the difficulties in conducting an institutional ethnography, I focused more of my research attention at the community level. I found the household surveys to be very useful and insightful for understanding household water use and household practices for ensuring water security. In Los Cabos, where desalinated water is piped into residents' homes, the survey was useful for understanding perceptions of desalination technology. In La Paz, I found that asking residents about their perceptions of a proposed desalination plant yielded less robust answers. In this case, respondents seemed confused by some of the questions related to desalination technology and appeared to be answering some of the questions to appease the interviewer. However, conducting surveys about the perception of desalination technology with water managers, academics, and community residents who were actively engaged water issues in La Paz proved to be much more robust and useful.

Following the maxim that political ecology is both a hatchet (i.e., a form of critique) and a seed (i.e., a strategy for achieving more equitable resource management) (Robbins, 2004), I helped co-organize a two-day participatory workshop on urban development and water management alternatives in La Paz (see methods section for details). I found this event to be the most rewarding research activity that I engaged in. In conjunction with the dedicated local residents who spearheaded the event, I felt that I was able to contribute (in a small way) to a more hopeful planning process that aimed to identify an alternative vision for urban development and water management in La Paz. While the appended articles in the dissertation do not address this area of research, it is a topic that I plan to return to in the future. Following is a summary of the specific research questions and findings in the appended articles.

Appendix A, “Discourse and Desalination: Potential Impacts of Proposed Climate Change Adaptation Interventions” examines a proposed Arizona-Sonora binational desalination project to be located in Puerto Peñasco, Sonora. The paper uses insights from risk and hazards literature to analyze how, why, and to what effect desalination is emerging as a preferred climate change adaptation response in this region. The research for this paper was carried out as part of team project funded by National Oceanic and Atmospheric Administration (NOAA) Sectoral Applications Research Program grant from 2008 to 2010. The research team, of which I was a part, conducted 75 semi-structured interviews, attended 10 binational water planning meetings, and hosted four workshops with Sonoran water managers. Additionally, I consulted secondary sources of information, including archival documents and published research. The specific research questions and findings in the article are:

- Following Douglas’ (1992) cultural theory of risk, Beck’s (1992) concept of the “risk society,” and Hewitt’s (1983) critical risks and hazards research this paper asks: What leads to production of risks related to water scarcity and the adoption of desalination technology in the Arizona-Sonora border region? Based on a review of the literature and semi-structured interviews, we found that processes of urbanization, border industrialization, uneven economic development, and persistent poverty, along with water-consumptive lifestyles, have created a rising demand for water, leading to high regional vulnerability to water scarcity.
- Following Beck’s (1992) concept of a “risk society” and Perrow’s (1999) complex systems analysis, this paper asks a second, related question: What are the anticipated

risks and potential vulnerabilities associated with the adoption of desalination technology? Using published reports on environmental impacts from desalination systems in other arid regions (e.g., Spain, California, Israel) and data from semi-structured interviews, binational meetings, and stakeholder workshops, we found that there is concern that the impact of the brine and chemical discharge may be disruptive to the fragile marine environment surrounding Puerto Peñasco. In addition, we found desalination technology can have several indirect impacts, including increased urban growth, increased energy demands and carbon emissions, increased water prices, increased path-dependency of water supply and reduced flexibility in water management options, increased reliance on technical expertise, reduced opportunities for participatory decision-making, and shifting geopolitical relations of water security.

- Following Hewitt's (1983) critical risk assessment approach, a third and related question this paper poses is: who is likely to win and lose with the adoption of desalination technology? Based on semi-structured interviews and a review of published research, our analysis finds that the tourist industry in Spain has been the primary beneficiary from water augmentation through desalination. We also found that increasing the price of water has uneven social impacts and disproportionately affects lower-income households. In considering whether the environment wins or loses with the adoption of desalination technology, our analysis concludes that while brine and chemical discharge and increased energy demands negatively impact the environment, desalination technology does have the potential to reduce pressure on aquifers and make more water available for environmental needs. However, the latter is only likely to happen if adoption of the technology is coupled with conservation measures.

- Lastly, the paper asks: how can risks be reduced if desalination technology is adopted as a water augmentation strategy? Our analysis concludes that while fundamental changes in existing political economic institutions are necessary to ultimately reduce risks, there are some near-term measures that could be taken. These include regulating the planning, construction, management, and use of desalination technology; implementing conservation measures; and adopting a fair pricing scheme.

Based on the findings presented above, our overall conclusions in this paper are:

- While the threat of climate change could provide the necessary impetus to fundamentally transform the carbon-based global economy, the current discourse of catastrophic climate change is used to promote more intensive forms of geo-engineering and technological fixes, including desalination.
- Desalination technology has the potential to reduce pressure on aquifers, thereby reducing future water supply vulnerability, and making more water available for environmental needs. However, the latter is only likely to happen if adoption of the technology is coupled with conservation measures.
- At the same time, desalination technology introduces new vulnerabilities by compounding the water-energy nexus, increasing greenhouse gas emissions, inducing urban growth, producing brine discharge and chemical pollutants, shifting geopolitical relations of water security, increasing water prices, hardening the path-

dependency of water supply and reducing the flexibility in water management options, increasing the reliance on technical expertise, and reducing the opportunity for participatory decision-making.

- The adoption of desalination technology provides a means to augment water supplies that does not require policy-makers to change institutional behavior or to address long-term trade-offs between different values and uses of water.
- Overall, we challenge the unproblematized notion of desalination technology as an adaptive strategy for addressing uncertainties related to future water supply. On the contrary, we conclude that desalination technology has the potential to be maladaptive—to increase water supply vulnerability and exposure to environmental risk—rather than reducing vulnerability and risk, as claimed by desalination proponents. Desalination technology may be adaptive if implemented within a culture and practice of water conservation, improvements in existing infrastructure, and efficiency gains (such as metering), changes in institutional behavior, and an explicit concern for equity in the distribution and accessibility of the water produced. In the absence of this comprehensive approach based on demand reduction, we conclude that desalination is likely to reproduce and possibly exacerbate existing vulnerabilities. In the context of the U.S.-Mexico border, plans for binational desalination systems may introduce new vulnerabilities into a complex web of relationships around transboundary water resources. In the context of arid regions, the findings presented in this paper suggest that the discourse on desalination as a

drought-proof water supply is overly-simplistic and under-estimates both the direct and indirect potential negative impacts of desalination systems on local communities.

This article adds to the body of scholarly knowledge in the fields of geography, water resource management, climate change vulnerability and adaptation, and risk and hazards by examining desalination technology from a critical risk analysis approach and providing evidence that demonstrates the potential for desalination technology to be maladaptive. Our analysis suggests that desalination technology must be understood based on its broader systemic impacts and that a range of alternative policy interventions should precede or accompany the investment in desalination.

Appendix B, "Desalination and Water Security: The Promise and Perils of a Technological Fix to the Water Crisis in Baja California Sur, Mexico" examines how the introduction of desalinated water into the municipal water supply portfolio has affected water security in Cabo San Lucas, BCS. It also analyzes proposals for a similar desalination plant in the city of La Paz, BCS and discusses alternative water management options for achieving water security. Using results from 154 household surveys conducted in the neighborhood of Los Cangrejos in Cabo San Lucas, the specific research questions and findings in the article are as follows:

- How much do residents of Los Cangrejos pay each month for public potable water service provided by the Los Cabos Desalination Plant? And how does this compare to how much they paid for household water supply prior to the construction of the desalination plant? My analysis finds that residents now pay considerably less for water service via desalination, as compared to water service by private water trucks.

While most respondents paid about $400 pesos ($33 USD) each month for water from private water trucks, now that desalinated water is distributed to the households via the municipal network, 52 percent of respondents now pay $50-99 pesos ($4-8USD) per month, and 36 percent pay $100-199 pesos ($8-17USD) per month. I conclude that the construction of the Los Cabos Desalination Plant has benefitted the residents of Los Cangrejos by reducing the amount of money they spend each month on household water provision.

- How satisfied are residents with water provision via the Los Cabos Desalination Plant? Respondents were generally satisfied with their water service, noting that now they have water “night and day” and they don’t have to “wait for the water trucks and buy from them.”
- Do residents consider desalination to be a suitable strategy for augmenting water supplies in the region? Respondents overwhelming (91 percent) agreed that desalination is a suitable strategy, though a few respondents expressed concern about what would happen if the plant broke down and concern about the quality of the water and the chemicals used in the process.
- How do residents use the desalinated tap water? Respondents use desalinated water for most household water needs such as bathing, cleaning the house, washing dishes, and washing the car. However, some (11 percent) preferred to use purified water to wash fruits and vegetables and the majority (87 percent) do not drink the desalinated tap water. Instead, most respondents still spend a significant amount of money each month to purchase purified drinking water. Respondents said that they continue to

purchase purified water because they: 1) are concerned about the quality of the desalinated tap water; 2) are accustomed to drinking purified water; or 3) don't have confidence in the desalination process. Although it's a cutting edge technology, in Los Cangrejos and across Mexico the cultural bias against drinking piped water is strong and the availability of desalinated water has not been able to overcome this bias.

Based on results from the analysis of 79 semi-structured interviews, a focus group, and a review of secondary sources, additional research questions and findings addressed in this paper are:

- Does desalination reduce vulnerability to water scarcity and increase water security in the context of communities such as Los Cabos and La Paz? My analysis shows that desalination has played an important role in providing continuous piped water service at reasonable cost to the *colonia* of Los Cangrejos in Cabo San Lucas, which otherwise would not have piped water and would pay for water from private water trucks. When analyzed at the scale of the *colonia*, desalination has been used to address pre-existing inequities in water provision and has increased water security in the narrow sense (i.e., increased water availability for human use). But, while the desalination plant has benefitted the 10,948 residents of Los Cangrejos, it has not solved the problem of water scarcity in Los Cabos. When analyzed at the scale of the city and state new vulnerabilities and challenges emerge. In Cabo San Lucas, other *colonias populares* still experience water shortages and residents in these neighborhoods continue to pay more for water from private water trucks. Given that steady demographic and economic growth has continued and system inefficiencies (i.e., leaks) have remained largely unaddressed, demand has continued to outstrip supply at the city-level. In sum, the degree to which desalination reduces vulnerability to water scarcity and increases water security is extremely uneven and depends on the scale of analysis used.

- Is the Los Cabos ‘model’ of municipal-scale desalination financially viable in the long-term? And is it a viable model for other cities in BCS? My analysis finds that the municipality of Los Cabos registered its first fiscal deficit in the same year that the desalination plant began operation. It is unlikely that other cities will be able to subsidize the expense of providing desalinated water to marginalized neighborhoods through higher tariffs on the hotel industry. In La Paz, one of the proposals for a municipal-scale desalination project would provide water to new tourist developments, rather than marginalized neighborhoods. These findings raise questions about the financial sustainability and social equity of adopting desalination as a means of achieving water security.
- What are the alternative options for augmenting or improving water supply in La Paz and Los Cabos? And how does the implementation of desalination at the municipal-scale affect alternative water management options? My analysis finds that water managers, academics, and non-governmental organizations have identified a range of options for improving water management, including: repairing and replacing broken infrastructure, controlling leaks, installing water meters, developing a long-term regional water plan, building greater adaptive capacity within the local water agency,

incentivizing water conservation, and improving efficiency of water use in agriculture. While desalination was viewed as a "last resort" option by most respondents, in the most recent state-level water planning document, desalination is listed as the principle means by which the cities of La Paz and Los Cabos are expected to balance water supply and demand by 2030. Given limited funds, a primary focus on desalination as the principal means of augmenting water supplies is likely to forestall or foreclose other water management options.

- What are the challenges to improving water management in BCS? My analysis concludes that the constant turnover of leadership positions within key administrative offices leads to institutional instability and makes long-term planning difficult. Additionally, a history of corruption and fiscal mismanagement within the local water utility has hindered the improvement of water management.

This article contributes to the field of geography and water resource management by providing a grounded case-study that addresses Cook and Bakker's (2012) call for multi-scalar analyses of water security. The household-level surveys provide a nuanced understanding of the inequities of water provision via private water trucks and highlight the importance of basic water infrastructure, such as water storage containers, as an adaptive strategy at the household level. The surveys also revealed the continued dependence of households on private water vendors for drinking supplies, adding to the literature on the inequities of the bottled water industry (Robbins, Hintz, and Moore, 2010). My analysis of desalination at the city and state levels raises several questions about the social equity and financial viability of adopting desalination as a means of achieving water security. Additionally, this paper provides evidence that adds support to Grey and Sadoff's (2007) assertion that the best path to water security is through investments in both infrastructure and institutions (i.e., governance). Insights gained through semi-structured interviews and published articles make it clear that simply investing more money in a technological fix to increase the availability of water will not solve the water scarcity problem in the region. Implementing a technical fix on top of water management system that is plagued with more systemic and structural problems does little to improve long-term water management. Investments also need to be made in repairing old infrastructure and installing meters, as well as in increasing the capacity of local agencies charged with water management and urban development. Furthermore, investments are needed to improve the governance and regulation of water, land, and related resources. In sum, this paper challenges the notion that desalination is an appropriate and sufficient technological solution for arid regions.

Appendix C "Deviating from the Mainstream? The Discourse and Practice of Desalination and Environmental Governance in Coastal Northwestern Mexico"
uses two large-scale desalination projects in BCS as case studies to examine how desalination, as a water augmentation strategy, fits within Mexico's contemporary water governance framework which emphasizes the key policy principles of implementing a comprehensive and coordinated water policy framework, decentralization, private sector involvement, public participation, and environmental sustainability. The analysis draws on data collected from a review of secondary documents (i.e., government reports,

newspaper articles, and scholarly articles), 79 semi-structured interviews, and a focus group. The specific research questions addressed in the article are:

- To what degree does the planning and implementation of desalination technology facilitate and/or deviate from the key policy principle of implementing a comprehensive and coordinated water policy framework? Within the national-level 2030 Water Agenda, desalination system build-out is not highlighted as a priority action for achieving balanced water supply and demand in Mexico. Instead, emphasis is placed on agricultural modernization and increasing system efficiencies. In contrast, desalination figures prominently in the state-level planning documents that are part of the 2030 Water Agenda. In the cities of La Paz and Los Cabos, desalination is expected to provide 44 percent and 54 percent, respectively, of future water supply increases to meet the water deficits expected by 2030. My analysis concludes that there is a clear disconnect between the federal and state level policies regarding desalination.
- To what degree does the planning and implementation of desalination technology facilitate and/or deviate from the key policy principle of decentralization? My analysis finds that, while desalination facilitates democratic decentralization by offering a local solution to water scarcity, most of the financing, permitting, and regulation for desalination remains in the hands of federal-level institutions, which reinforces the state-led hydraulic paradigm.
- To what degree does the planning and implementation of desalination technology facilitate and/or deviate from the key policy principle of private sector involvement?

A Public Private Partnership (PPP) was used to finance, build, and operate Mexico's first-ever public desalination facility in Los Cabos, BCS in 2006. Sixty-four percent of the funding comes from private resources and the remaining 36 percent comes from the federal resources. My analysis finds that the PPP model is an important source of funding for desalination. However, my analysis raises questions as to the long-term financial viability of desalination as a water augmentation option and the ability of other cities in BCS, and throughout Mexico, to subsidize this new technology. The high cost of the technology raises concerns about whether desalination technology will be used to meet the needs of the most marginalized residents, or whether it will further contribute to the 'archipelagic' nature of urban water infrastructure that primarily benefits the tourist sector and wealthier residents who are perceived to be able to pay the higher cost of desalinated water, especially in La Paz. Furthermore, the difficulty in obtaining public documents regarding these desalination projects raises questions about the transparency and accountability of PPP projects. Given the relatively recent experience with this form of private sector financing, it is too early to determine whether this PPP model represents a viable option for financing desalination projects.

- To what degree does the planning and implementation of desalination technology facilitate and/or deviate from the key policy principle of public participation? My analysis finds that, while there is strong support for increasing public participation in water management as part of a new constitutional provision that guarantees access to water and sanitation as a human right, there is little evidence that such participation is occurring in a meaningful way. In the case of planning for desalination in BCS, stakeholder input has not been adequately incorporated into the evaluation and prioritization of water management alternatives.

- To what degree does the planning and implementation of desalination technology facilitate and/or deviate from the key policy principle of promoting environmental sustainability? And what new institutions have developed to regulate the construction, management, and use of desalination technology? My analysis finds that, while desalination has the potential to redress negative environmental impacts associated with the overpumping of aquifers, existing institutional arrangements are insufficient to achieve the purported environmental benefits of the technology. Additionally, the feasibility study for the La Paz project focuses on the impact of the brine discharge on the marine ecosystem; it does not address environmental sustainability more broadly.
- Where does the core support for adopting desalination as a water augmentation strategy come from? It is difficult to determine where the core support for desalination as the principal means for achieving water balance by 2030 is coming from. While a former advisor to the Los Cabos water utility seemed to take pride in the local government's role in establishing the Los Cabos Desalination Plant, there appears to be more resistance to municipal-scale desalination within the La Paz water utility, primarily due to concerns about cost, as well as the need to address other water management measures. At the federal level, Conagua provides financial support, and the regional Conagua office has been instrumental in the development of the BCS planning documents for *2030 Water Agenda* that promote desalination as the

principal means for addressing the water supply gap. The state water agency (CEA) also supports desalination and has a department dedicated to the development of this technology. The role of international finance capital is also clearly important.

- What are potential institutional arrangements that could be implemented to help ensure that desalination achieves the purported environmental benefits? My analysis concludes with four policy recommendations to help ensure that if desalination technology is adopted, some of the environmental benefits are realized. These recommendations include: 1) integrating land use and water planning; 2) improving monitoring and regulation of groundwater extraction; 3) increasing the capacity within water and planning agencies; and 4) pre-conditioning desalination (or other supply-side water infrastructure projects) upon the successful implementation of a range of water conservation and system efficiency measures.

This article contributes to geography and environmental policy by providing an in-depth regional analysis of water management in Mexico. The literature review highlights five key principles of contemporary water governance frameworks developed by international actors, such as the World Bank and the transnational network of water experts that promote Integrated Water Resources Management (IWRM). The analysis provides a textured, case-study example of how and why developing a comprehensive and coordinated water policy framework is difficult to achieve. My analysis of the discourse and practice of desalination at the national and state level highlights the fragmentation of national versus regional water policy priorities in BCS. My conclusions support Wilder's (2008b) assertion that water reforms in Mexico have led to a more fragmented national and regional politics. The focus of the analysis is on how Mexico's recent adoption of desalination technology as a water augmentation strategy in BCS facilitates or deviates from these key water governance principles. Desalination is increasingly becoming a preferred water augmentation strategy in many regions (i.e., Spain, Israel, southwestern U.S., Mexico), but there is relatively little research on the technology. The focus on the development of institutional arrangements for the regulation and management of the technology is especially important in the developing country context. My analysis shows, while discursively, Mexico's water management strategy embraces principles of contemporary environmental governance (i.e., decentralization, public participation, and sustainability), these principles have yet to be fully implemented in practice, save private sector involvement. The paper goes beyond description and critique and identifies specific institutional arrangements that are needed for desalination technology to contribute to sustainable water management.

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APPENDIX A. DISCOURSE AND DESALINATION: POTENTIAL IMPACTS OF PROPOSED CLIMATE CHANGE ADAPTATION INTERVENTIONS IN THE ARIZONA-SONORA BORDER REGION

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Abstract:

The specter of climate change threatens fresh water resources along the U.S.-Mexico border. Water managers and planners on both sides of the border are promoting desalination—the conversion of seawater or brackish groundwater to potable water—as an adaptation response that can help meet growing water demands and buffer against the negative impacts of climate change on regional water supplies. However, the uneven distribution of costs and benefits of this expensive energy-intensive technology is likely to exacerbate existing social inequalities in the border zone. In this article, we examine the discourses employed in the construction of the climate problem and proposed solutions. We focus our analysis on a proposed Arizona-Sonora binational desalination project and use insights from risk and hazards literature to analyze how, why, and to what effect desalination is emerging as a preferred climate change adaptation response. Our risk analysis shows that while desalination technology can reduce some vulnerabilities (e.g., future water supply), it can also introduce new vulnerabilities by compounding the water-energy nexus, increasing greenhouse gas emissions, inducing urban growth, producing brine discharge and chemical pollutants, shifting geopolitical relations of water security, and increasing water prices. Additionally, a high-tech and path-dependent response will likely result in increased reliance on technical expertise, less opportunity for participatory decision-making and reduced flexibility. The article concludes by proposing alternative adaptation responses that can offer greater flexibility, are less path dependent, incorporate social learning, and target the poorest and most vulnerable members of the community. These alternatives can build greater adaptive capacity and ensure equity.

Keywords: Climate Change Adaptation; Maladaptation; Risk Analysis; Water Policy; Desalination

1. Introduction: Tarnishing a Silver Lining—The Advent of Maladaptive Climate Responses

The silver lining of the climate crisis is that it could provide the necessary impetus to fundamentally transform our unsustainable energy-intensive, carbon-based, and consumption-driven economy. Academics and development practitioners recognize that, "Radical changes are needed in development trajectories to reduce fossil-fuel consumption and this challenges 'business-as-usual' development" (Boyd et al. 2009, p.666). Brooks, Grist and Brown (2009) call for a "…radical shift in how we relate to our environment and to each other, and a rethinking of patterns of production and consumption, and of who and where we are" (p. 753). Recent literature on climate change adaptation focuses on the concept of integrating, or "mainstreaming" adaptation planning into sustainable development planning (Boyd et al., 2009; Brooks et al., 2009; Huq and Reid 2009; Persson and Klein, 2009; Sanchez-Rodriguez, 2009; Golkany, 2007; Lemos et al., 2007; McGray et al., 2007; Klein, Schipper and Dessai, 2005; Klein and Smith, 2003).

In practice, however, this silver lining is tarnishing fast. Rather than focusing on broader changes in our economy or philosophical changes in our human-environment relations, the discourse surrounding the response to climate change is increasingly focused on technological fixes that allow 'business as usual' development in a highly unequal world. This article briefly examines the discourses employed in the construction of the climate problem and proposed solutions. We focus our analysis on the discourse of desalination as a "solution" to water supply uncertainties by looking at the case study of a proposed Arizona-Sonora binational desalination project. We then draw on insights from risk and hazards literature to analyze how and why desalination is emerging as a preferred climate change adaptation response and consider the potential impacts of this proposed intervention.

Discourses, in the Foucauldian sense, “compromise groups of related statements which govern the variety of ways in which it is possible to talk about something and which thus make it difficult, if not impossible, to think and act outside of them” (Allen 2004, p.18). Given the important roles that language and discourse play in shaping worldviews (Hajer, 2006) and policy interventions (Ribot and Marino, this issue), we believe it is important to understand the discursive context in which desalination is being proposed as a “solution” to projected climate change impacts. As evidenced by recent proposals to deal with the climate crisis, many scientists and policymakers believe that the same technical logic that precipitated the crisis can be used to fix it. With the increasingly “alarming” and “urgent” character of the scientific climate discourse, in which climate change is described as “abrupt”, “irreversible” and “catastrophic” (Travis, 2010; Hulme, 2008; Risbey, 2008), more intensive forms of geo-engineering and technological fixes are being proposed (Kousky et al., 2009; Hulme, 2008; Niemeyer, Petts and Hobson, 2005). For example, some atmospheric and climate scientists support the development of solar radiation management – a suite of “solutions” which includes dumping iron dust into the ocean in an attempt to trigger algae blooms that will absorb carbon dioxide; injecting the stratosphere with aerosols and filling the skies with giant satellites that will reflect solar rays back into the atmosphere; genetically engineering crops to increase their carbon uptake capacity; and further developing carbon capture and storage techniques (Robock, 2008; Schnieder, 2001). But as Robock (2008) asks, "Is the cure worse than the disease?" (p. 1).

In a similar vein, desalination – the conversion of seawater or brackish ground water to potable water – is being touted as an "almost inexhaustible" source of water that can meet growing water demands and buffer arid regions against climate change (NRC 2008, p. 1, see also Smith, 2009). To be sure, technical infrastructure development has dominated water resources planning throughout most of the twentieth century, with water development based on the construction of dams, reservoirs, aqueducts, and hydropower plants (Gleick, 2000; Tortajada, Rockstrom and Figueres, 2003; Conca, 2006). Despite the emergence of a new water paradigm in the last 30 years that is focused on demand management, social participation, decentralized governance and environmental sustainability, the technological agenda remains surprisingly strong. Desalination as a "drought-proof" solution to water scarcity and future climate change (Cooley, Gleick and Wolff 2006, p. 2) has appeal worldwide, with plants recently constructed or in the planning stages in Spain, Israel, Mexico, Australia and the United States, among multiple examples. In total, as of 2005, 130 countries have developed over 10,000 desalination plants (Cooley et al., 2006). Proposals for many of these projects invoke the discourse of climate change and point to desalination as an adaptation response. For example, in Australia, the cost of building desalination plants has been described as "the cost of adapting to climate change" (Onishi 2010, p.A6). Although the impetus for Spain's dramatic policy shift toward to the use of desalination technology in 2004 was to quell regional fights over interbasin water transfers, it is also lauded as a source of water that "can be predicted independently of climate changes and drought" (Downward and Taylor 2007, p. 280). While noting its high energy costs, the Intergovernmental Panel on Climate Change lists desalination as an "adaptation option" (Bates et al., 2008, p. 49). This IPCC technical report states, "In the future, wastewater reuse and desalination will possibly become important sources of water supply in semiarid and arid regions" (p. 10).

We focus our analysis on one of several recent proposals to build binationally funded desalination plants along the Gulf of California in Sonora, Mexico (Fig. 1). Such projects would augment water supplies in both Sonora and Arizona. Arizona's allotment would either be pumped northward to Imperial Dam near Yuma, Arizona, or exchanged for additional Colorado River water (HDR, 2009; López-Pérez, 2009; USTDA, 2008; McCann, 2008). In this region, climate change is expected to result in increased temperatures, intensified droughts, and greater variability in rainfall patterns (Wilder et al., 2010; IPCC, 2007). In light of these changes, desalination is being promoted by various local, state, and regional decision-makers as an adaptation response that can allow the arid west to meet increased water demands driven by increasing population and economic growth, as well as buffer the region's water supply against climate change. For example, water managers from nine U.S.-Mexico border states attended a border governors' conference on binational desalination in San Diego in May of 2010. The conference's website states:

> The U.S.-Mexico border region needs upgraded and enhanced water infrastructure for projected population and economic growth as well as environmental protection. *Expected climate change impacts will exacerbate competition for the region's finite water resources. Communities throughout*

> *the border region from California to Texas are increasingly examining desalination - of seawater or brackish groundwater – as a potential water supply option.* Possible U.S. – Mexico desalination opportunities are under evaluation in the cooperative Colorado River binational process (Water Education Foundation, 2010, italics added).

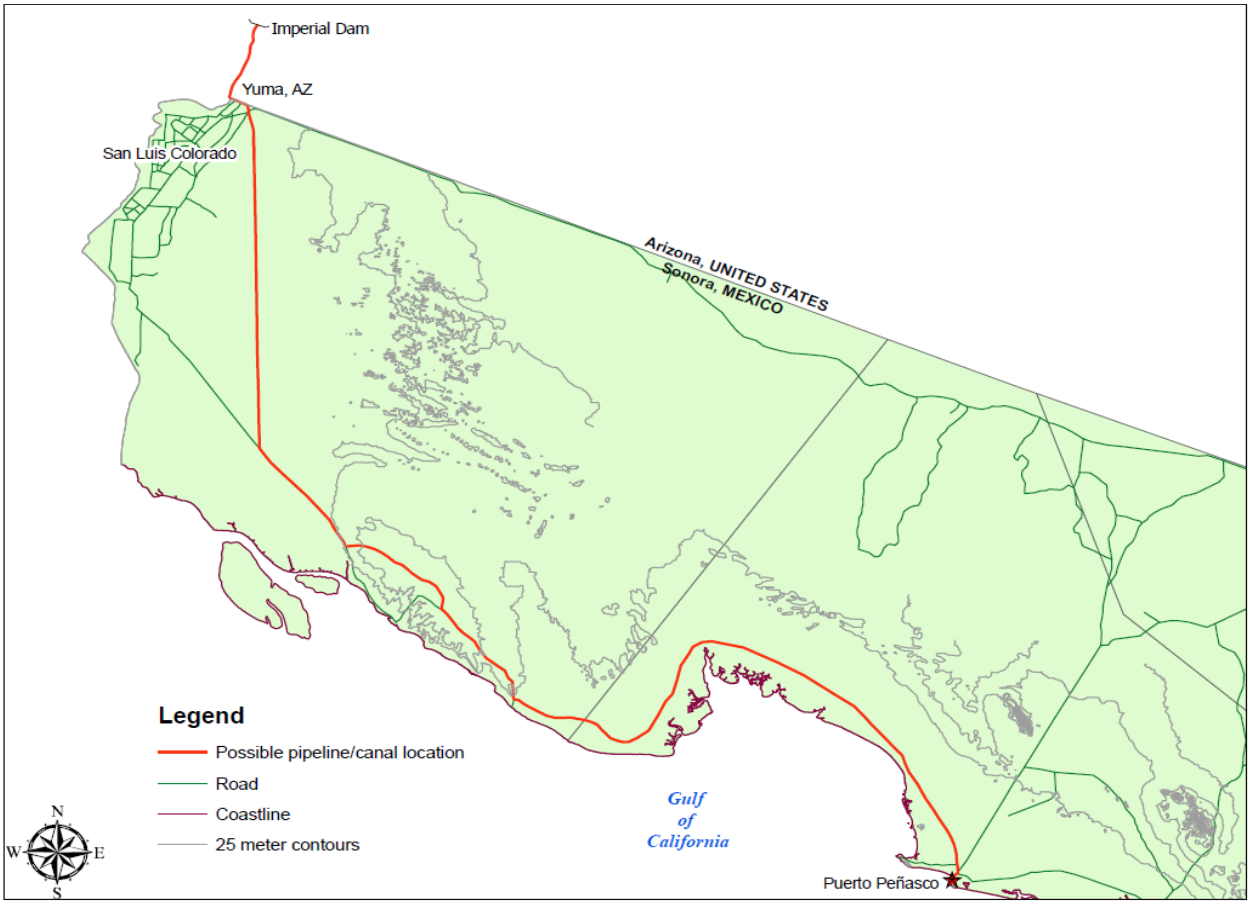

Fig. 1. Proposed Binational Desalination Plant in Puerto Peñasco, with canal to transport water northward to Imperial Dam near Yuma, Arizona (Carpenter 2008) **permission needed**

In this paper, we ask: how and why has desalination emerged as a preferred climate change adaptation response and what are its potential impacts? Using Douglas' (1992) cultural theory of risk, Beck's (2009) theory of the "risk society," Perrow's (1999) "complexity/coupling" framework, and critical risk literature (Hewitt, 1983), we evaluate desalination as an adaptation response. In the following sections, we define our use of the terms vulnerability, (mal)adaptation, and adaptive capacity. We then review the key theories on technological risk and hazards that frame our analysis and are relevant for the evaluation of other adaptation proposals. Next, we present the Arizona-Sonora case study, analyze how and why desalination has become a preferred adaptation response, and conduct a critical risk analysis of the Arizona-Sonora binational desalination proposal. We conclude with a summary of the vulnerabilities and inequalities posed by desalination technology and recommendations for more flexible adaptation responses.

2. Key Terms: Vulnerability, (Mal)Adaptation, Adaptive Capacity

In order to evaluate climate change adaptation responses, it is critical to understand what is meant by key terms such as vulnerability, (mal)adaptation, and adaptive capacity. One insight from critical hazards research is that *vulnerability*, or "the capacity to be wounded," is caused by more than simply the physical exposure to a hazard (Füssel 2007, p. 1). Researchers taking a political economy approach to risk and hazards have found that social, political, and economic conditions also shape people's vulnerability in the face of hazards (Ribot, 2010; Füssel, 2007; Adger, 2006; Liverman, Yarnal and Turner, 2004; Bohle, Downing and Watts, 1994; Hewitt, 1983). As summed up by Ribot (2010), vulnerability does not "fall from the sky" (p. 47). Instead, it is socially produced by on-the-ground conditions and results in differentiated outcomes for different social groups.

Adaptation is defined as "actions taken to adjust to the consequences of climate change, either before or after impacts are experienced" (Lemos et al. 2007, p. 1; see also

Smit and Wandel, 2006). In other words, adaptation measures can be either planned and proactive or autonomous and reactive (Smit and Pilifosova, 2003), but the ultimate goal of an adaptation measure is to reduce vulnerability. Adaptation measures are ideally dynamic, flexible, and able to change in response to new stimuli and conditions (Wilder et al., 2010).

The potential for adaptation measures to (inadvertently) increase vulnerability is referred to as *maladaptation* (IPCC 2001). Barnett and O'Neill (2010) use the case of desalination in Melbourne, Australia as a prime example of maladaptation. They propose that maladaptive responses have some combination of the following characteristics: 1) increase emissions of greenhouse gases 2) disproportionately burden the most vulnerable 3) have high opportunity costs 4) reduce incentives to adapt and 5) are path dependent. Desalination, being an energy intensive, expensive technology with unintended side effects fits these first three characteristics. In addition, the perception of "limitless" water undermines conservation efforts. And once built, fixed capital invested in a large infrastructure project creates a path dependency and reduces the flexibility of future generations to respond differently (Barnett and O'Neill, 2010).

Whereas "specific adaptations" typically refer to particular actions (e.g., building new infrastructure), the concept of "generic adaptation" or "*adaptive capacity*" refers to creating an enabling environment that "allows a society to prepare for and cope with climate change" (Klein and Smith 2003, p. 320). Enabling environments are necessary to ensure that specific adaptations are successfully implemented. Hence, much of the recent literature focuses on the concept of building adaptive capacity to enhance the ability of individuals, communities, institutions, and states to respond effectively to climate change impacts (Wilder et al., 2010; Moench, 2009; CCSP, 2008; Füssel, 2007; Lemos et al., 2007; Smit and Wandel, 2006; Smith, Klein and Huq, 2003).

As outlined by Smit and Wandel (2006), adaptive capacity is influenced by "managerial ability, access to financial, technological and information resources, infrastructure, [and] the institutional environment within which adaptations occur…" (p. 287). Social learning and knowledge sharing among communities of practice are critical elements of building adaptive capacity at the institutional level (Pelling et al., 2008; CCSP, 2008; Pahl-Wostl, 2007; Cash et al., 2003). Such learning can take place during iterative interactions that facilitate peer-to-peer learning and build trust among institutional actors (Wilder et al., 2010).

Many of the attributes associated with building adaptive capacity resonate with attributes emphasized in the literature on "adaptive management" of natural systems (Gunderson and Holling, 2002; Feldman, 2008). For example, both processes involve the concept of social learning, encourage participatory decision-making, and emphasize the importance of maintaining flexibility and favoring reversible, non-path dependent management options. As summarized by Feldman (2008), appropriate adaptive management decisions, "should be modest in scope, scientifically sounds, and reversible in impact. To implement adaptive management, decision makers must learn from previous mistakes, monitor impacts, adopt mid-course changes, and reach consensus" (p. 512-13). Therefore, the literature on adaptive management offers a resource for planners, managers and policy-makers who are tasked with creating and implementing climate change adaptation measures.

Mearns and Norton (2010) call for climate research that examines “not only how climate change contributes to vulnerability, but also how climate policy and response measures may magnify the effects of many existing drivers of vulnerability” (p. 3). As Kates (2009) and Dow, Kasperson and Bohn (2006) have observed, one group’s adaptation may be another group’s hazard. This potential to increase vulnerability among certain groups means that assessments of climate adaptation measures must be “pro-poor”, taking into account the impacts of these policies on the poorest members of a community across multiple scales (Ribot 2010, p. 47; Kates, 2009; Adger et al., 2006). In sum, based on our understanding of adaptation, responses to climate change that are inflexible, non-responsive to changing stimuli and conditions and expert-driven (i.e., non-participatory) rank relatively low as adaption strategies, and may be considered maladaptive if they, on balance, actually worsen vulnerability, reduce the vulnerability of some social groups at the expense of others, and/or produce new vulnerabilities.

3. Theory and Literature Review: Risk and Hazards Research—Framing an Analysis of Adaptation

In this section we review the contributions of scholars from four areas of risk and hazards research in order to frame our analysis of desalination as a climate change adaptation response. These four areas include: cultural perspectives of risk (theorized by Mary Douglas), modern technological risks (Ulrich Beck), complex systems analysis (Charles Perrow) and critical hazards research (Kenneth Hewitt and colleagues).

Anthropologist and cultural theorist Mary Douglas developed a typology of cultural attitudes toward risk (1992). Her work can be used to argue that the discourse of the technological fix as a solution to serious environmental problems is based on a culturally inscribed faith in science and engineering and a belief that humans have the ability and right to control nature. This culturally constructed world-view of a “robust” nature is associated with a growth paradigm that sees no reason to limit economic expansion or question our society’s ability to engineer our way out of any problem. As Douglas (1992) explains, this view of nature encourages “bold, individualistic experimentation, expansion, and technological development” (p. 263). We use Douglas’ typology of the instrumental, growth-based paradigm to understand the cultural drivers that give rise to proposals for desalination as solution to water supply management in the face of climate change.

While Douglas is useful for understanding how and why technological solutions arise, Beck’s theory of the “risk society” and reflexive modernization” gives us cause to question what the unintended consequences of these technological fixes might be (Beck, 2009; Beck, 1994; see also Winner, 1977). Additionally, Beck’s theory highlights a tension between an increased reliance on expert knowledge to manage complex systems and a growing distrust of experts by the public. Beck argues that western industrialized countries transitioned from a traditional society to a modern society based on scientific knowledge and trust in experts. In turn, modernity, and its associated unintended consequences, brought about new risks and hazards, hurtling us into a new phase of reflexive modernity, or a “risk society.” Beck summarizes his theory, stating, “…the further the modernization of modern societies proceeds, the more the foundations of the industrial society are dissolved, consumed, changed and threatened" (1994, p. 176). Beck emphasizes that it is the very "triumphs" of modernity that bring about new risks (Beck 2009, p. 8). With respect to technology, Beck observes, "we are living in the *age of side effects*" (Beck 1994, p. 175, italics in original) in which unknown and unintended consequences have become a dominant force in society leading to a disillusionment with the idea of linear progress and a waning trust in experts (Beck 1992, p. 22). We use Beck's notions of "side effects" and "unintended consequences" to consider the full-range of desalination-related risks.

Beck makes an important distinction between simple (early) modernity and reflexive (late) modernity in terms of trust in science and experts. He argues that simple modernity, brought about by the industrial revolution, is characterized by an increasing knowledge of the world through science, trust in experts and faith in linear progress. Simple moderns were optimistic about the ability to use increasing knowledge to improve society, confident in the ability to calculate risks using rational cost-benefit analyses, and trusting of experts to make decisions that were in the best interest of the collective. In contrast, reflexive modernity (also called the "risk society") is characterized by "non-knowledge" (Beck 1994, p. 175). Dietz, Frey and Rosa (2002) call this "meta-uncertainty" or "uncertainty about the degree of uncertainty" (p. 332). The notion of uncertainty in risk literature resonates with the concept of uncertainty in climate change science. Climate change has a characteristic of non-stationarity, meaning that past climate trends and historical climate patterns are not a reliable predictor of the future (Milly et al., 2008). Uncertainty is one of the most challenging problems for water managers planning for future water supply. In sum, the unintended side effects of technology, a waning trust in experts, and the increasing scientific uncertainty about technologies and future climate conditions calls into question the modern reliance on technological fixes.

Complementary to Beck's theory of the risk society is Perrow's (1999) analysis of complex systems. However, in contrast to Beck's grand theory, Perrow provides a grounded analysis of complex systems based on empirical case studies of technologies such as nuclear power plants, petrochemical plants and airplanes. In order to determine the riskiness of a system, Perrow looks at the interactive complexity of the system and how tightly coupled it is (pp. 88, 96-97). A complex system has multiple parts in close proximity that may share common connections between components. In contrast, a linear system has temporal and spatial separation between processes and units (Perrow 1999, p. 88). Complex systems are more efficient, but linear systems are less risky. The second factor in Perrow's analysis is system coupling, which refers to the degree to which two units or processes are interdependent. In a tightly coupled system, there is no buffer between units or processes so that what happens in one system has a direct effect on what happens in another. Conversely, in a loosely coupled system the connections and interactions between various units and processes are more ambiguous and flexible. This allows certain parts of the system to respond and act according to their own characteristics. He concludes that tightly coupled systems are more risky and less able to cope with system shocks. Perrow argues that technological fixes tend to increase complexity and tighten coupling, making accidents even more likely. Together, Beck and

Perrow's insights contribute to our framework for analyzing how the complexity of desalination (and energy dependency) and potential side effects may create new vulnerabilities.

Closely related to Beck and Perrow's work on technological risk, but stemming from a different academic tradition, Hewitt and colleagues (1983) provide a critique of early risk and hazards research. Their main critique is that traditional risk and hazard analyses (e.g., White's [1945] work on human settlements in floodplains and Burton, Kates and White's [1978] work on environmental hazards) take a reductionist view of human action and pay too much attention to individual perceptions and individual choice, rather than focusing on the causal structures or systemic nature of risks. The dominant focus on rational choice ignores the fact that the choice sets are constrained by macro-level structures. A critical risk analysis, as outlined in Hewitt (1983) must take into account not only the biophysical factors that make a social group vulnerable to risks, but also the political economic pressures that differentially affect a social group's vulnerability and shape people's ability to cope with and respond to risks. This type of analysis often finds that the underlying drivers of risk are related to the economic requirement for constant growth and expansion (Smith, 2008; Harvey, 2006; Hewitt, 1983).

The counter-critique of Hewitt and colleagues' (1983) approach is that such a critical analysis makes it difficult, if not impossible, to offer policies that are easy for managers and policy-makers to implement. Short of calling for radical changes in our political economic institutions, there may seem to be few solutions that a critical analysis can offer. However, if researchers and decision-makers wish to break the iterative risk cycle in which technological fixes simply mask the underlying problems and spawn additional risks, then a critical analysis must be conducted. It is important to seriously consider potential side effects because they may threaten to dissolve, consume, and change the foundations of industrial society (to paraphrase Beck, 1994, p. 176). Such an analysis would not only show how the economic requirement for growth and expansion breeds new risks, it would also show who wins and who loses from policies that support a status quo focus on development. With this framework in mind, we describe the case of desalination at the Arizona-Sonora border and provide a critical analysis of desalination as a technological risk.

4. Case Study: Binational Desalination as a Climate Change Adaptation Response in the Arizona-Sonora Region

As part of a larger study on climate change and water vulnerability in the Arizona-Sonora border region, we have worked with water managers in four urbanizing hot spots (Fig. 2) to identify water-related vulnerabilities and assess current and future adaptation responses. Over a two-year period, our research team conducted 75 semi-structured interviews, attended 10 binational water planning meetings and hosted 4 binational workshops with water mangers, emergency preparedness planners, decision-makers, and local water users. In addition, we consulted archival documents such as municipal development plans, water agency reports, aquifer assessments, feasibility studies and newspaper reports to understand the context in which water management strategies arose. The case study presented here draws on fieldwork in the municipality of

Puerto Peñasco—the principle site for a proposed Arizona-Sonora binational desalination plant (Fig. 1).

Fig. 2. Map of “urban hotspots” in the Arizona-Sonora Border Region, including Puerto Peñasco (figure created by Rolando Diaz-Caravantes)

Puerto Peñasco is a burgeoning coastal resort community located on the Gulf of California. Just a four and half hour drive from Tucson, Arizona, Peñasco is a favorite beach and retirement destination for landlocked Arizonans. The depleted groundwater aquifers can no longer support the growth that has recently been the economic engine of Peñasco, so water managers are searching for new ways to augment local water supplies. Peñasco’s municipal planners and officials have pinned their hopes on the construction of a major desalination plant to serve municipal needs. The desalination proposal has significant binational implications, since both Arizona and Nevada water authorities have plans to potentially utilize desalinated water from the Peñasco plant to provide water for urban dwellers in Phoenix, Tucson and Las Vegas, or farmers in Yuma.

In 2008, the municipality of Puerto Peñasco contracted with the U.S. Trade and Development Agency (USTDA) to determine the feasibility of building a desalination plant. The municipality is interested in desalination to meet its own needs, as well as to support the growing tourist sector in the region. The former president of the municipality, Heriberto Rentería Sánchez, considered seawater desalination to be the "only option for this desert community at this point in time" (USTDA 2008, p. 20). The current president, Alejandro Zepeda Munro, is also interested in pursuing desalination as a water augmentation strategy for his town (personal communication, 2009).

During the same time period, water managers from the Salt River Project and the Central Arizona Project (CAP), along with representatives of the Arizona Department of Water Resources, the U.S. Bureau of Reclamation and Sonora's State Water Commission authorized a feasibility study to determine the costs of producing and transporting desalinated water from Puerto Peñasco, Sonora to Imperial Dam near Yuma, Arizona. The study compared the estimated costs of a smaller-scale Arizona-Sonora Scenario and a larger-scale Regional Scenario (HDR, 2009). The findings show that, in the Arizona-Sonora Scenario, 120,000 acre-feet per year (AFY) of desalinated water could be produce and conveyed via pipeline from Puerto Peñasco to Imperial Dam at a cost of $2,727/AF.

In the Regional Scenario, 1.2 million AFY could be produced and conveyed to Imperial Dam via canal for $1,183/AF (HDR 2009, p. 9).

Arizona is not the only state in the region considering binational desalination. In a recent report commissioned by the seven Colorado River basin states, the construction of an ocean water desalination plant in California, Baja California, or the Gulf of California was highlighted as an option that could increase the water supply of the region (Colorado River Water Consultants, 2008). The Southern Nevada Water Authority has expressed interest in binational desalination (Holme, 2010). Additionally, the International Boundary and Water Commission (IBWC), the institution responsible for settling issues related to boundary and water treaties between U.S. and Mexico, has established a core working group dedicated to finding new water resources, of which desalination is a high priority for both countries (Ruth, 2009). The IBWC is considering potential binational desalination projects in Ensenada, Baja California; Rosarito, Baja California; and Puerto Peñasco, Sonora (López-Pérez, 2009; Salmón, 2009; McCann, 2008). At a border governors' conference on binational desalination, a representative of the North American Development Bank (NADB) stated that the Bank is interested in funding binational desalination projects. He expects to see such proposals approved through the Bank in the near future, because, as he emphasized, "Desalination will be an important part of meeting future water needs" (Garcés, 2010).

Despite the complex international arrangements that a binational project would entail, some water managers and policy experts view it as a less politically divisive solution to the region's water scarcity than the reallocation of water from rural agricultural users to urban users (Smith, 2009; Kohlhoff and Roberts, 2007). Desalination is also a more politically salient solution than imposing dramatic conservation measures or calling into question the growth paradigm that drives regional water policy (Hirt, Gustafson, and Larson, 2008). The push to locate a desalination plant in Mexico, rather than California, is a result of differential power relations and uneven development. As noted by a senior CAP official, among the primary benefits of a binational desalination plant are reduced regulatory hurdles and fewer environmental protection measures in Mexico (personal communication, 2010).

5. A Critical Risk Analysis of Arizona-Sonora Binational Desalination

In this section, we conduct a critical risk analysis of proposals to build binationally funded desalination plants along the Arizona-Sonora border. Using the analytical framework described in section three, this four-step analysis considers the production of risks, anticipates future risks, identifies winners and losers and proposes options to reduce risks (Table 1). Data for the analysis comes from our fieldwork including archival documents (i.e., government reports, planning documents and newspaper articles) and information from meetings, workshops and interviews, as well as relevant information available in grey literature and academic publications.

5.1 The Production of Risks

Our critical risk analysis begins by understanding how risks are produced. In the case of desalination along the U.S.-Mexico border, processes of urbanization and border industrialization, uneven economic development and persistent poverty, along with water-consumptive lifestyles, have created a rising demand for water in this arid region,

Step	Theoretical Frame	Data Sources	Findings
1. Production of Risks	Cultural Perspectives of Risk (Douglas) Modern Technological Risks (Beck)	Archives, grey literature, academic publications	Processes of urbanization, border industrialization, uneven economic development and persistent poverty, along with water-consumptive lifestyles, have created a rising demand for water, leading to high regional vulnerability Large-scale infrastructure projects (i.e., CAP), assume that the environment is robust and trust that human ingenuity will engineer a solution to alleviate current and future water vulnerabilities Desalination may be perceived to be less risky than wastewater re-use, leading to its preference as a water augmentation strategy Large-scale infrastructure projects often lead to expert rule, create power relations over water, and are path dependent (rather than flexible)
2. Anticipated Risks	Modern Technological Risks (Beck) Complex Systems Analysis (Perrow)	Archives, meetings, workshops, interviews	Discharge of brine water and chemicals is the most widely-recognized risk Indirect, or unintended, risks include increased energy demands, increased greenhouse gas emissions, and increased urban growth (which is associated with a host of environmental impacts) High energy demands increase the coupling of the water-energy nexus and may encourage the co-location of desalination and nuclear energy, which entails additional risks Creation of large cities, highly dependent upon a single source of water, may make environmental security more tenuous Binational arrangements may reduce national autonomy and shift geopolitical power relations over water.

3. Identification of Winners and Losers	Critical Hazards Research (Hewitt)	Workshops, interviews, grey literature, academic publications	The tourist industry benefits from water augmentation through desalination Increase in the price of water has uneven social impacts, disproportionately affecting poorer households Discharge of brine and chemicals, along with increased urban growth and higher energy demands could result in negative environmental impacts If coupled with conservation measures, desalination could reduce pressure on aquifers and make more water available for in-stream environmental flows, making the environment a winner
4. Risk Reduction	--	--	Changes in political economic institutions are needed to ultimately reduce risks that are driven by our current economic system's requirement for constant growth and expansion Regulation could minimize some risks in the near-term Conservation measures, in conjunction with growth and/or water consumption limits should be implemented before desalination is adopted in order to avoid Jevons paradox or business-as-usual A fair pricing scheme must be developed so that all residents are able to benefit from desalination

Table 1. Summary of Critical Risk Analysis Findings

leading to high regional vulnerability (Wilder et al., 2010; Ray et al., 2007; Liverman and Merideth, 2002). The city of Tucson, in southern Arizona, relies on the Central Arizona Project (CAP) to transport Colorado River water 336 miles eastward and nearly 3,000 vertical feet uphill to meet growing urban water demands at a cost of more than $4 billion (Akhter, Ormerod, and Scott, 2010). Water shortage sharing agreements mandate that, in the event of a water shortage, Arizona would be the first state to lose its Colorado River water allocation (Akhter et al., 2010). As Douglas' (1992) typology of culture and risk suggests, this approach to water management assumes that the environment is robust and trusts human ingenuity to engineer a solution to alleviate current and future water vulnerabilities. Similarly, desalination offers a technological fix to overcome the region's water deficit without requiring policy-makers to address long-term trade-offs between different values and uses of water (Downward and Taylor, 2007; Waterstone 1992). As Smith (2009) observes, desalination allows the region to "have limitless development 'cake' and eat it too" (p. 77).

In contrast to these optimistic attitudes towards technological solutions, Beck's theory of the "risk society" describes how the very triumphs of modernity and industrialization create a new category of risk. In other words, "modernization *undercuts* modernization" (Beck 1994, p. 176). His theory also suggests that trust in experts is declining (Beck, 2009; Beck, 1994). When the option of desalination is juxtaposed to the option of wastewater re-use (i.e., "toilet-to-tap"), Beck's observations about trust in expert opinion may help to explain why desalination is the preferred policy alternative. Although desalinated water requires four times as much energy and is more costly than treated wastewater re-use, there may be a greater preference for desalinated water over treated wastewater. As shown by Ormerod (2010), the public's aversion to treated wastewater in southwestern Arizona has less to do with the "yuck" factor and more to do with a concern about the technology and a lack of trust in public officials to safely manage this resource. This is particularly worrisome in the developing country context where, as noted by Dietz et al. (2002), "Developing nations…have a limited ability to assess and manage technological risks…The legislative basis for risk protection is often weak or nonexistent. In turn, existing legislation and regulations are not adequately enforced. The problem is exacerbated by the fact that developing nations do not have enough trained operators and managers with skills necessary for managing risky technologies effectively" (p. 339).

Although the public may trust experts to manage a desalination plant, it is still a highly technical process that leads to the creation of expert networks. This is precisely the type of expert rule that Wittfogel (1957) and Worster (1985) claimed could lead to undemocratic and bureaucratic rule. Although Worster's thesis has been heavily critiqued by political ecologists who argue that water politics is a highly-fragmented, contested sphere, not one controlled by an oligarchic elite (Wilder, 2002; Pisani, 1989), Worster did contribute an essential insight that in arid lands elites tend to desire control over water resources and establish a system of power relations based upon that control. This highly technological management of water resources runs contrary to the Dublin Principles and an emerging water management paradigm that calls for more participatory, transparent and decentralized water management strategies (Wilder, 2010; Conca, 2006). It also runs contrary to calls for more “flexible” management strategies to deal with climate change impacts (Blatter and Ingram, 2001) and calls to take a “soft-path” planning approach focused on demand management, as opposed to a “hard-path” strategy reliant on fixed infrastructure to address supply management (Gleick, 2003).

5.2 Anticipated Risks

A second step in our critical risk analysis is anticipating what types of risks are likely to arise. Beck (2009; 1994; 1992) and Perrow (1999) provide a useful framework for thinking about the phenomenon of “unintended risks” or “side effects” that could be associated with the construction of a binational desalination plant to solve issues of water scarcity on the U.S.-Mexico border. Although desalination technology has been used quite extensively since the 1960s in oil-rich Middle Eastern countries and arid islands (e.g., Canary Islands), little research has been conducted on the social and environmental impacts of this technology (NRC, 2008). Of the environmental research that has been conducted, most has focused on the direct impact of the brine, or saltwater concentrate, discharge on marine ecosystems (Cooley et al., 2006). Little research has been conducted on the indirect environmental impacts—or unintended side effects—of this technology (NRC, 2008), though important exceptions exist (see Cooley et al., 2006, pp. 59-66). These indirect, unintended impacts include increased energy demands, greenhouse gas emissions, and urban growth—which is associated with a host of environmental impacts.

As currently practiced, 41 percent of desalination plants in the U.S. discharge the brine concentrate by-product back into the ocean (NRC, 2008). Findings from existing studies on the impact of brine discharge on marine ecosystems are contradictory; some studies indicate minor to major impacts on marine ecosystems; others found no significant impacts (NRC, 2008, p. 130). The technology for producing a Zero Liquid Discharge (ZLD) process, particularly for the inland desalination of brackish groundwater, is available, but is much more expensive than dispersing the brine concentrate back into the sea. And even with ZLD, there is still a solid waste pollutant to contend with. In addition to concern about the direct impact of the brine discharge on marine ecosystems, there is also concern about the direct impact of the variety of chemicals used in the reverse osmosis process.

Perrow's (1999) complexity/coupling analysis is useful for understanding the types of potential side effects wrought by the biophysical characteristics of the desalination process. One of the main indirect environmental concerns is the energy intensity of the process (see also Cooley et al., 2006, p. 59-66). On average, desalination requires four times as much energy as water produced in water re-use plants, ten times as much energy as traditional treatment for surface water, and nearly twenty times more energy than pumping groundwater 200 vertical feet (NRC, 2008; Prats Rico and Melgarejo Moreno, 2006). Most cost-benefit analyses of desalination fail to account for increases in energy prices over time. As Cooley et al. (2006, p. 58) found, potable water produced by seawater desalination rises in cost more rapidly than other sources, and demonstrates higher year-to-year variability, because less of its cost is due to fixed capital expenses. Future increases in energy costs add a critical element of uncertainty to the desalination calculus. The high energy requirements of this technology cause the energy and water systems to become more tightly coupled. This is referred to as the "water-energy nexus" and it suggests that any disruption in power supply would directly impact water provision, and vice versa.

Given these energy demands, it is often proposed that desalination plants be located next to an energy production facility in order to benefit from the excess heat produced in energy production, and to provide water for the cooling process required in the electric plant. Additionally, the wastewater for the energy plant can be used to dilute the brine water concentrate that is a polluting by-product of the desalination process. Using Perrow's complexity analysis, we conclude that co-location of two processes increases the complexity of a system with non-linear production sequences, common components, and interacting controls.

Currently, most desalination plants are powered by carbon-based fuels, making them contributors to greenhouse gas emissions. This creates an ironic "hydro-illogical" cycle in which the "solution" to water scarcity caused by climate change directly contributes to a positive feedback loop that exacerbates the conditions that lead to increased climate change (Tannehill, 1947; see also Feldman 2011). An alternative fuel source is nuclear energy, which is associated with a host of known and unknown side effects. The complexity and riskiness of the system increases dramatically if the desalination plant is located next to a nuclear power plant (as was previously proposed by the U.S.-Mexico International Atomic Energy Agency in an initial Arizona-Sonora binational desalination project in 1968).

Another major concern regarding the indirect environmental impacts of this technology is its growth inducement potential. In arid regions, scarce water resources have limited urban growth. The introduction of “limitless” desalinated water is likely to encourage urban growth, which is associated with a range of environmental impacts including increased air and water pollution, habitat fragmentation, coastal development, saline intrusion into agriculture, and loss of biodiversity (Smith, 2009; Sax et al., 2006; Cooley et al., 2006; Johnson, 2001). It is possible to imagine a scenario in which “limitless” desalinated water encourages urban growth that is highly dependent upon this sole water source, making the system more vulnerable.

Furthermore, once these urban areas come to rely upon this expensive, energy-intensive technologically produced source of water, their environmental security and autonomy may become more tenuous. Wolf (2009) suggests that desalination could have important implications for geopolitical and spatial shifts in power over water resources, with control moving from headwaters to coasts. In the case of a binational desalination plant, where the ownership and management of the plant is not within the jurisdiction of one’s own country, cities and water users within the region would be increasingly dependent upon maintaining good binational relations (Wilder et al., 2010).

In sum, while the desalination plant itself poses little threat of “catastrophic potential” (in Perrow’s terms), we expand Perrow’s (1999) theory to consider the system as a whole. This reveals a greater level of risk due to the tightly coupled water-energy nexus, the interconnected complexity of potentially being co-located with a nuclear power plant, a range of direct and indirect environmental impacts, and the tight coupling of growth and water dependency on a single source of water.

5. 3 Identification of Winners and Losers

A third step in our critical risk analysis is to anticipate who wins and who loses from the adoption of a proposed technology or policy. Initial investigation in Spain and Mexico suggests that it is the burgeoning tourist industry that benefits the most from this new supply of water. Water augmentation through desalination opens up new development opportunities and allows the tourist industry to grow at a profitable rate. Equity issues become increasingly important if there is a public or taxpayer subsidy for the operation of a desalination plant (Feldman 2011). Research suggests that poorer residents are negatively impacted by the introduction of desalinated water into the public supply network. In Alicante Spain, after desalinated water was introduced in 2003, residents' water bills nearly doubled, rising from $0.30 Euro cents per cubic meter in 2003 to $0.55 Euro cents per cubic meter by 2009 (Prats Rico and Melgarejo Moreno, 2006). This dramatic increase in the price of water has uneven social impacts. While some water managers and policymakers argue that increasing the price of water leads to conservation of the resource, studies have shown that responses to price increases differ between wealthy and poor households (Renwick and Archibald, 1998; March and Saurí, 2009). A study of California water users found that a price increase of 10 percent resulted in a 5.3 percent reduction in water use among low income households, while wealthier households reduced their water usage by only 1.1 percent (Renwick and Archibald, 1998). This introduces an additional burden to poor households, which may only be using enough water to meet basic needs.

Lastly, it is important to consider whether the environment becomes a winner or loser when desalination is adopted. As discussed above, potential negative environmental impacts include the direct impact of the brine discharge and chemicals, as well as the indirect impacts of increased urban growth and energy demands. However, if coupled with strict conservation measures, desalination could reduce the pressure on aquifers and make more water available for in-stream environmental flows, making the environment a winner.

5.4 Risk Reduction

A final step in our critical risk analysis is to consider how some of these risks may be reduced. While a narrow interpretation of a critical risk analysis might leave managers and policy-makers with the impression that, short of radical structural changes to the political economic institutions that maintain an incessant drive for the expansion of capital, there is little that can be done to reduce risks. A broader interpretation, however, recognizes that the value of a critical risk analysis is the attention given to the full-range of underlying drivers of risk. Additionally, a critical risk analysis may spur debate and politicize an issue and potentially enrich the options for policy interventions.

For decision-makers looking for less radical ways to reduce the risks associated with adopting desalination as water supply strategy, the following options can be considered. If desalination were regulated in all phases of the process (planning, construction, management and use), some of the risks could be reduced. Regulation must include a well-developed permitting and monitoring system to ensure that all operators are in compliance. The downside of regulation, as evidenced by the 2010 British

Petroleum Deepwater Horizon disaster in the Gulf of Mexico, is that regulators (in both developed and developing countries) are often unable to competently monitor and enforce regulations. This may be due to either a lack of resources, conflict of interests, or both.

To avoid unrestrained urban growth and to reduce indirect environmental impacts, two key measures should be taken. First, before desalination is considered as a water augmentation option, all conservation measures should be implemented. Once the decision to adopt desalinated is made, an urban growth limit and/or water consumption limit should be set. If this step is not taken, it is probable that increased conservation efforts and new supplies will foster further growth, rather than actual conservation (according to Jevons Paradox, see Alcott, 2005).

Finally, to ensure social equity and access to the new resource, a fair pricing scheme must be developed so that all residents are able to benefit from the project. Fairness must be determined through transparent processes that involve public debate, political engagement, and address issues of representation. As desalination is currently practiced, it is largely the tourist industry that derives the most benefit from the implementation of this technology. More research is needed to determine if, and how, desalination could be made more socially equitable and environmentally sustainable.

6. Discussion and Conclusions

By examining the proposed intervention of binational desalination as a technological solution to increasing water scarcity under conditions of growth and climate change in the Arizona-Sonora border region, we have shown how such interventions are likely to have differentiated impacts, with costs and benefits being unevenly distributed among already stratified social groups. Our critical risks analysis shows that the associated (and unintended and under-examined) consequences of desalination are likely to exacerbate existing inequalities and introduce new vulnerabilities by compounding the water-energy nexus, increasing greenhouse gas emissions, inducing urban growth, producing brine discharge and chemical pollutants, shifting geopolitical relations of water security, and increasing water prices.

Desalination, as a highly technological form of water management, runs contrary to the Dublin Principles and an emerging water management paradigm that calls for more participatory, transparent, and decentralized water management strategies. It also runs contrary to calls for more "flexible" management strategies to adapt to climate change impacts. We understand adaptation and the development of adaptive capacity to be dynamic processes based on social learning between and within institutions. Therefore, a process-oriented analysis focused on social learning, representation, and political engagement, rather than expert-driven technological fixes, allows a better understanding of the dynamism and uncertainty associated with climate change[2].

Furthermore, recognizing the inherent contradictions in capitalism's drive for growth and expansion and the goals of water resource conservation and environmental protection, we highlight the concerns posed by critical risk analysts who suggest that any intervention that does not address this contradiction will eventually fail. The challenges posed by climate change provide an opportunity to re-think and re-orient our fundamental

[2] For further discussion of process-oriented adaption responses in the water sector, see Wilder 2010.

institutions in more sustainable and equitable directions. However, radical political and economic changes in social and economic institutions are not easily implemented by managers. An intermediate solution for managing desalination and reducing risk in the near-term is to ensure that, before the technology is adopted, all conservation measures are implemented and urban growth and/or water consumption limits are established. Once the technology is introduced, the industry must be well regulated and monitored. A fair pricing scheme, along with alternative energy sources need to be developed to reduce the social and environmental risks. Without mandatory conservation measures and greater focus on alternatives sources of water supply, desalination could enable a status-quo water culture that views desalinated water as a limitless substitute for freshwater, adding little to the region's adaptive capacity.

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APPENDIX B. DESALINATION AND WATER SECURITY: THE PROMISE AND PERILS OF A TECHNOLOGICAL FIX TO THE WATER CRISIS IN BAJA CALIFORNIA SUR, MEXICO

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For Submission to: *Water Alternatives*

Abstract

Using empirical evidence from household surveys, semi-structured interviews, and planning documents, this article examines how the introduction of desalinated water into the municipal water supply portfolio has affected water security in the coastal tourist city of Cabo San Lucas in Baja California Sur (BCS), Mexico. It also analyzes proposals for a similar desalination plant in the capital city of La Paz, BCS and discusses alternative water management options for achieving water security. This article challenges the notion that desalination is an appropriate and sufficient technological solution for arid regions. The findings provide evidence of increased yet delimited water security at a neighborhood scale while identifying new vulnerabilities related to desalination, particularly in the context of the global South. This article concludes that implementing a technological fix on top of a water management system that is plagued with more systemic and structural problems does little to improve long-term water management and is likely to foreclose or forestall other water management options. This multi-scalar analysis makes an important contribution to the emerging literature on water security by considering both a narrow and broad framing of water security and identifying a range of factors that influence water security.

Keywords

Water Security; Desalination; Adaptive Water Management; Los Cabos; Baja California Sur, Mexico

Introduction

Ensuring adequate quantities of clean, safe water for the needs of humans and ecosystems is one of the greatest challenges worldwide. Water is required for economic development, urban growth, and agricultural production. Reliable access to clean drinking water is a necessity for human life, prompting many governing bodies (including in Mexico) to declare water a human right (Gleick, 1998; Sultana and Loftus, 2012; Gerlak and Wilder, 2012). And there is a growing recognition of the importance of sufficient water supplies to support natural ecosystems functions and ecosystem services, with important implications for the wider socio-ecological system (Postel and Richter, 2003). Satisfying water demands for multiple users, including the environment, is expected to become increasingly challenging in the context of a changing climate, with many regions facing more variable precipitation patterns and decreased water availability (Milly et al., 2008).

In this context, some water managers and planners are looking towards desalination – the conversion of seawater or brackish groundwater to freshwater – as a technical, supply-side solution that can meet current water demands and buffer against the negative impacts of climate change on water resources. Despite its high energy demands, the Intergovernmental Panel on Climate Change (IPCC) lists desalination as an "adaptation option" which may be particularly important in arid and semi-arid regions (Bates et al., 2008: 49). In Australia, the cost to build new desalination plants has been described as "the cost of adapting to climate change" (Onishi, 2010). In the US-Mexico border region, the need for new infrastructure, including desalination, was discussed at the 2010 Border Governors' Binational Desalination Conference in terms not only of population and economic growth, but also climate change (Water Education Foundation, 2010). The bilateral International Boundary and Water Commission (IBWC), which is responsible for settling issues related to boundary and water treaties between the US and Mexico has established a core working group dedicated to finding new water resources, including proposed binational desalination projects in Ensenada, Baja California, Rosarito, Baja California, and Puerto Peñasco, Sonora (López Pérez, 2009; McEvoy and Wilder, 2012). As part of Mexico's 2007-2012 National Infrastructure Program, the federal government identified eight priority desalination projects in northwestern Mexico (Conagua, 2012a) (figure 1). In Baja California Sur, the state's long-term water plan identifies desalination as the principal means by which the major cities and growing tourist destinations of Los Cabos and La Paz will overcome future water deficits, which are projected to be 34 hm^3 and 14 hm^3, respectively, by 2030 (Conagua, 2012b).

Figure 1. Priority desalination projects (Conagua, 2012a)

1. Tijuana, BC
2. Guaymas, SON
3. Ensenada, BC
4. Ensenada, BC (La Misión)
5. La Paz, BCS
6. Los Cabos, BCS (Expansion)
7. Puerto Peñasco, SON
8. Loreto, BCS

A National Research Council (NRC, 2008) analysis of desalination technology found that desalination is a realistic option for future water supply. In the last fifteen years, the cost of producing desalinated water has dropped by 50 percent due to continued improvements in reverse osmosis membrane technology, implementation of energy recovery devices, increased efficiencies of pumps, increased competition among suppliers, and benefits of economies of scale associated with larger projects (Elimelech and Philip, 2011; Tal, 2011). Desalination is also appealing in arid regions where it may be less politically divisive than other water management options, such as interbasin and intersectoral transfers (Downward and Taylor, 2007; Kohlhoff and Roberts, 2007; Swyngedouw, 2013).

However, as the NRC (2008) report concludes, there is a lack of long-term research and considerable uncertainty about the environmental impacts of desalination. The limited research conducted on the impacts of seawater desalination has mainly focused on the direct environmental impact of the saltwater concentrate or brine discharge on marine ecosystems (NRC 2008). Findings from existing studies are inconclusive, with some studies indicating minor to major impacts on marine ecosystems, while others found no significant impacts (NRC 2008:130). An analysis by McEvoy and Wilder (2012) considers a broader range of potential impacts and risks of desalination technology, including compounding water-energy demands, increasing greenhouse gas emissions, inducing urban growth, shifting geopolitical relations, and increasing water prices, among others. But there remains a lacuna of empirical research that looks at the impact of the technology on water security.

To this end, in this article I use empirical evidence from household surveys, semi-structured interviews, and planning documents to examine how the introduction of desalinated water into the public water supply portfolio has affected water security in the coastal tourist city of Cabo San Lucas in Baja California Sur (BCS), Mexico. This is followed by an analysis of proposals for a similar desalination plant in the capital city of La Paz, BCS and discussion of alternative water management options for achieving water security. I address the following research questions: 1) Is desalination an adaptive solution to a developing water "crisis" in arid Baja California Sur, Mexico? 2) Does desalination reduce vulnerability to water scarcity and increase water security in the context of communities such as Los Cabos and La Paz? and 3) How does the implementation of new desalination systems at the municipal-scale affect alternative water management options? The results from this case study provide empirical evidence regarding the potential benefits and problems of desalination as a solution to water management in Mexico and other arid regions, particularly in the global South. This multi-scalar analysis makes an important contribution to the emerging literature on water security by considering both a narrow and broad framing of water security and identifying multiple drivers of water security. I now turn to a review of three dominant water management paradigms, with a more focused discussion of the emerging concept of water security, and then discuss the research results.

Water Management Paradigms: From the Hydraulic Paradigm, to Integrated Water Resources Management, to Water Security…And Back Again?

Over seventy years ago, Gilbert White, the iconic early hazards and water management expert, embarked on a study of United States national floodplain management practices (White, 1945). His study came to the counterintuitive conclusion that structural flood controls (i.e., dams and levees) did not necessarily reduce people’s vulnerability to flood damage. Given the limitations of structural works, a large flood event was likely to overcome the design protections. In such cases, the additional development induced by the perceived protective works would increase the magnitude of flood loses beyond what they would have been without the structural protective works. White argued that instead of building more single-purpose infrastructure, management agencies needed to consider “multiple adjustments” to floods, most notably better land-use planning (Platt, O’Riordan, and White 1997).

This debate is mirrored in two competing contemporary water management paradigms. Early 20th Century water projects, under what is often referred to as the “hydraulic paradigm,” focused on hard-path solutions to provide subsidized water for irrigation and urban development (i.e., the construction of dams and aqueducts) (Saurí and del Moral, 2001; see also Worster,1985; Gleick, 2000; Kallis and Coccossis, 2003). But this supply-oriented paradigm largely ignored issues of equity and environmental degradation, resulting in an uneven distribution of costs and benefits, with marginalized social groups and the environment typically incurring the greatest costs of water projects through displacement, loss of livelihoods, and environmental degradation (Ingram, Whiteley, and Perry, 2008).

In the last 20 years, with growing concerns about the social and environmental costs associated with large infrastructure projects, a new water management paradigm, known as Integrated Water Resource Management (IWRM) has emerged. This market-led approach to water management has the twin goals of achieving neoliberal efficiency and environmental sustainability (Conca, 2006; see also World Bank, 1993; 2003). It moves away from centralized, state-led water management to decentralized, market-led water governance (Bakker, 2002; Kaika, 2003; Wilder, 2010). It is characterized by the application of neoliberal economic principles to encourage rational water use and foster the re-allocation of water among competing interests (Glennon and Pearce, 2007). It also promotes the use of efficient technologies (e.g., drip irrigation, lined canals, leak detection, and modernization of infrastructure) (Gleick, 2000), gives consideration to environmental water needs (Postel and Richter, 2003), and supports increased stakeholder participation (Kaika, 2003). In sum, this paradigm marks a shift from supply-side management to demand-side management and emphasizes soft-path solutions (e.g., water conservation) over hard-path solutions (e.g., dams) (Gleick, 2003). Despite this recent push to move away from expensive, large-scale, supply-driven water infrastructure projects, desalination is becoming a preferred water augmentation strategy throughout the Gulf of California region in northwestern Mexico (Conagua, 2012a, 2012b; Conagua, 2012b).

Parallel to the IWRM paradigm, the concept of water security has received increased attention in recent years. The term was used by the Global Water Partnership at the Second World Water Forum in the Hague in 2000 to describe a similarly integrative approach to water management. The term has since become increasingly used by academics and practitioners (Cook and Bakker 2012). The discursive root of the term "security" has historically referred narrowly to national security in terms of military threats from other nation-states (Ullman, 1983). However, as Cook and Bakker's (2012) review concludes, there is actually very little emphasis on military security in the current use of the term water security. Perhaps, as they note, the more problematic discursive association is with the term "crisis," which may be used to leverage other goals (p. 100) (see also McEvoy and Wilder, 2012; Swyngedouw, 2013).

Recognizing both the productive and destructive potential of water, Grey and Sadoff (2007) provide one of the more widely cited definitions of water security: "the availability of an acceptable quantity and quality of water for health, livelihoods, ecosystems and production, coupled with an acceptable level of water-related risks to people, environment and economies" (p. 547-548). Scott et al. (2013) build off this definition to account for the dynamic nature of coupled human-natural systems and uncertainties in water management. Their definition states that "water security constitutes the sustainable availability of adequate quantities and qualities of water for resilient societies and ecosystems in the face of uncertain global change" (p. 281). In this definition, adaptive water management becomes an important corollary to water security. Adaptive water management relies on social learning, knowledge exchange, and flexible strategies to increase the capacity to respond to uncertainties and change (Pahl-Wostl et al., 2007; Wilder et al., 2010).

These definitions reflect what Cook and Bakker (2012) consider a “broad framing” of water security, which shares much in common with IWRM. This broad framing of water security considers both water quantity and quality, and recognizes the importance of meeting human and ecosystems needs. This includes clean and safe sanitation (i.e., sewerage) (Gerlak and Wilder, 2012). Additionally, it underscores the important role of good governance and adaptive water management institutions in achieving water security. By contrast, approaches that focus only on the quantity of water available for human use, or that emphasize infrastructure (and not institutions) exemplify a narrow framing of water security. Grey and Sadoff (2007) observe that “While it is likely and understandable that countries initially will place a premium on physical capital investments, human capacity and institutions can take much longer to build and adapt” (p. 559). They conclude that the best path to water security is through balanced investments in water infrastructure and institutions (i.e., governance), while giving special attention to issues of equity in the distribution of the benefits of these investments.

In this article, the term water security encompasses the possibility of water “insecurity” at various scales. Water insecurity refers to a lack of access to, or unavailability of, sufficient, clean, affordable, and reliable potable water and sanitation (Gerlak and Wilder, 2012).

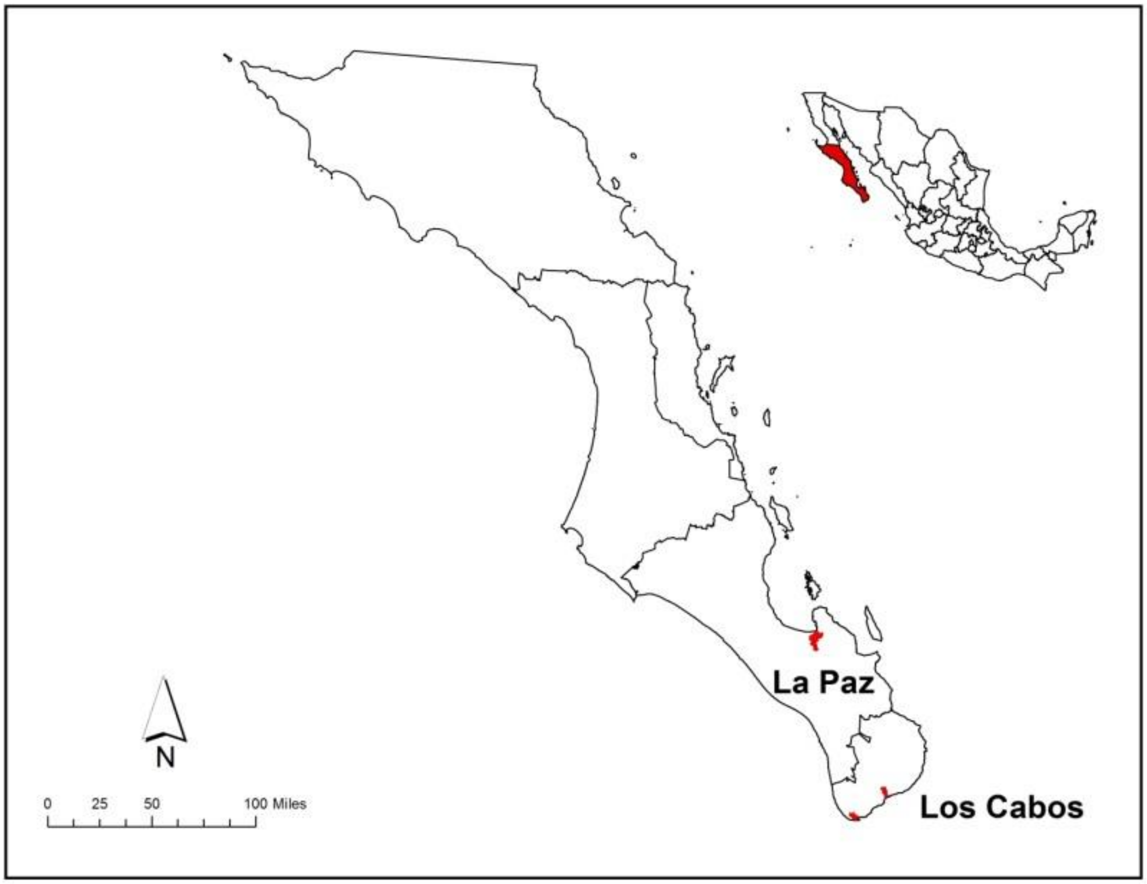
In determining the factors that influence water security, it is helpful to draw on the insights from natural hazards and vulnerability research (Hewitt, 1983; Bohle, Downing and Watts, 1994; Liverman 1994; Adger, 2006; Ribot, 2010). Akin to vulnerability, water security, is determined by more than just biophysical availability of water (i.e., the natural hydrological regime). There are also social, political, economic, and technological factors that shape water security (Zeitoun, 2011). This paper considers how water availability (i.e., supply), water demand by sector, technology and infrastructure, managerial abilities, and institutional environments influence water security. Because water security, like vulnerability, is disproportionately experienced by poor and marginalized social groups (Ribot, 2010; Zeitoun, 2011), attention is given to issues of equity and the distribution of water security.

While Cook and Bakker (2012) argue for a broad, integrative use of the term water security, they note that narrower definitions are needed for operationalization in empirical research. But in doing so, they call for narrow framings to be "usefully allied" with broader framings in order to account for the "multiple stressors that affect water security" (p. 99). In addition, they call for "multi-scalar" analyses that provide a more nuanced understanding of water security. This paper makes a significant contribution to this call by first evaluating water security, narrowly defined as accessible and affordable water of sufficient quality and quantity for household use in one particular neighborhood in San José del Cabo, BCS. The analysis then scales out to assess the impact of desalination on water security at the scale of the city and state, which employs a broader framing of water security by considering a wider range of determinants of water security and examining issues of equity, environmental impacts, and the role of governance institutions. This paper makes an important contribution to the emerging literature on water security by advancing our understanding of how desalination impacts water security at various scales, and how it may constrain alternative water management options.

Methodology and Case Study Sites

This analysis is based on data collected during nine months of fieldwork in the *municipios* (equivalent to US counties) of Los Cabos and La Paz in southern BCS (figure 2). To assess the impact of desalination on water security at the household level, this article presents the results of 154 household surveys. These surveys were conducted in the *colonia popular,* or working-class neighborhood, of Los Cangrejos in Cabos San Lucas where a desalination plant was built in 2006 to augment they city's public water supply. To assess how desalination affects water security at the city and state level, as well as how it relates to alternative water management options, I present my analysis of 79 semi-structured interviews with 71 different stakeholders (table 1) and government planning documents. Following is a description of each method, as well as the two case study sites.

Figure 2. Map of Case Study Sites: Los Cabos and La Paz, BCS, Mexico



Household Surveys: Los Cabos

I conducted a systematic random sample survey (Neuman 2006) of 154 households in the *colonia popular* of Los Cangrejos, where the Los Cabos desalination plant was built in 2006. Los Cangrejos is the only *colonia popular* that now has a nearly continuous supply of water. The other *colonias populares* still experience a *tandeo*, or water-sharing system, where water is directed to the neighborhood once every three to fifteen days. Since the purpose of the survey in Los Cabos was to assess the impact of the desalination plant on water security at the household level, I elected to conduct the surveys in the neighborhood that was likely to have benefited the most from the desalination plant[3].

The survey was designed to assess: 1) household characteristics and accessibility of public services; 2) household water supply; 3) household water use; 4) perceptions of water issues and desalination; and 5) socioeconomic data. The survey consisted of 66 questions to be answered by the respondent, including both closed and open-ended questions. An additional six questions regarding gender and construction material of the house (as a commonly-used indicator of relative poverty level) were filled out by the researcher, independently. Survey time averaged 20-30 minutes per survey.

According to INEGI census data (2010), Los Cangrejos has 10,984 residents and 2728 households on about 155 blocks. I conducted one survey per block, alternating between houses on the end of the block and in the middle of the block. Of the 154 respondents, 53 percent were male and 47 percent were female. When possible, the survey was conducted with the head-of-household. Sixty-one percent of respondents identified as the head-of-household, while the remaining 39 percent did not identify as head-of-household. I entered data from the 154 surveys into an Excel spreadsheet and analyzed the data using descriptive statistics.

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[3] Most respondents assumed that the *colonia* of Los Cangrejos received the most desalinated water because of its physical proximity to the desalination plant (see figure 9).

Semi-Structured Interviews

A total of 79 semi-structured interviews were conducted with 71 different stakeholders (table 1). The semi-structured format was selected because it allows the researcher to begin with some predetermined questions, but also move and/or digress from the interview schedule through probes and new insights that emerge during the interview (Berg, 2007). Also, the interview schedule varied depending on the interviewees' area of expertise. Interviews were designed primarily to 1) elicit perceptions of desalination as a solution to the region's water scarcity issue; 2) understand the legal, political, economic, and environmental context within which desalination technology was considered or adopted; and 3) assess how the newly produced water resource is (or should be) managed. Of the 79 interviews, 46 were conducted in La Paz, 27 in Los Cabos and 6 in other locations. Interviews ranged from 5 minutes to 4 hours in length, but averaged 50 minutes, with most interviews lasting 30 minutes. Interviews were recorded when information was technical, detailed, and/or lengthy; and when it seemed comfortable to ask permission to do so.

Respondents were selected using a combination of purposive, snowball, and convenience sampling. Neuman (2006) defines purposive sampling as "selecting cases with a specific purpose in mind" (p. 222). My primary purpose was to select respondents who represented different interests, perspectives, and opinions regarding water management, desalination, and development. This included: 1) federal, state and local water managers, 2) other governmental departments that manage water, urban planning, and environmental protection 3) developers and realtors 4) environmental groups and 5) residents of various *colonias*. Occasionally, I used a snowballing technique to ask previous respondents if they could recommend someone else I might talk to for additional information. Since water service was fairly standard within *colonias*, I conducted 16 brief (5-15 minute) interviews using convenience sampling to rapidly assess differences in water service in various *colonias* in Los Cabos.

Table 1. List of interviewees by affiliation type

Affiliation	**# of Interviewees**
Federal water commission (Conagua)	3
Federal government (other)	6
State water commission (CEA)	2
State government (other)	2
La Paz municipal water utility (SAPA)	3
La Paz municipal government (other)	3
Los Cabos municipal water utility (OOMSAPASLC)	2
Los Cabos municipal government (other)	3
Environmental Non-Governmental Organizations (NGOs)	5
Academic/Researcher	6
Private development, architecture, or real estate firm	9
Private desalination operator	1
Colonia residents	16
Colonia leaders	4
Expat residents	3
Other	3
Total # of Interviewees	**71**

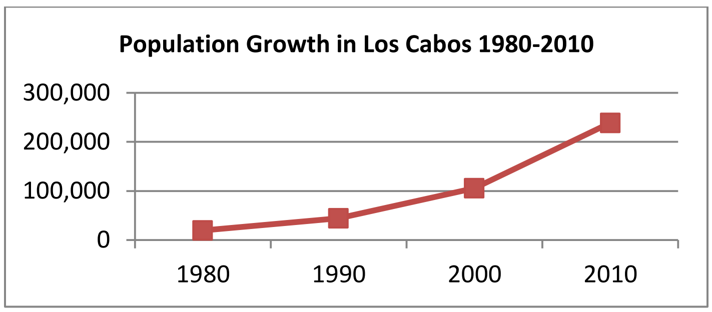
The transcripts and notes of interviews were analyzed and coded using content analysis to identify key themes. A critical discourse analysis (CDA) was used to examine how certain discourses about water management and development become naturalized, who emphasizes the benefits of desalination (and how), who expresses concern about the potential negative environmental or socio-economic impacts of desalination (and how), who favors alternatives to desalination (and why), and how the trade-offs between the pros and cons, and desalination and alternative management strategies are discussed.

Case Study Site: Los Cabos

Los Cabos is one of Mexico's most well-known tourist destinations. With vast white beaches and over 300 days of sunshine per year, this arid coastal region attracts over a million visitors each year, many of whom come to recreate on one of the more than 10 golf courses (H. XI Ayuntamiento de Los Cabos, 2011: 179; IMPLAN, 2011). It is also home to 251,871 residents, most of whom are employed in the service sector (INEGI, 2010; IMPLAN, 2011). Los Cabos refers to the city of San José del Cabo, the city of Cabo San Lucas, and the 18-mile tourist corridor that stretches between the two urban centers. The *municipio* of Los Cabos is the local administrative unit, and consists primarily of these two urban centers, along with a few smaller outlying towns. Most data is reported at the level of the *municipio*.

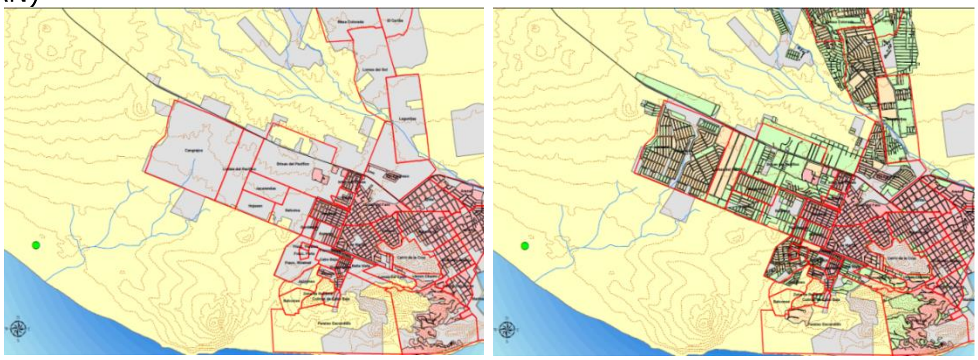
The transition of Los Cabos from a quiet fishing community to a tourist mecca began in 1976 when it became part of the federal government's National Tourist Development Fund (FONATUR). FONATUR is part of a regional development strategy to create economic centers that attract businesses, industry and foreign investment (Borja Santibáñex, Cruz Chávez, Juárez Mancilla, and Rodríguez Villalobos, 2006). It is responsible for fomenting the development of major tourist destinations in Mexico, including Cancún. Growth in Los Cabos exploded in the 1990s, with the number of hotels rooms growing from 1524 in 1982 to 9663 in 1998, with 21,857 new jobs being added to the *municipio* from 1988 to 1998 (Santibáñex et al., 2006). The growth in the tourist economy attracted migrants from Guerrero, Sinaloa, and other parts of Mexico in search of jobs. Currently, tourism is the principal economic activity, with the service sector accounting for 83 percent of the *municipio's* gross domestic product (GDP) (H. XI Ayuntamiento de Los Cabos, 2011: 89).

Figure 3. Population growth in Los Cabos, 1980-2010 (INEGI, 2010)



The population of the *municipio* of Los Cabos grew from 19,117 in 1980 to 71,031 in 1995, nearly quadrupling in just fifteen years (Santibáñex et al., 2006) (figure 3). With limited housing options for workers and their families, a politically led social movement began in 1994 to establish the *colonia popular,* or working-class neighborhood, of Los Cangrejos on the outskirts of Cabo San Lucas (personal communication, 2012). Los Cangrejos was one of the first *colonias populares* to be established on the outskirts of the Cabo San Lucas city center and it grew quickly from 3451 residents in 2005 to 10,948 in 2010 (INEGI, 2005; Valdez Aragón, 2006). Several other *colonias populares*, both formal and informal, have been established on the outskirts of Cabo San Lucas to accommodate the continued growth (figure 4).

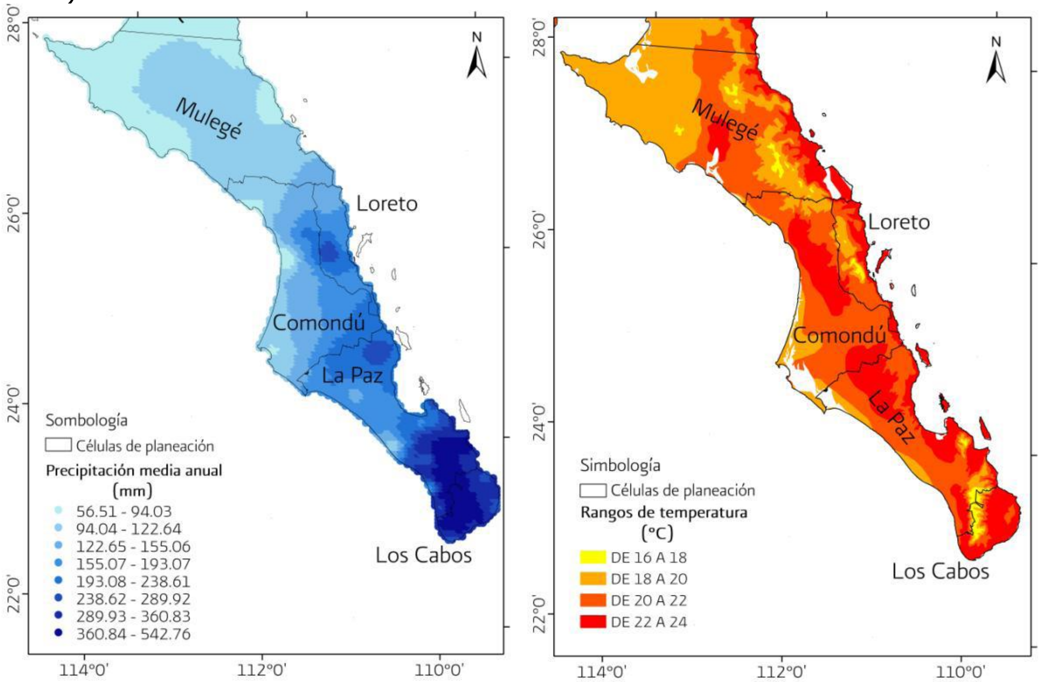
Figure 4. Map of growth around the center of Cabo San Lucas, 2000 and 2010 (IMPLAN)



2000 2010

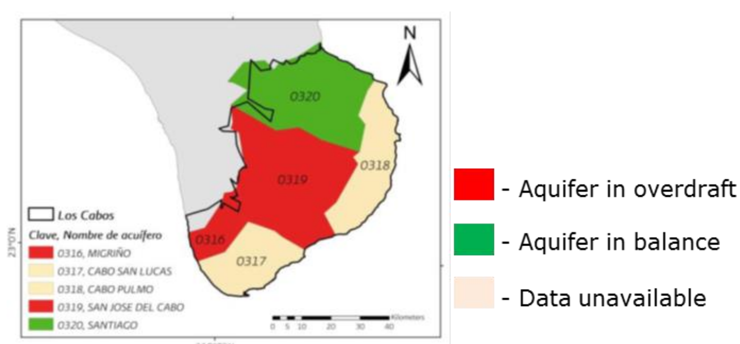
The *municipio* has struggled to provide infrastructure and services, including electricity, potable water, and sewerage, to the growing population of Los Cabos. In 2004, the *municipio's* potable water supply network reached only 74% of the households, leaving 26% of the residents to rely on water trucks for water provision (Implan, 2011). The challenge of providing a clean, reliable supply of water to residents and businesses is due to both biophysical and socio-political factors, as discussed in more detail below. With an average annual rainfall of less than 285 mm, average annual temperatures between 22ºC (71.6ºF) and 24ºC (75.2ºF), and temperature extremes of over 40ºC (104ºF), the southern tip of Baja California Sur is one of Mexico's most arid regions (Conagua, 2009a; Conagua, 2012b) (figure 5). The projected water deficit for Los Cabos by 2030 is 34 hm^3 (Conagua, 2012b).

Figure 5. Map of average annual precipitation and temperature in BCS (Conagua, 2012b:8)



Groundwater is the primary source of water. Of the five aquifers in Los Cabos, two are overdrawn (i.e., water extraction exceeds natural recharge) (Conagua, 2012b: 60) (figure 6). This includes the San José aquifer, which provides 64 percent of the water for Los Cabos (IMPLAN, 2011: 74).

Figure 6. Hydrological balance of aquifers in Los Cabos (Conagua, 2012b: 60)



Climate change is expected to negatively impact water resources and reduce water availability in the region. Downscaled models of climate change scenarios project that by 2070, precipitation in this region will decrease by 10 to 20 percent, and annual temperatures will increase on the order of 4.5 ºF (Magaña et al., 2012; see also Martínez Austria and Patiño Gómez, 2010) (figures 7 and 8).

Figure 7. Map of climate change projections showing (%) precipitation change for the 2040−2069 period. This projection is based on the Hadley Centre Coupled Model, version 3 (HADCM3) under the A2 emission scenarios. A2 emission scenarios are on the high end, but are not the highest emission scenarios. (Magaña et al., 2012:180, emphasis box added over BCS).

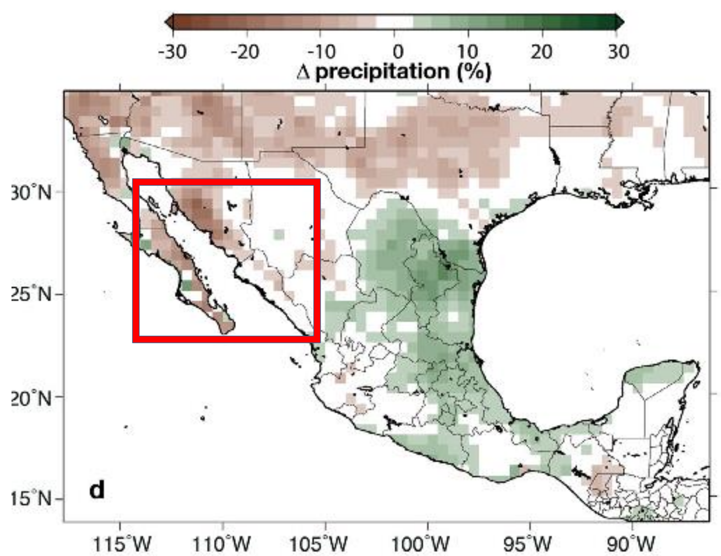
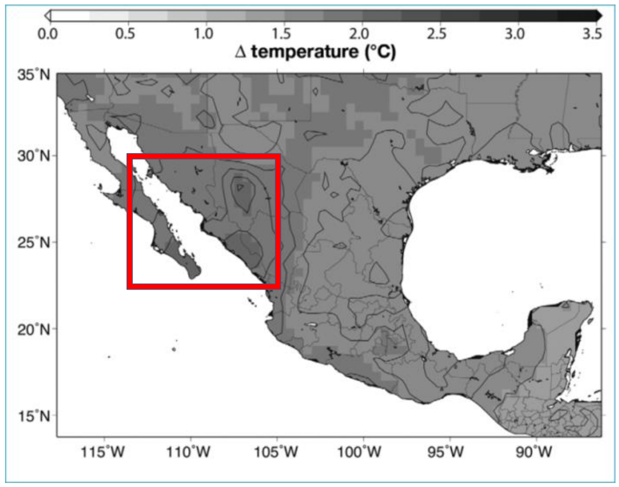


Figure 8. Map of climate change projections showing surface temperature changes (°C) (shading) for the 2040−2069 period. This projection is based on median values of the ensemble of downscaled annual surface temperatures with respect to the 1971−1999 climatology under the A2 emission scenario. The A2 scenarios are a marker scenario based on the high end of scenarios included in the *Special Report on Emissions Scenarios (SRES)* (Nakicenvoic and Swarts, 2000); but it is not the highest scenario. (Magaña et al., 2012:178, emphasis box added over BCS).



But beyond the biophysical water scarcity, there are socio-political factors that limit water availability. As in many parts of Mexico, the water distribution system operates inefficiently due to deteriorating infrastructure and/or lack of reinvestment and repair. Conagua (2008) estimates that water systems in Mexico lose an average of 30 to 50 percent of their water due to leaks and system inefficiencies (p. 37). Although the water distribution networks in many of the recently established *colonias populares* in Los Cabos are new, there is still an estimated 19 to 30 percent of water loss due to system inefficiencies (H. X Ayuntamiento de Los Cabos, 2008; Valdez Aragón, 2006). However, the water system is not completely metered (including metering at the extraction wells, as well as meters for individual users), so it is not possible to calculate exactly how much water is lost in the system (Valdez Aragón, 2006).

In contrast to water demand worldwide, in Los Cabos it is the urban sector that is the largest water user (not the agricultural sector). The majority (69%) of water concessions in Los Cabos are for public-urban use (Valdez Aragón, 2006). From 1997 to 2004, during the period of rapid urban growth, the consumption of water by the domestic sector rose from 5.2 Mm^3 to 9.4Mm^3, an 80% increase (*ibid*). During this same time period, water use in the industrial sector, which includes hotels, did not increase. This is due, in part, to an increased use of reclaimed water by many hotels for their golf courses and green areas. Additionally, the 1995 Los Cabos master plan recommended that new hotel developments "*auto-abastecer*" or "self-supply" (i.e., provide their own source of water) (*ibid*; POEL Los Cabos, 1995). Without an assured water supply from the *municipio,* new hotel developments had an impetus to build their own small-scale desalination facilities. Some older hotels also built their own desalination facility to ensure a reliable water supply. There are now 22 private, small-scale desalination plants in Los Cabos (Pombo, Breceda, and Valdez Aragón, 2008).

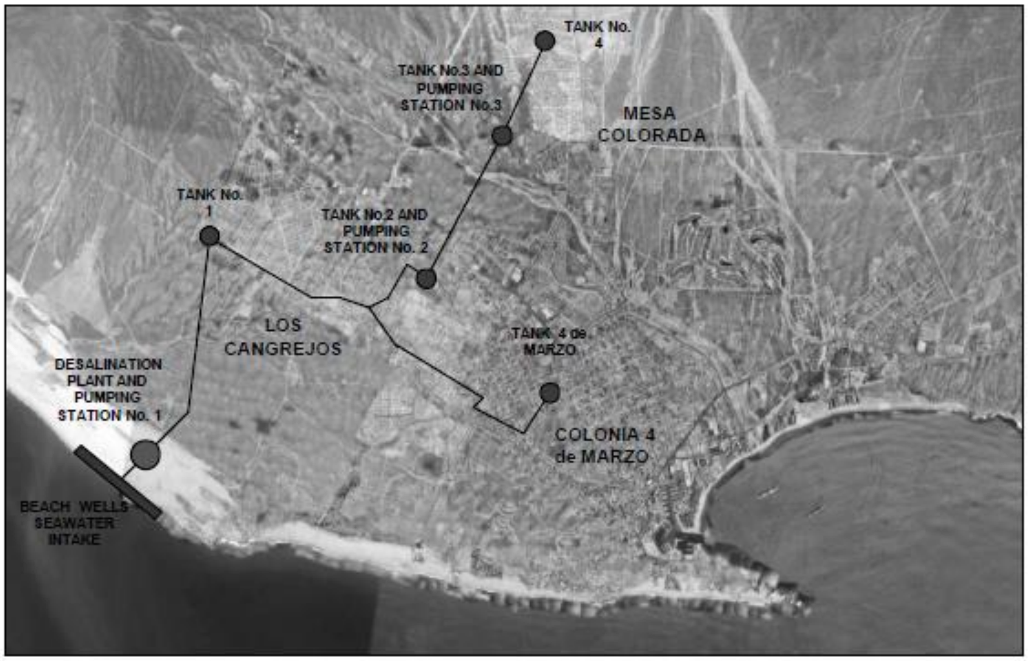
In 2006, the *municipio's* water utility (OOMSAPASLC) — in partnership with the state and federal water authorities, and a private firm (INIMA) — built Mexico's first-ever, municipal-scale desalination plant for public water supply. The Los Cabos desalination plant is financed, constructed, and operated through a Public-Private Partnership (PPP). In 2001, Mexico's federal Program for the Modernization of Water Utilities (PROMAGUA) was established to attract private sector investment in municipal water supply systems in cities of 50,000 inhabitants or more (Conagua, n.d.: 6; see also McEvoy, forthcoming). PROMAGUA receives federal funding through the Infrastructure Investment Fund (FINFRA), which is under the management of Banobras (the national development bank of Mexico). Using this PPP model, the Los Cabos desalination plant was financed with 36% federal funding through FINFRA (Conagua 2006: 31). INIMA, a Spanish-based company, won the bid to build and operate the Los Cabos desalination plant for a period of 20 years.

The desalination plant is located in the *colonia* of Los Cangrejos and began operation in 2006 (Figure 9). The plant was designed to produce 200 liters of water per second (lps) and meet the water demands of 40,000 residents in various *colonias populares* in Cabo San Lucas[4]. When the plant began operations, 100 lps of water were to be sent to Los Cangrejos (10,984 residents), 40 lps to 4 de Marzo (4673 residents), 20 lps to Las Palmas (8654 residents), and 20 lps to Mesa Colorado (13,823 residents) (personal communication, 2010; INEGI 2010).

Since the construction of a new desalination plant, potable water supply coverage has increased from 74% to 96% (Implan, 2011). Los Cangrejos, the *colonia* that is located closest to the desalination facility now has a nearly continuous supply of water. However, for 44 percent of the water users in the other *colonias populares* in Cabo San Lucas, this service is intermittent (*ibid*). The *municipio* has a scheduled *tandeo*, or water-sharing schedule, that directs water to different *colonias* during certain hours on set days every week. While *colonias populares* are supposed to receive water every three days, residents report going as long as fifteen days without piped water service (personal communications, 2012).

[4] While the Los Cabos desalination plant (200 lps) is a large-scale plant, it is considerably smaller than the largest plants in the world. For example, the Jebel Ali desalination plant in the United Arab Emirates produces 6134 lps (Simpson, 2013), the Ashkelon desalination plant in Israel produces 4572 lps (Cooley, Gleick and Wolff, 2006), and upon completion in 2016, the desalination plant in Carlsbad, California is slated to produce 2190 lps (Poseidon Water, 2013).

Figure 9. General plan of the Los Cabos desalination plant (Seawater Desalination Plant, n.d.).



To adapt to, or cope with, the intermittent service, residents use a variety of water storage containers to maintain a water supply when the municipal piped water service goes out. These containers range from very basic *tambos*, or plastic jugs, to *tinacos*, or rooftop water storage containers, to more elaborate underground cement *cisternas*, or cisterns (figures 10-12). The cisterns fill-up automatically when the municipal water is on, and then use a pump to deliver water to the house when needed. A cistern with a 10,000 liter capacity costs around $50,000 pesos ($4167 USD). *Tinacos* range in price, depending on size and brand, but cost around $1300 pesos ($108 USD). A set of three *tambos* can cost $1600 pesos ($133 USD) (personal communication, 2012). While a cistern provides the greatest degree of water security, the cost is prohibitive for many households.

The *municipio* has a public water truck service, or *pipas*, which deliver water to neighborhoods that are not connected to the public network or experience an extended *tandeos.* However, the public service is insufficient and private entrepreneurs have filled the market, providing water at a high cost. A full water truck delivery of 10,000 liters of water (sufficient to fill a cistern) typically costs $500 pesos ($40 USD) (personal communication, 2012). But households that do not have the capacity to store that much water at once are charged for a portion of water, at the discretion of the private vendor (see results below).

Figure 10. Water storage containers known as *tambos*, or plastic barrels (Author's photo)

Figure 11. Water storage containers known as *cisterna*, or underground cistern (Author's photo)

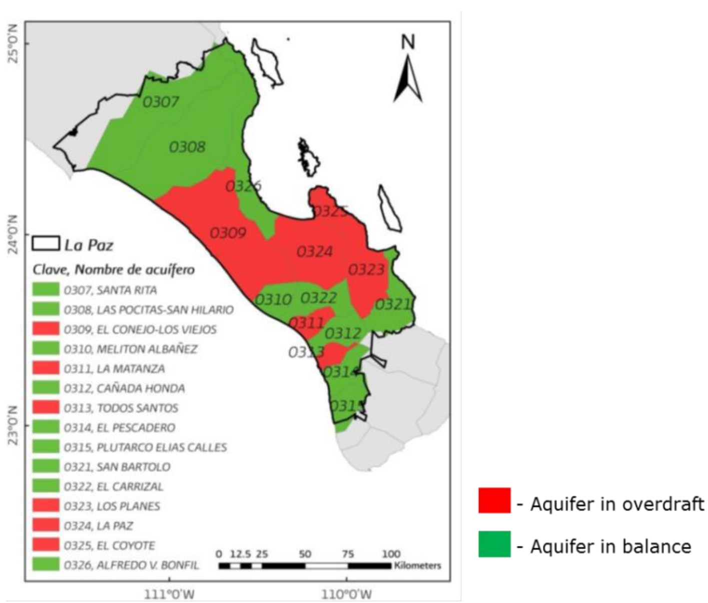
Figure 12. Water storage containers known as *tinacos*, or rooftop water tanks (Author's photo)

Case Study Description: La Paz

In 2001, La Paz was listed among the 100 cities in Mexico that is most likely to experience a "severe water crisis" (Cruz Falcón, 2007:2). The scenario of growth and water availability in the *municipio* of La Paz, which includes the state's capital city of

La Paz, along with a few smaller towns, is similar to that of Los Cabos. Of the 15 aquifers in the *municipio*, six are overdrafted (figure 13). This includes the La Paz aquifer, which is the primary source of water supply for the city of La Paz (Carrillo Guer, 2010). While Conagua estimates that the deficit of the La Paz aquifer (i.e., the difference between the amount of average annual extraction and recharge) is only 0.58 Mm³, other studies have concluded that much greater deficits exist, ranging from a deficit of 8.98 Mm³ annually to 20 Mm³ annually (Cruz Falcón, 2007:103)[5]. The La Paz aquifer has experienced saline intrusion since the 1960s and in the 1980s, nearly all the groundwater wells within the city limits were closed and relocated, due to saline intrusion (Cruz Falcón, 2007).

Figure 13. Hydrological balance of aquifers in La Paz (Conagua, 2012b: 51)

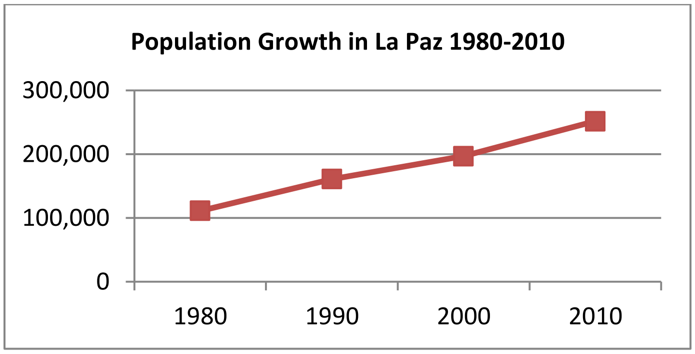


[5] In other regions in Sonora, scholars have noted an apparent intentional lack of scientific aquifer studies due to the political disinclination to create public awareness of the severity of water problems (see Moreno Vázquez, 2006; Wilder and Romero Lankao 2006).

Conagua has issued a *veda*, or moratorium on new water concessions (Conagua, 2009b). Existing water concessions for the La Paz aquifer are used primarily for public-urban water supply, which accounts for 62 percent of all water use. Agriculture accounts for 30 percent of water use (Carrillo Guer 2010:10). The distribution system for urban water supply is old and inefficient, with an estimated water loss rate of 44 percent (Carrillo Guer 2010: 20). Despite these challenges, the water utility offers piped water service to 93.3 percent of all households (H. XIV Ayuntamiento de La Paz, 2011a:118). But this service is not continuous for many users who experience a *tandeo*, with water being directed to specific *colonias* every three to fifteen days (personal communications, 2012). Households in La Paz rely on a variety of water storage containers and water trucks to make-up for the lack of reliable, continuous water service. In La Paz, the public water truck service is more extensive than it is in Los Cabos. This public service is free, though residents say that truck drivers often ask for a *propina*, or tip, for service. The current mayor of La Paz is promoting a *municipio*-wide program (*Tinacos para Todos*) to distribute water storage containers to residents in marginalized neighborhoods at a subsidized price.

The economy of La Paz is more diverse than that of Los Cabos, with more government sector jobs, the state university (UABCS), and various NGOs. It is also an important port city and the largest employment sector is retail, followed by jobs in construction, hotels, manufacturing and other services (H. XIV Ayuntamiento de La Paz, 2011:59). But increasingly, national and international tourism is gaining importance. There are several major new hotel and condominium developments. Currently, there is just one golf course in La Paz, but there are proposals for nine new golf courses (H. XIV Ayuntamiento de La Paz, 2011a). The population has grown steadily from 111,310 in 1980 to 251,871 in 2010 (INEGI 2010) (Figure 14).

Figure 14. Population growth in La Paz, 1980-2010 (INEGI 2010)



Despite the limited water resources, the federally imposed moratorium on new concessions and increasing water demand from the burgeoning tourist sector, La Paz has not adopted a similar recommendation in its master plan that new developments must provide their own water source. However, two of the newer developments in La Paz built their own desalination facilities to guarantee water supply to their residents. There is interest among some water managers and urban planners to build a large municipal-scale desalination plant, like the one in Los Cabos. A feasibility study for such a facility has already been conducted (IIUNAM, 2010). The state water plan, identifies desalination as the principal means by which La Paz will overcome the increasing water deficit projected by 2030 (Conagua, 2012b). The administration of the recently elected President Enrique Peña Nieto identified the La Paz desalination plant as one of the nation’s top 38 water infrastructure projects (Cortés, 2012).

Results: Desalination, Water Service, and Water Security in Cabo San Lucas

I now turn to a discussion of the results of the household surveys conducted in Los Cabos in order to understand how the adoption of desalination technology has affected water security at the household level. This is followed by an analysis of semi-structured interviews and planning documents, in order to understand how desalination technology affects water security more broadly defined.

Before the Los Cabos desalination plant was built in 2006, the *colonia popular* of Los Cangrejos was not connected to the city's water supply network. Residents depended on *pipas*, or water trucks, for their water supply. The public water truck service was insufficient to meet residents' needs, so private – and expensive - water trucks became the primary source of water for most households. Survey responses indicate that 83 percent of respondents who had lived in the *colonia* prior to the construction of the desalination plant had used private water trucks before 2006 (n = 54) [6]. Like most respondents, one resident indicated that he had to hail a water truck twice a week, and paid $400 pesos ($33 USD) a month for this service. As a side note to the survey question, he commented, "It was not fair, but that's all there was." Another respondent who had built a large cistern to store water spent $1000 pesos a month for water from private water trucks.

In addition to the financial strain of accessing household water from private *pipas*, survey respondents also made comments detailing the inconvenience of having to

[6] Of the 154 survey respondents, 81 (52%) moved there in 2007, after the desalination plant was operating, resulting in a smaller number of responses (n) to this question.

chase down a truck. For example, one respondent recalled how his neighbor would go out on his motorcycle at 5 a.m. to chase down the water trucks and try to get them to bring water to their block. Several respondents commented that private water trucks favored the houses that have large *cisternas*, or holding tanks, because they could make more money in just one stop. In contrast, as one woman commented, she only had small *tambos*, or plastic barrels and she struggled to get the private water trucks to stop at her home. Several respondents commented that it was difficult to know when the trucks would come through the neighborhood, and they often missed an opportunity to fill their water storage containers while they were at work. Respondents in certain neighborhoods reported that water trucks were less frequent in their block because the street was badly rutted or because their neighborhood was farther away.

In contrast, now that desalinated water is piped directly into homes via the municipal network to this *colonia*, 52 percent of respondents report paying between $50-99 pesos ($4-8 USD) per month, and 36 percent pay $100-199 pesos ($8-17 USD) per month (n= 135) (table 2). The new connections require a water meter, which accounts for the difference in billing. With desalinated water being delivered directly to the household water connection, most respondents are now paying less than half – and in many cases just a fraction – of what they previously paid for water from private water trucks.

Table 2. Survey Responses: Potable Water Service

Question	Responses (%)
How much do you pay each month for your public potable water service? (open ended*) (n=135)	
$50-99 pesos ($4-8 USD) per month	52%
$100-199 pesos ($8-17 USD) per month	36%
$200-299 pesos ($17-$25 USD) per month	9%
$300 pesos or more ($25 USD or more) per month	3%
How satisfied are you with your [public potable water] service? (n=140)	
Very Satisfied	38%
Satisfied	38%
Neutral	23%
Dissatisfied	1%
Very Dissatisfied	0%

*note: categories for all open-ended questions were created during data analysis

When asked how satisfied residents are with their water service now (i.e., since the construction of the desalination plant), 76 percent of respondents reported being satisfied or very satisfied with their current water service (n = 140). Comments included satisfaction that “day and night we have water” or “now we don’t have to wait for the water trucks and buy from them.” Twenty-three percent of respondents were neutral because, “sometimes there is no water.” One respondent reported being dissatisfied with his service because of a billing problem (table 2).

When asked about the suitability of desalination as a water supply strategy for Los Cabos, respondents overwhelmingly (91 percent) agreed that it was a suitable strategy (n = 151) (table 3). While 70 percent of respondents did not list any concerns or worries about the desalination plant in an open-ended response, 16 percent expressed concern about what would happen if the plant broke down, 6 percent expressed concern about water quality and 5 percent expressed concern about the chemicals used in the process (n= 140). Only two respondents expressed concern about the cost of the water in the future. When asked to list the benefits of the plant, the overwhelming response was the increase in water availability (n=152) (table 3).

Table 3. Survey Responses: Desalination (Suitability, Problems, and Benefits)

Question	Responses (%)
Indicate your level of agreement with the following statement: Seawater desalination is a suitable strategy to supply water in Los Cabos (n=151)	
Agree	91.4%
Neutral	5.3%
Disagree	3.3%
What have been the problems or concerns about the Los Cabos Desalination Plant? (open ended) (n=140)	
No problem stated, stated “no problems” or “no problems up until now”	70%
Stated concern about “plant break down”	16%
Stated concern about “water quality”	6%
Stated concern about “chlorine” or “chemicals” in the water	5%
Stated concern about “cost of water”	2%
What have been the benefits of the Los Cabos Desalination Plant? (open ended) (n=152)	
Stated “there’s more water” or “now we don’t lack water”	97%
Stated “don’t know”	3%

Respondents in Los Cangrejos were also asked about their household water use activities (table 4). Respondents reported using desalinated tap water for most activities, including bathing, cleaning the house, and washing dishes (n = 155). While 89 percent use desalinated tap water to clean fruits and vegetables, 11 percent preferred to use purified water for this task (n = 153). Seventy-three percent of respondents reported using desalinated water to wash their cars, three respondents mentioned using recycled water for this task and three respondents mentioned using a bucket to save water. While most houses had dirt yards with perhaps a couple of plants, 76 percent of respondents reported using desalinated tap water in the garden, primarily to keep the dust down (n=132). Five respondents reported using recycled water from the laundry for this activity as well.

Interestingly, only 13 percent of respondents reported drinking their desalinated tap water (n=151). Instead, the majority of households rely on purified drinking water purchased from a vendor. Despite the relatively new and modern distribution network and the water utility's assurance that the water delivered from the desalination plant is potable, respondents' primary reason for not drinking the desalinated tap water was concern that the water is not hygienic or could cause illness. The second most commonly cited set of reasons for not drinking the water was that it was too chlorinated and tasted or smelled bad. Many respondents also said they were simply "accustomed" to drinking purified water, typically from a 5-gallon g*arrafón*, or plastic jug sold in stores and by street vendors. Six respondents mentioned being concerned about the desalination process or not being fully aware of what this process involves.

Survey respondents reported spending a considerable amount of money each month on purified drinking water. Forty-seven percent of respondents spent $40-120 pesos ($3-10USD) per month on purified water. Thirty-one percent spent $212-200 pesos ($11-$17 USD) a month. Another 12 percent paid $201-280 pesos ($18-23USD).

Ten percent spent as much as $281-600 pesos ($24-50USD) a month on purified water (n = 144).

Table 4. Survey Responses: Use of Tap Water

Question	Responses (%)
Do you use tap water for the following? If no, why not?	
Yes, bathing (n=155)	100%
Yes, cleaning the house (n=155)	100%
Yes, washing the dishes (n=155)	100%
Yes, washing fruit and vegetables (n=153)	89%
No, use purified water to wash fruit and vegetables	11%
Yes, washing the car (n=146)	73%
No, I don't have a car	21%
No, I use recycled water	2%
No, no reason given or other	4%
Do you drink the tap water? (n=151)	
Yes	13%
No	87%
If you don't drink the tap water, why not? (n=132) (open ended)**	
Stated "too much chlorine," "smells bad" or "tastes bad"	39%
Stated "it's not healthy" or "I get sick"	48%
Stated "I'm used to drinking purified water"	14%
Stated, "I don't have confidence in/am unsure about the desalination process"	5%

****** note: respondents could list more than one reason

In sum, desalination has played an important role in providing continuous piped water service at reasonable cost to this particular *colonia*, which otherwise would not have piped water. When analyzed at the scale of the *colonia*, desalination has been used to address pre-existing inequities in water provision and has increased water security in the narrow sense (i.e., increased water availability for human use). The results from the household survey also highlight the important role that water storage containers play in increasing water security at the household scale. An underground cistern, which fills up with water automatically when water is delivered to the household, is one of the most important water security adaptations at the household level.

Despite resistance to drinking the desalinated tap water, residents of this *colonia are* generally satisfied with their water service and have a favorable opinion of desalination, seeing it as a suitable water supply strategy that has improved their access to water for carrying out household activities (e.g., bathing, washing clothes, dishes and vegetables). Residents have seen a substantial decrease in their expenditure on water now that they no longer have to purchase water from private water trucks. Although desalinated water is an important source for household needs, most respondents did not trust it as a drinking water source. Due to concerns about the quality of the piped desalinated water, most residents continue to pay a considerable amount of money each month on purified water from vendors for their drinking water supply. Although desalination is a cutting edge technology, in Los Cangrejos and across Mexico the cultural bias against drinking piped water is strong and the availability of desalinated water has not been able to overcome this bias. Given this finding, the degree to which desalination improves water security, even in the narrow sense, is questionable.

While the desalination plant has benefitted the 10,948 residents of Los Cangrejos, it has not solved the problem of water scarcity in Los Cabos. The desalination plant was built in 2006 to serve 40,000 residents, and this was expected to meet the city's water demands. But, since the construction of the desalination plant, the population of Cabo San Lucas has continued to grow with the number of water connections increasing from 36,053 in 2004 to 62,803 in 2009 (Implan, 2011). With water demand continuing to outpace increases in supply through desalination, other *colonias populares* continue to receive water on a *tandeo* system and may go as long as 15 days without piped water delivered to their house. Residents fill their storage containers on the days when water is available, and many pay for water delivery from private (and expensive) water trucks when they run out. The degree to which desalination technology has increased water security is extremely uneven and depends on the scale of analysis used. When considering desalination as a water management strategy at the state level, other issues emerge.

Results: Desalination and Water Security at the State Level

At the federal, state, and local levels throughout BCS, water managers and urban planners are looking towards desalination as the principal way to close the gap between water demand and supply in this arid, coastal state. A recently completed state water plan, which is part of national *Agenda 2030* planning process, identifies desalination as the principal means by which the major cities and growing tourist destinations of Los Cabos and La Paz would meet the growing deficit between water demand and supply (Conagua, 2012b). In La Paz, desalination alone is expected to account for 44 percent of the projected water deficit of 15 hm^3 by 2030 (Conagua, 2012b: 25-26). The state plan also emphasizes the need for water efficiency, including agricultural modernization, efficient appliances in both industrial and commercial settings, and repairing leaks and improving infrastructure, and an expanded role for treated wastewater reuse. Taken together, these actions are expected to contribute an additional 42 percent of the water needed to overcome the projected water deficit in La Paz. The state water plan provides a breakdown of the proposed water management measures and their contribution to the projected deficit in La Paz (table 5). Similarly, in Los Cabos, expanded desalination is expected to make up 54 percent of the projected water deficit of 34 hm³, with other measures accounting for 37 percent (Conagua, 2012b:28).

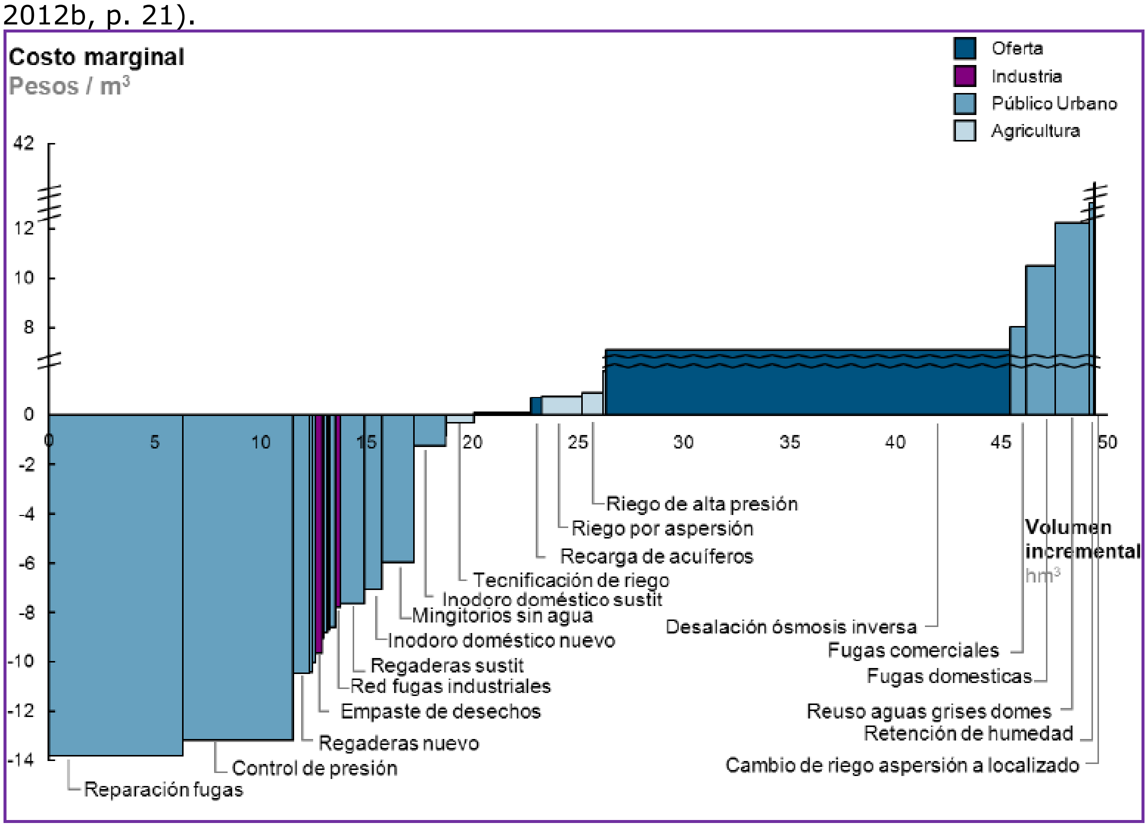
Table 5. Measures for covering the water deficit in La Paz, BCS (Conagua 2012b, p. 26, author's translation of table originally published in Spanish)

Measure	**Quantity**	**Unit**	**Contribution to deficit (hm³)**
Irrigation modernization (parcel)	159	ha	1.10
High precision irrigation	189	ha	0.20
Sprinkler irrigation	347	ha	0.90
Replacing domestic toilets	100,759	person	0.80
Replacing commercial toilets	33,541	person	0.10
New domestic toilets	9,015	person	0.10
New commercial toilets	5,748	person	0.02
Replacing showerheads	78,368	person	0.60
New showerheads	13,431	person	0.10
New low-flow faucets	13,431	person	0.02
Dry urinals (commercial buildings)	2,623	urinal	0.50
Pressure control and sectorization	31,374	connection	1.80
Repairing leaks in the distribution network	1,764	leak	2.10
Repairing domestic leaks	131,141	leak	0.50
Repairing commercial leaks	131,141	leak	0.30
Reusing domestic gray water	65,570	person	0.58
Using reclaimed water to irrigate parks	0.77	ha	0.03
Industrial leaks			0.10
Industry waste filling			0.10
Water used in industry			0.10
Aquifer recharge			0.20
Desalination plants	2	plants	7.80

*ha = hectare

The state plan also provides a cost-benefit analysis of each water management measure (figure 15). In this graph, the vertical axis indicates the marginal cost in pesos per cubic meter of each option. The horizontal axis indicates the potential volume of water that could be saved and/or supplied by each option. The options listed on the left side of the graph have a negative marginal cost, meaning that the revenue generated by the implementation of these options would be greater than the cost of their investment. Measures that promote conservation and improve system efficiencies (e.g., repairing certain leaks, agricultural modernization, and low-flow appliances) have a negative marginal cost. In contrast, the measures listed on the right side of the graph, including desalination (shown as *desalación osmosis inversa)* have a positive marginal cost.

Figure 15. Technical solutions for bridging the water deficit in BCS by 2030 (Conagua 2012b, p. 21).



While the current desalination plant in Cabo San Lucas has had some immediate success in increasing water security in the *colonia* of Los Cangrejos, it unclear if this is a financially viable solution in the long-term. The desalinated water is subsidized at a rate of 9.2 pesos/m³ (US$0.77/m³) (Gámez Vázquez 2009; see also McEvoy, forthcoming). The analysis by Gámez Vázquez (2009) notes that the same year that the desalination plant began operation (2006), the municipality's fiscal surplus disappeared and the municipality registered its first deficit. This raises questions as to the long-term economic viability of desalination as a water augmentation option.

Furthermore, it raises questions about the ability of other cities in BCS, and throughout Mexico, to implement this model of water augmentation through desalination. It is unlikely that other cities will be able to cross-subsidize the expense of desalination through higher tariffs on the hotel industry. This may introduce new vulnerabilities in terms of water pricing and equitable distribution of new water sources. For example, in La Paz, one of the proposals for a desalination facility would provide water to new tourist developments, rather than marginalized neighborhoods. The justification is that new users in the tourist sector would pay the full-cost of desalinated water (personal communication, 2012). But, given a lack of transparency, inaccessibility of information, and a history of financial mismanagement within the local water utility in La Paz (see Rubio, 2012), critics are concerned about the equity aspects of this solution (Gámez Vázquez, 2009; IIUNAM, 2010). Second, there are preoccupations about the environmental impact of the brine discharge from the desalination plant on the marine ecosystem (IIUNAM, 2010). This is of particular concern in La Paz, where the surrounding bay has shallower waters and less circulation, which may inhibit the dispersion of the brine concentrate (IIUNAM, 2010). Third, desalination requires significant energy inputs. Most of the energy supplies for BCS, including gasoline, diesel, and liquefied petroleum gas, are shipped from the mainland. While the federal electrical commission (CFE) is confident that the necessary energy can be made available (Pombo, Breceda, and Valdez Aragón, 2008; personal communication, 2011), some stakeholders are concerned about the additional air pollution and carbon emissions this would entail (IIUNAM, 2010). While solar powered reverse osmosis desalination is technically feasible, it is currently too costly (Bermudez-Contreras, Thomson, and Infield, 2008). Solar powered reverse osmosis desalination in BCS has only been attempted for a small-scale desalination project producing 0.23 lps for 250 inhabitants of a small fishing village (Bermudez-Contreras, Thomson, and Infield, 2008: 435; see also Ela and McEvoy 2013). There is on-going research on the feasibility of other renewable energy options, including geothermal energy and solar power for desalination in the region (Nava Escudero and Hiriart le Bert, 2008).

While the state water plan describes desalination as the principal means for achieving water balance (Conagua, 2012b), many stakeholders insist that it should be the "last resort" (personal communications, 2011; 2012; see also Breceda and Valdez Aragón, 2008; IIUNAM, 2010). Given limited resources, a priority focus on desalination is likely to forestall or foreclose alternative strategies.

Results: Water Management Alternatives

In 2009, as part of a collaborative initiative between water managers in Arizona and BCS, various stakeholders including federal and local water managers and representatives from non-governmental organizations, participated in a series of water management workshops[7]. At the end of the workshop series, twenty-eight participants completed a survey in which they were asked to rank the priority of eighteen possible water management strategies (Dos Santos, 2010). This survey indicates that respondents' top priority is to establish a program to control leaks. Other priorities include carrying out more water reuse projects, developing a long-term regional water plan, and building greater adaptive capacity within the local water agency. The lowest priorities were desalination and increasing the costs to new users (McEvoy, 2011).

An NGO's assessment of water management in La Paz argues that the first step should be the installation of water meters on all groundwater wells in order to have an accurate measure of how much water is being extracted (Carrillo Guer, 2010). In addition, micro-meters on all households, and commercial, and industrial buildings should be installed. This would allow the utility to better detect leaks, improve system efficiencies, and encourage conservation through education and the implementation of progressive tariffs that charge consumers more as they use more water. This assessment identifies other priority conservation actions, including repairing and replacing broken infrastructure, incentivizing the installation of water efficient appliances, promoting xeriscaping and rainwater harvesting, expanding

[7] This workshop series, titled Arizona-Baja California Sur Partnership for Sustainability, was supported by the International Community Foundation.

wastewater reuse, and increasing agricultural efficiency. It also highlights the importance of providing every family with sufficient water storage containers, so that they can maintain water security during the *tandeo*. Similar recommendations have also been made for Los Cabos, including the need to improve water metering, restructure the tariffs to incentivize water conservation, and improve billing collection for service (Valdez Aragón, 2006). In Los Cabos, there is also a need for meters at the well pumps in order to know more precisely how much water is being extracted (*ibid*).

There are two important regional projects that take into account the management of the broader watershed. First, is a series of projects aimed at revegetating and conserving soil in the upper watershed, where poor land-use practices have caused degradation leading to increased run-off. A group of NGOs, along with students and teachers from a local technical high school are building small-scale retention basins, planting native vegetation, and installing fences to keep cattle out of eroded areas. There is also a federally funded program through the state forestry office (CONAFOR) that provides payment for environmental services, including water recharge projects and reforestation in parts of the upper watershed (personal communications, 2011).

The second watershed-scale project is located seven miles south of the city center of La Paz, in an area that has undergone rapid urbanization in recent years. This area is one of the principal recharge zones for the aquifer (IIUNAM, 2010). A private urban development firm, in collaboration with the federal government and an international development organization, is seeking certification and funding from the Sustainable Integrated Urban Development (DUIS) program for an urban development plan that would incorporate a large water catchment system and green space to increase infiltration and reduce runoff (personal communication, 2011).

Another set of alternatives focus on issues of governance within water management and planning agencies. One of the greatest challenges to improved water management in Mexico is the frequent turnover of leadership positions within key administrative offices (Pineda Pablos and Briseño Ramírez, 2012). This turnover is typically associated with political elections every three years at the municipal level, and every six years at the state and federal levels. In a study of four different municipal water utilities in Sonora and Baja California, Pineda Pablos and Briseño Ramírez (2012) found that the average term for the director of a local water utility in each location was 2.6 and 3.5 years, respectively (p. 209). This study found a correlation between more frequent changes in political parties and lower levels of performance by the utility (Pineda Pablos and Briseño Ramírez, 2012). This continual rotation of leadership leads to institutional instability and makes long-term planning difficult.

In Los Cabos, the Municipal Institute of Planning (IMPLAN), a public planning consultancy, was established in 2009 to provide advice and coordination between various agencies. It is composed of members from the public, private, and academic sectors. Because it is a consultancy with private sector constituents (rather than a governmental office), the leadership positions within IMPLAN are expected to be more permanent, and thus provide a degree of continuity between political administrations (personal communication, 2012). Furthermore, IMPLAN has the explicit goal of coordinating between various sectors. An IMPLAN report (2011) observes that there has been a lack of coordination between different sectors to resolve service problems and enforce regulations and laws. The report also notes that integrated planning for urban development has been limited, with a narrow focus on resolving short-term problems (IMPLAN 2011). While it is too soon to assess the effectiveness of this nascent institution, some *municipio* officials in La Paz think it is a potential solution for overcoming some of the problems associated with the constant turnover in government leadership positions (personal communication 2012).

An additional governance challenge, which is widely discussed but hard to document, is corruption and mismanagement. In La Paz, a watch-dog organization believes that the water utility is used as a "*caja chica*" – or petty cash box for the city (personal communications, 2011). In a study of urban water governance in a different regional context, Bakker (2010) observes that, "As one of the largest revenue-generating agencies under the control of the municipalities, water utilities in some instances became "cash cows," furnishing opportunities for cash injections into the municipal budget or for patronage through the allocation of desirable government jobs" (pg. 62). Ortiz Rendón (2011), who worked in the water sector in Mexico for twenty years lists several examples of corruption, including giving jobs to unqualified individuals as political favors, approving permits for restricted uses or zones, manipulating the approval of an environmental impact studies, allowing illegal uses or permits to continue without sanction, and so on. He notes that larger infrastructure projects provide more opportunities for corruption to occur. He also lists action that are perhaps simply the result of poor management, rather than flagrant corruption, such as reliance on bad information, operating with a lack of information, or making bad investment decisions. Also, there's a culture of non-payment among water users, based on past high subsidies for water and belief that water is a 'free' good (Pineda 2006). Whether through corruption, insufficient resources, inadequate billing collection, or simply fiscal mismanagement, the local water utility in La Paz has accrued a debt of over $23 million pesos (nearly $2 million USD) to the federal water authority (Rubio 2012). In this situation of financial turmoil, the utility is ineligible to receive federal funding to re-invest in the water infrastructure network, which inhibits its ability to improve water services.

In sum, using a broader frame to assess water security highlights challenges for achieving water security through desalination. While desalination may improve water access in one particular neighborhood, when analyzed at the scale of the city and state new vulnerabilities and challenges emerge. In Cabo San Lucas, other *colonias populares* still experience a *tandeo*. In these neighborhoods, residents have limited access to water and continue to pay more for water from private water trucks. Given that steady demographic and economic growth has continued and system inefficiencies (i.e., leaks) have remained largely unaddressed, demand has continued to outstrip supply at the city-level. Additionally, the high cost of desalination technology raises questions about the long-term financial feasibility of achieving water security through desalination, particularly in cities that lack the strong economic base that the tourism industry provides in Los Cabos. This may introduce new vulnerabilities in terms of water pricing and equitable distribution of new water sources.

Furthermore, using the broader framing of water security brings issues of governance and institutional development to the foreground. By considering a range of factors that contribute to water security, it becomes clear that simply augmenting the amount of water in the system is an insufficient solution. Other issues, such as improving system efficiencies, promoting water conservation, considering the water-energy nexus, managing vegetation cover and soil quality in the upper watershed, and protecting the area of aquifer recharge from the development of impervious surfaces are not addressed by this technological solution; in fact these issues may be more easily ignored with the implementation of desalination. Institutional issues within the water and planning agencies themselves, such as lack of coordination between sectors, high rates of turnover in key leadership positions, and politicization of water management decisions also remain unresolved by this solution. This analysis supports the conclusion of Grey and Sadoff (2007), which suggests that the best path to water security is through balanced investments in water infrastructure and institutions (i.e., governance).

Discussion and Conclusions

In conclusion, this multi-scalar analysis indicates that water security in Los Cabos and La Paz is influenced by biophysical, infrastructural, socioeconomic, and institutional factors. Certainly, the limited precipitation (averaging less than 285 mm annually) in this arid region contributes to the challenge of providing a clean, reliable water supply to a growing population. Future reductions in precipitation and increased temperatures due to climate change are projected to compound this challenge (Milly et al., 2008; Magaña et al., 2012). Desalination, a supply-side infrastructure investment, is an option for augmenting municipal water supplies. As shown in the case of the neighborhood of Los Cangrejos, desalination has the potential to increase water security in the narrow sense (i.e., increased water availability for human use). In this particular case, desalination addresses pre-existing inequalities in water supply, to some extent, by delivering water to working-class neighborhoods that would otherwise pay more for water delivery from private water trucks.

However, even in this neighborhood, the increase in water security is limited. Survey results highlight the degree to which most water users continue to rely on private water vendors and the bottled water industry for their drinking water supply, and in many cases for washing fruits and vegetables. Despite assurance from the water utility that the desalinated water is potable, there is a sense of distrust by many users in the desalination process and/or the water distribution system. This is an important finding because it reveals that this high-tech, high-cost solution to water scarcity is not addressing the most basic water needs of residents (i.e., drinking water). If residents do not consider the water to be acceptable for human consumption, they remain at the mercy of private water vendors to meet this need. As such, the degree to which desalination improves water security, even in the narrow sense, is questionable. Furthermore, other *colonias populares* in Cabo San Lucas still have limited water access and continue to pay more for their water from informal sources (i.e., water trucks).

The results from the household survey also highlight the important role that the most basic technology – water storage containers – play in increasing water security at the household scale. In *colonias* that do not have continuous water supply, a household's ability to store water depends on their water storage capacity. An underground cistern, which fills up with water automatically when water is delivered to the household, is one of the most important water security adaptations at the household level.

Using a broader framing of the concept of water security highlights the need for institutional development and capacity building to promote good governance (Cook and Bakker 2012). Desalination, as a technological fix to water scarcity, does little to address the more systemic and structural problems that are related to the socioeconomic and institutional factors that also determine water security. The sustainability of a socioeconomic development model based on constant economic growth and mass tourism remains unquestioned. For example, the type of tourism promoted by FONATUR is based on highly water-consumptive activities (i.e., golfing and swimming at five-star hotels). Rather than challenging this business-as-usual development strategy, desalination enables it. As Smith (2009) observes, desalination can allow arid regions to "have limitless development 'cake' and eat it too" (p. 77). This solution also does little to improve the institutional capacity of the water and planning agencies.

Desalination is not the only infrastructure investment available to water managers. Indeed, many stakeholders insist that desalination should be considered as the "last resort." There are many other soft-path infrastructural investments that could be undertaken first (i.e., fixing leaks, re-investing in deteriorating infrastructure, installing water meters, incentivizing the installation of water-saving devices, and promoting water conservation). Given limited resources, an emphasis on desalination as the solution to water scarcity is likely to foreclose or forestall other water management options.

Lastly, augmenting municipal water supplies through desalination does not require water managers to undertake more difficult institutional and political transformations within the water management agencies themselves. As Swyngedouw (2013) concludes in his study Spain, "desalination is increasingly seen as a socionatural fix that permits a productivist water logic to remain the bedrock of Spain's global eco-modernization projects so that 'nothing really has to change' (di Lampedusa 1960)" (p. 268). In BCS, as in much of Mexico and the global South, the lack of long-term, integrated water planning strategies, as well as lack of transparency in water and urban planning institutions results in poor water governance that ultimately reduces water security.

In sum, the nuanced and contextualized understanding of water security presented in this paper considers a range of factors that influence water security at multiple scales. This analysis highlights important, and often overlooked, dimensions of water security (Zeitoun, 2011). It also shows the benefits of considering a broader framing of the concept of water security, which allows for a consideration of both water quantity and quality, and human and environmental needs (Cook and Baker, 2012). Additionally, it highlights the importance of investing in both infrastructure and institutions (i.e., governance) to improve water security (Grey and Sadoff, 2007; Cook and Bakker 2012). This underscores the need to build adaptive capacity within water management and urban planning institutions in order to achieve water security, broadly defined (Pahl-Wostl et al., 2007; Wilder et al., 2010; Scott et al. 2013).

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APPENDIX C: DEVIATING FROM THE MAINSTREAM? THE DISCOURSE AND PRACTICE OF DESALINATION AND ENVIRONMENTAL GOVERNANCE IN COASTAL NORTHWESTERN MEXICO

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For Submission to: *Environment and Planning C: Government and Policy*

Abstract

In the last forty years, environmental governance broadly, and water governance more specifically, has been influenced by a set of policy principles emphasizing the implementation of a comprehensive and coordinated policy framework, decentralization, private sector involvement, public participation, and environmental sustainability. In Mexico, these policy principles were incorporated into the water sector in the 1990s. Simultaneously, growing water demands and uncertainty about climate change and the future quality and quantity of water supplies has led to an increased interest in desalination technology as a way to augment water supplies in many regions. In coastal northwestern Mexico, desalination technology has recently been identified as a solution to address regional water scarcity. Using two large-scale desalination projects in the state of Baja California Sur (BCS) as case studies, this article examines how desalination, as a water augmentation strategy, fits within the contemporary water governance framework. This paper concludes that adoption of desalination technology in BCS facilitates some policy principles (e.g., semi-decentralized and semi-privatized), but also deviates in important ways (e.g., lacks genuine stakeholder participation, fails to ensure aquifer recovery, and introduces new environmental vulnerabilities). Furthermore, the disconnect between the discourse and practice of desalination at the national level versus state level suggests that water policy in Mexico is fragmented. The policy recommendations identify specific institutional arrangements that may be needed in order for desalination technology to contribute to sustainable water management, including further institutional development and capacity building within local water utilities and urban planning agencies. The set of recommendations is applicable to the management of desalination, and other supply-side water management strategies, particularly in developing countries.

Keywords

Environmental Governance; Mexico Water Policy Reforms; Desalination Technology; Decentralization; Private Sector Involvement; Public Participation; Environmental Sustainability

Introduction

In the last forty years, environmental governance broadly, and water governance more specifically, has been influenced by a set of policy principles emphasizing the implementation of a comprehensive and coordinated policy framework, decentralization, private sector involvement, public participation, and environmental sustainability. These principles are key tenets of the World Bank's 1993 "Water Resources Management" policy paper, which has guided water sector reforms over the last decade in many developing countries, including Mexico. These principles have also been promoted by an influential global network of water experts as part of an Integrated Water Resource Management (IWRM) approach (Conca, 2006).

Simultaneously, growing water demands and uncertainty about climate change and the future quality and quantity of water supplies has led to an increased interest in desalination technology as a way to augment water supplies in many regions. In coastal northwestern Mexico, desalination technology has recently been identified as a solution to address regional water scarcity. Using two large-scale desalination projects in the state of Baja California Sur (BCS) as case studies, this article asks the following research questions:

- What are the (potential) benefits and criticisms associated with each of the guiding principles of contemporary water governance?
- Where does the core support for adopting desalination as a water augmentation strategy come from?

- To what degree does the planning and implementation of desalination technology facilitate or deviate from each of the principles?
- What new institutions have developed to regulate the construction, management, and use of desalination technology?

This paper begins with an overview of the rise of desalination as a preferred water augmentation strategy and introduces two case studies of desalination in BCS. I then turn to a literature review that outlines the emergence of each the key principles of contemporary water governance and discusses how these principles have influenced Mexico's water sector reforms. This is followed by a more detailed explanation of each principle and the debates surrounding them, as well as a discussion of how each principle has been incorporated in Mexico's water policy reforms. I then turn to an in-depth analysis of how desalination facilitates or deviates from the five key water policy principles. The paper concludes with policy recommendations for specific institutional mechanisms that may be necessary to ensure that desalination contributes to sustainable water management.

The Rise of Desalination as a Preferred Water Augmentation Strategy

Desalination is a technical process that removes salts and other minerals from seawater and brackish water to create potable water for domestic, municipal, industrial, and emergency purposes (Cooley, Gleick and Wolff, 2006). According to the International Desalination Association's 24th Worldwide Desalting Plant Inventory, worldwide there are nearly16,000 desalination plants with the capacity to produce over 71 million cubic meters (MCM), equivalent to 57,500 acre-feet (AF) of water per day

(IDA, 2011). The capacity to produce desalinated water has grown by 57 percent in the last five years (GWI, 2012).

There is growing interest in adopting this technology to augment water supplies in northwestern Mexico. For example, as part of the 2007-2012 National Infrastructure Program, the federal government with guidance from Conagua and the federal Environmental Ministry (SEMARNAT) identified eight priority desalination projects, all in northwestern Mexico (Conagua, 2012a) (Figure 1). The International Boundary and Water Commission (IBWC), the institution responsible for settling issues related to boundary and water treaties between US and Mexico, has established a core working group dedicated to finding new water resources, including proposed binational desalination projects in Ensenada, Baja California, Rosarito, Baja California, and Puerto Peñasco, Sonora (McEvoy and Wilder, 2012). In BCS, at the tip of the Baja Peninsula, desalination technology is already being used to support continued growth in the tourist industry (Pombo, Breceda, and Aragón, 2008). In 2006, Mexico's first-ever large-scale public desalination facility was built in the *municipio* (equivalent to a U.S. county) of Los Cabos, BCS to provide water to 40,000 residents (McEvoy, forthcoming). There is a proposal to build a similar large-scale desalination facility in the capital city of La Paz, 110 miles north of Los Cabos. In a recent state-level comprehensive water planning document, desalination is identified as the principal means by which the cities of Los Cabos and La Paz will address the gap between water demand and water supply by 2030 (Conagua, 2012b).

1. Tijuana, BC
2. Guaymas, SON
3. Ensenada, BC
4. Ensenada, BC (La Misión)
5. La Paz, BCS
6. Los Cabos, BCS (Expansion)
7. Puerto Peñasco, SON
8. Loreto, BCS

Figure 1. National Infrastructure Program's priority desalination projects (Conagua, 2012a)

There are several reasons that water managers and planners are looking towards desalination as something of a panacea for arid regions, including growing water demands, limited clean water supply, and concerns about future water availability due to climate change impacts on water resources. Additionally, improvements in reverse osmosis membrane technology and energy recovery devices have reduced the cost of desalinating water. So while desalination is an energy intensive (and hence expensive) water supply option, it is becoming an increasingly attractive augmentation option.

Case Study Areas and Methods

Using two large-scale desalination projects in BCS as case studies, this paper assesses the degree to which planning and implementation of desalination technology facilitates and deviates from five water management principles that are integral to contemporary water governance, including: the implementation of a comprehensive and coordinated water policy framework, decentralization, private sector involvement, stakeholder participation, and environmental sustainability. This analysis is based on ten months of dissertation research in the urban centers of La Paz and Los Cabos, BCS (Figure 5).

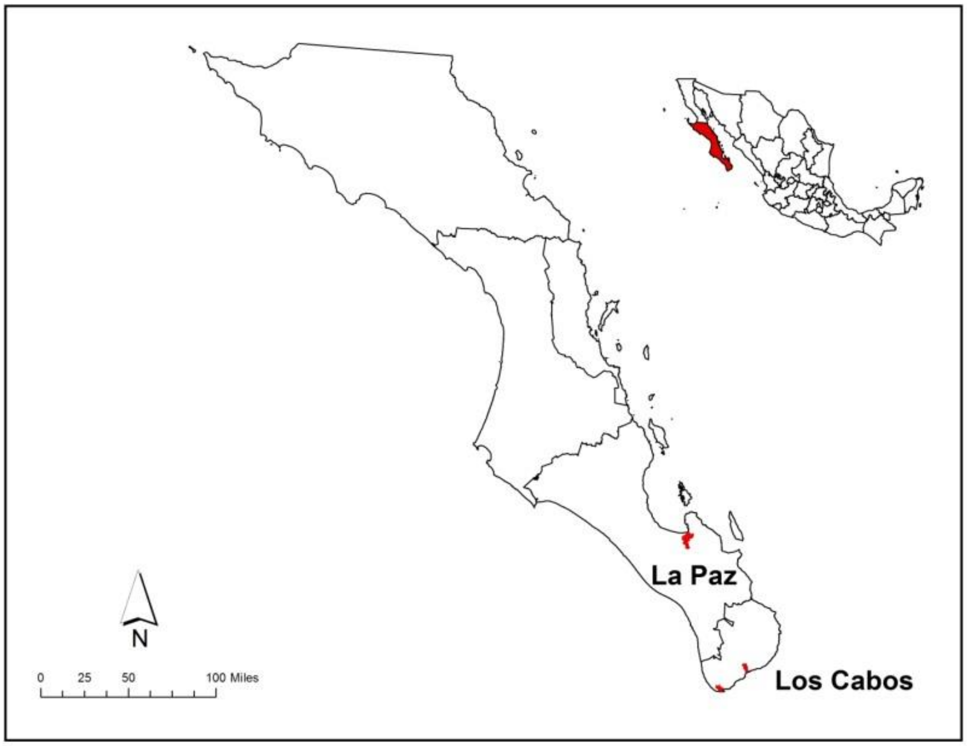

Figure 5. Map of Study Sites: La Paz and Los Cabos, BCS

Los Cabos is one of Mexico's most well-known tourist destinations. This arid coastal region attracts over a million visitors each year and is home to 251,871 residents, most of who are employed in the service sector (INEGI, 2010; IMPLAN, 2011). Los Cabos refers to the city of San José del Cabo, the city of Cabo San Lucas, and the 18-mile tourist corridor that stretches between the two urban centers. The *municipio* of Los Cabos is the local administrative unit, and consists primarily of these two urban centers, along with a few smaller outlying towns. In 2006 Mexico's first-ever large-scale public desalination facility was built in Cabo San Lucas to provide water to 40,000 residents in working class neighborhoods (McEvoy, forthcoming).

There is a proposal to build a similar municipal-scale public desalination facility in La Paz. In 2001, La Paz was listed among the 100 cities in Mexico that is most likely to experience a “severe water crisis” (Cruz Falcón, 2007: 2). The La Paz aquifer, the primary source of water supply for the city, is already in overdraft and experiences saline intrusion (Carrillo Guer, 2010). The economy of La Paz is more diverse than Los Cabos, with more government sector jobs, the Autonomous State University of Baja California Sur (UABCS), and various NGOs. It is also an important port city. The largest employment sector is retail, followed by jobs in construction, hotels, manufacturing and other services (PDU La Paz, 2011: 59). But increasingly, national and international tourism is gaining importance. There are several major new hotel and condominium developments. Currently, there is just one golf course in La Paz, but there are proposals for nine new golf courses (SAPA, 2011). The population has more than double in the last thirty years, growing steadily at about 7.5 percent from 111,310 residents in 1980 to 251,871 in 2010 (INEGI, 2010) (Figure 6).

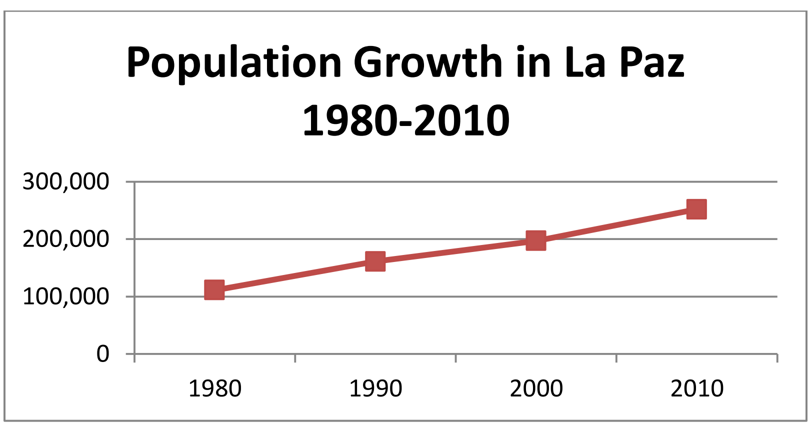

Figure 6. Graph of population growth in La Paz, BCS (INEGI, 2010)

The data presented in this article are derived from analysis of secondary documents (i.e., government reports, newspaper articles, and scholarly articles), as well as information gathered during semi-structured interviews and a focus group. All quotes and excerpts have been translated from Spanish by the author, with the exception of excerpts from the national *2030 Water Agenda* (Conagua 2011) and the *Statistics on Water in Mexico, 2010 Edition* (Conagua, 2010a), which are published in English.

The four primary government documents that are analyzed in this paper are: 1) the national-level *2030 Water Agenda* (Conagua, 2011); 2) a BCS state-level 2030 Water Agenda planning document titled *Programa de Acciones y Proyectos para la Sustentabilidad Hídrica: Visión 2030, Baja California Sur* (Program for Actions and Projects for Water Sustainability: Vision 2030, Baja California Sur) (Conagua, 2012b); 3) The socio-economic evaluation for the Los Cabos Desalination Plant, titled *Evaluación Socioeconómica* (Conagua, 2006); and 4) a feasibility study for a proposed desalination plant in La Paz (IIUNAM, 2010). The latter was conducted by researchers in the Engineering Institute (*Instituto de Ingenería*) at Mexico's National Autonomous University (UNAM) who were contracted by Conagua to conduct the feasibility study.

As part of the field research, I conducted semi-structured interviews with 71 different stakeholders (Table 1). In addition, I conducted surveys and a two-day focus group with 36 individuals who were participating in a week-long seminar on water management in arid regions at the Universidad Autónoma de Baja California Sur (UABCS), in La Paz. Participants included marine biologists, students, government employees, professors, water-related NGOs, and others (Table 2).

Affiliation of Participants in Semi-Structured in Interviews	# of Interviewees
Federal water commission (Conagua)	3
Federal government (other)	6
State water commission (CEA)	2
State government (other)	2
La Paz municipal water utility (SAPA)	3
La Paz municipal government (other)	3
Los Cabos municipal water utility (OOMSAPASLC)	2
Los Cabos municipal government (other)	3
Environmental Non-Governmental Organizations (NGOs)	5
Academic/Researcher	6
Private development, architecture, or real estate firm	9
Private desalination operator	1
Colonia residents	16
Colonia leaders	4
Expat residents	3
Other	3
Total # of Interviewees	**71**

Table 1. List of interviewees by affiliation type

Affiliation of Participants in Survey and Focus Group	# of Interviewees
Marine biologists	7
Students (marine biology, sustainable development, ecology, and unspecified)	7
Government employee (federal, state and local)	5
Professors (marine geology, agronomy, economy, unspecified)	4
Water-related NGO representatives	2
Other (geologist, economist, environmental consultant, system engineer)	4
No affiliation listed	7
Total # of Interviewees	**36**

Table 2. List of participants in survey and focus group by affiliation type

Literature Review: Neoliberal Environmental Governance and International Water Policy Principles

The term "environmental governance" has been used to describe trends in natural resources management that have developed over the last forty years. Environmental governance can be defined as "the set of regulatory processes, mechanisms and organizations through which political actors influence environmental actions and outcomes" (Lemos and Agrawal, 2006: 298). Bakker (2010) expands the traditional definition of governance (i.e., "the art of steering society") to describe a "process of decision making that is structured by institutions (laws, rules, norms, and customs) and shaped by ideological preferences" (p. 44). An important aspect of the concept of governance is that it includes the actions of both state and non-state actors, including non-governmental organizations (NGOs), businesses, communities, and transnational institutions.

The shift from government to governance has taken place in the context of broader political-economic changes associated with neoliberalism (Bakker, 2013; Heynen et al, 2007; Liverman and Vilas, 2006). The neoliberal economic doctrine emphasizes free markets, free trade, and strong private property rights as the most efficient mechanism for increasing economic growth, encouraging modernization, and promoting individual freedoms (Harvey, 2005). In natural resource sectors, neoliberal reforms typically involve the introduction of market mechanisms to allocate resources (i.e., market environmentalism). This approach to environmental management asserts that the establishment of private property rights and free markets, along with the inclusion of environmental externalities into the full-cost accounting of resource cost-benefit analysis will lead to a more efficient use of resources, and ultimately greater environmental conservation (Bakker, 2005; 2010; Liverman, 2004; Robbins, Hinzt, and Moore, 2010). The implementation of neoliberal policies and market environmentalism involves creating, enforcing, and maintaining new roles and relationships between markets, states, and individuals (Wilder, 2008a).

International development and lending institutions, namely the World Bank and the International Monetary Fund, have been key promoters of this neoliberal approach to environmental governance in many developing countries, including Mexico (Bakker, 2010; Castro, 2007; Goldman, 2007; Wilder, 2008a). These institutions have been able to assert their policy prescriptions through structural adjustment policies, in which loans for infrastructure development are conditioned on the adoption of neoliberal reforms. Neoliberal reforms have been carried out in various sectors, including the water sector. The World Bank's influential water resources policy papers outline a set of reforms emphasizing the implementation of a comprehensive and coordinated water policy framework, decentralization, involvement of the private sector, public participation, and environmental sustainability (World Bank, 1993; 2004; see also Bakker, 2010; Castro, 1995; Conca, 2006; Goldman, 2007; Wilder, 2008a). As stated in the 1993 policy paper:

> Water resources management that follows the principles of comprehensive analysis, opportunity cost pricing, decentralization, stakeholder participation, and environmental protection outlined in this volume will yield more coherent policies and investments across sectors, promote conservation and improve the efficiency of water allocation (World Bank, 1993: 11)

In addition to the political-economic and geopolitical forces emanating from large, multilateral development institutions, other non-state actors have played an important role in shaping contemporary environmental governance broadly, and water policy more specifically (Goldman, 2007; Varady, Meehan, and McGovern, 2009). A global network of water policy experts and their associated institutions (e.g., Global Water Partnership, World Water Council, and World Commission on Water for the 21st Century) have influenced water reforms in many countries (Conca, 2006). While these experts are able to disseminate their vision for water policy reforms through high-level water conferences, training and capacity building workshops, and policy papers, their policy guidelines are given teeth by multilateral lending institutions. As Goldman (2007) explains, “The most direct way the network’s idioms, technologies, and ‘water action plans’ get translated into action in borrowing countries is, of course, through the imposition of conditionalities on World Bank and IMF loans…[which] are using the carrot of debt relief to foist water policy reform on borrowing-country governments” (p. 794).

Within these international water policy networks, the concept of Integrated Water Resources Management (IWRM) has emerged in the last thirty years to replace the state-led, supply-focused hydraulic paradigm. This market-led approach to water management has the twin goals of achieving neoliberal efficiency (often through privatization or decentralization) and environmental sustainability (Conca, 2006). One of the goals of IWRM is to coordinate the development and management water, land, and related resources (Varis, 2008). Increasing public participation and community management of services is also a key aspect of the IWRM approach. As Conca (2006) notes, IWRM continues to be “*the* discursive framework of international water policy.”

With its emphasis on efficiency and environmental sustainability, IWRM marks a shift from a focus on supply management to an emphasis on demand management. This fits with the overall trend that Mexico’s National Water Commission (Conagua) has observed in their water policy reforms. As stated in a Conagua (2011) planning document, “In the 20th century, Mexican water policy went through a clear evolution:

from being guided by the increase in supply that dominated for more than half a century, through the focus on demand control that characterized the 1980s and 90s, to finally give rise to the emphasis on sustainability that is beginning to dominate at the start of this century (p. 10).” While discursively, an emphasis is now placed on demand management and environmental sustainability, the preference for seawater desalination, as an innovative, supply-side water augmentation option is gaining traction among water managers, urban planners, and decision-makers worldwide.

Literature Review: The Influence of International Water Policy Principles on Mexico’s Water Reforms

Overview and Context of Mexico’s National Water Law Reforms

Water management in Mexico is marked by an imbalance in the distribution of people, industry, and water. Northern Mexico is where the majority of irrigated agriculture, industry, and population are located, but has only nine percent of the country’s water resources (Conagua, 2009). Arid northwestern Mexico faces high levels of water stress (Conagua, 2010) (Figure 2). In 2008, 101 of Mexico’s 653 aquifers were in overdraft, with 21 of these located in the northwest and Baja Peninsula (Conagua, 2010a: 43) (Figure 3). This geographic context has contributed to the overpumping of northern aquifers, costly river basin transfers, and conflicts among competing users (Herrera Toledo, 1997).

Figure 2. Water Stress by Hydrological-Administrative Unit, 2008 (Conagua, 2010a: 74)

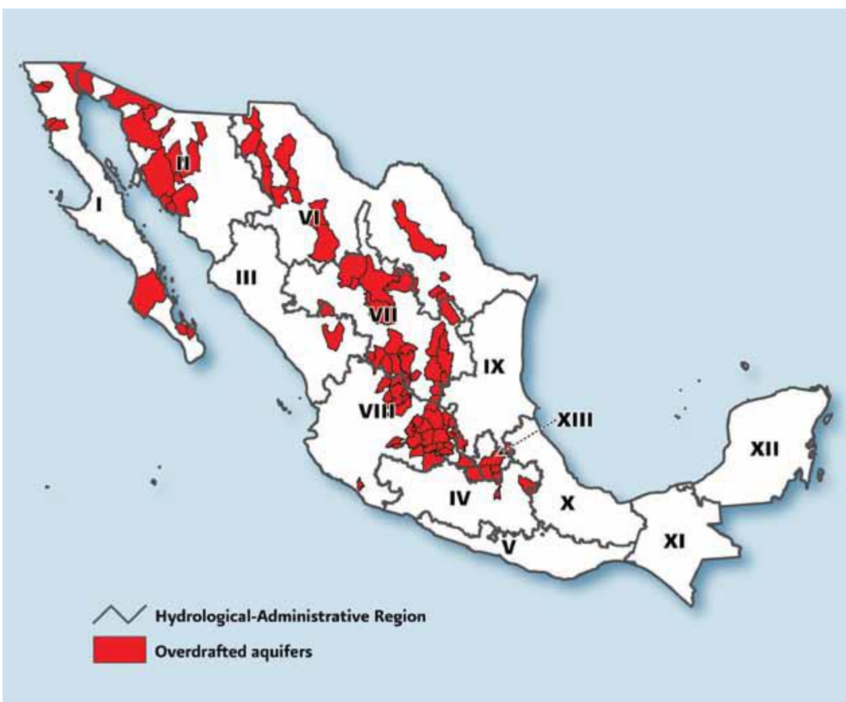

Figure 3. Overdrafted aquifers in Mexico by Hydrological-Administrative Region, 2008 (Conagua, 2010a: 44)

In addition to the imbalance of water supply and demand, there is a lack of financial and technical resources, a weak regulatory environment, and limited institutional capacity to improve water management and invest in water infrastructure. In 1990 (prior to water policy reforms), 21.6 percent of the population lacked residential water hook-ups and 14 percent lacked sanitation services (Conagua qtd. in Wilder, 2008a: 10). There was (and remains) an urgent need to improve water resources management.

In the 1990s, Mexico underwent significant policy reforms in the water sector and adopted a new National Water Law (NWL) in 1992, which was further modified in 2004. These reforms followed broader neoliberal reforms, which were institutionalized in response to the economic debt crisis of the 1980's and gained full strength under President Salinas (1988-1994) (Liverman and Vilas, 2006; Teichman, 2004; Wilder, 2010; Wilder and Romero Lankao, 2006). Following the neoliberal doctrine, Salinas privatized many state enterprises and banks and liberalized foreign trade (Pastor and Wise, 1997). In 1986, Mexico signed on to the General Agreement on Tariffs and Trade (GATT), which liberalized all agricultural products, except maize and corn. In 1992, Article 27 of the constitution was amended to allow for the privatization of *ejidal* land, or communal farms. Article 27 also established that, "The Nation is the owner of all water within its territory, with a few exceptions, and authorizes the government to administer these resources and grant 'concessions' for water use" (Garduño, 2005: 89). Although the federal government still remains the owner of most water, the reform of Article 27, "gives the formal basis for creating land and water markets through giving the ejidal and communal land, as well as water, the status of private property" (Castro, 1995: 464). In 1994, Mexico entered into the North American Free Trade Agreement (NAFTA). In preparation for the passage of NAFTA, Mexico faced pressure to modernize its water and agricultural sectors (Wilder, 2010; Whiteford and Melville, 2002).

It is in this context that the 1992 National Water Law (NWL) was enacted in December 1992 and the regulations to enforce the law were enacted in 1994. As Wilder (2008a) notes, "The 1992 national water law mirrored the major features of World Bank water resources policy for developing countries…" (p. 5). By closely observing the World Bank's prescriptions for development of water markets, privatization of rights and services, decentralization, and elements of public participation when it adopted a new National Water Law in 1992 and revised it in 2004, Mexico became one of the early adopters of World Bank style reforms (Wilder, 2010).

Hearne (1998) suggests that two major changes were brought on by the 1992 reforms: decentralization and market-based incentives. Other authors have emphasized the importance of increased stakeholder participation in water planning and management due to the reform process (Wilder, 2005; Wilder and Romero Lankao, 2006). Despite the emphasis on decentralization, the Mexican state has maintained a central regulatory role through the authority of Conagua, the national water agency (Castro 1995; Hearne 1998). This makes it a less extreme free-market model as compared to the relatively unregulated Chilean model (Bauer, 2004) and provides some degree of environmental protection.

With its modernized water policy, Mexico became a model for the rest of Latin America, showcasing its progress by hosting the World Water Forum in 2006. Nevertheless, water is still inequitably distributed and centrally controlled especially in water-scarce, arid regions of the country (Castro, 2006; Wilder, 2008b). Furthermore, despite efforts to implement a comprehensive and coordinated water policy framework, there is evidence that water sector reforms have led to a more fragmented national and regional politics (Wilder, 2008).

Recent Advances in Mexican Water Policy

Since the adoption of the 1992 Water Law Reforms and the 2004 modifications, three significant events have occurred within the Mexican water policy context. On World Water Day in 2010, former Mexican president Felipe Calderón called for the creation of a “roadmap” for the nation’s water sustainability (Conagua, 2011: 10). This resulted in the creation of the 2030 Water Agenda – a long-term planning tool that aims to achieve water sustainability by 2030 (Conagua, 2011: 8) (see detailed discussion below). As noted in the document, the approaches to water management outlined in the Agenda have “come out of the international meeting over the last two decades, on sustainable development in general and on the sustainable use of water resources in particular” (p. 12).

A second important evolution in Mexican water policy is the inclusion of water and sanitation as a human right in Article 4 of the Mexican Constitution. This new constitutional provision was adopted in 2011, and published in the Official Journal of the Federation (*Diario Oficial de la Federación*) on February 8, 2012 (Herrera Ordóñez, n.d.: 3; VI World Water Forum, 2012). It guarantees that:

> Every person has the right to water access, disposal and sanitation for personal and domestic use in sufficient, healthy, acceptable and affordable way. The State guarantees this right and the Law will define the foundations, support, and access methods for the equitable and sustainable use of water resources, establishing the participation of the Federation,

> federal agencies and Municipalities, as well as the participation of citizens for the achievement of these ends (VI World Water Forum, 2012: 31).

This constitutional amendment is significant because it not only addresses the right to water for personal and domestic use, but also guarantees the participation of citizens in sustainable water management. Discursively, it lends tremendous support for supporters of universal access to public water services. Legally, the constitutional guarantee can be used in the Mexican court system to support plaintiffs seeking access to improved water services.

As part of the constitutional guarantee of water as a human right, a new Drinking Water and Sanitation Law is being drafted to implement this amendment. The objective for the new law, as outlined in a confidential draft proposal, is to regulate the services and providers in the water and sanitation sector (personal communication, 2013). The law would apply to all types of services providers (e.g., public, private or mixed) and require them to provide equitable and efficient water and sanitation services, while demonstrating financial self-sufficiency. However, the bill has not yet been presented in the Mexican Congress, most likely due to the change in presidential administrations in December 2012, which resulted in new leadership within Conagua. The new administration is working on its own version of the bill (personal communication, 2013).

With this broader context as background, I now turn to a more detailed discussion of five guiding policy principles of contemporary water governance and provide an overview of how they have been incorporated into Mexico's water sector reforms. These principles include the implementation of a comprehensive and coordinated water policy framework, decentralization, private sector involvement, public participation, and environmental sustainability.

Guiding Water Policy Principles: Pros, Cons, and Implementation in Mexico

Guiding Policy Principle #1: Implementation of a Comprehensive and Coordinated Water Policy Framework

The World Bank (1993) and IWRM approaches to water management (Conca, 2006; Biswas, Varis and Tortajada, 2005) emphasize the need for countries and states to implement a comprehensive and coordinated water policy framework. Integration and coordination among various sectors, institutions, and levels of governance is necessary for achieving a coherent water policy framework and avoiding counterproductive and fragmented policies (World Bank, 1993; Varis, 2008).

As stated in the 1993 World Bank water policy paper:

> Many governments face growing problems because they have failed to address water resources in a comprehensive manner. Government activities are generally organized so that each type of water use is managed by a separate department or agency—for example, irrigation, municipal water supply, power, and transportation—each responsible for its own operations and independent of the others. Issues related to the quantity and quality of water as well as health and environmental concerns are also considered separately, as are matters related to surface and groundwater. Problems of uncoordinated and fragmented decisionmaking abound. Resolving these problems is particularly difficult in federal governments, where states or provinces have jurisdiction over water in their territory. In such cases, individual states may develop the same water source without considering the impact on other states... (p. 27)

However, achieving integration and coordination has proven to be difficult. As Biswas et al (2005, p. 254) observe:

> …operationally it has not been possible to identify a water management process that can be planned and implemented in such a way that it becomes inherently integrated however this may be defined, right from its

> initial planning stage and then to implementation and operational phases…(qtd. in Scott and Banister, 2008: 64)

As Scott and Banister (2008) note, implementing integrated plans requires "conformity of large water resources bureaucracies to open themselves to integration" (p. 61). This is further complicated by "extensive turf wars, bureaucratic infighting, and legal regimes" (p. 64). They question whether these obstacles are just "bottlenecks" that could be overcome with appropriate interventions, or if they are a sign of "fatal structural flaws" of IWRM (p. 64).

Mexico's water reforms have stressed the need for a comprehensive and coordinated national water policy framework. As outlined in the 2007-2012 National Water Program (Conagua, 2008a):

> A fundamental aspect [of the program] consists of achieving greater commitment and efforts towards coordination among the federal government and state and municipal governments, non-governmental organizations, and our citizens in general so we may continue to move forward together towards the future we have charted for ourselves (p. 5).

Additionally, the document emphasizes that:

> In order to meet current challenges and reach the goals set, an essential factor is the joint, harmonious work of the institutions and organizations that participate in water management and conservation (Conagua 2008a: 6).

The 2030 Water Agenda, Mexico's most recent "roadmap" for the nation's water sustainability, is a long-term planning tool that aims to achieve sustainability in four key aspects of water management by 2030, including 1) clean water bodies 2) balanced supply and demand for water 3) universal access to water services and 4) settlements safe from catastrophic floods" (Conagua, 2011: 5) (Figure 4).

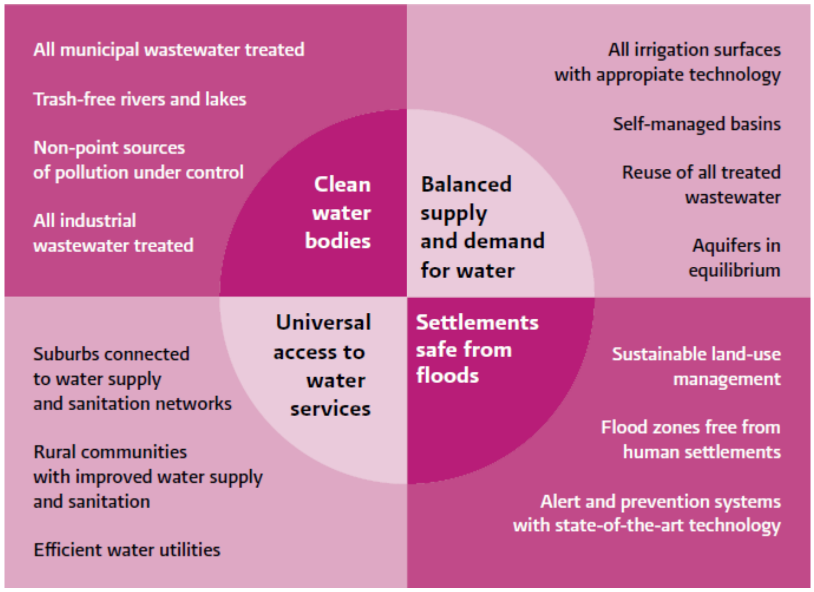

Figure 4. Visualization of the goals of the 2030 Water Agenda (Conagua, 2010a: 160)

The Agenda defines "the nature and magnitude of the challenges to be overcome and the solutions" (Conagua, 2011: 11) and acts as "an instrument for the appropriate implementation of sustainable water policy" (Conagua, 2011: 8).[8] Furthermore, it "prioritizes the lines of action that should be deployed" to achieve the goals of the Agenda (p. 12). As stated in the document:

> The 2030 Water Agenda is an instrument that promotes solidarity between Mexicans from different regions and localities of the country at this point in time, and between this generation and future ones. It also encourages the concurrent action of all institutions—governmental and nongovernmental—nationally, regionally and locally (Conagua, 2011: 12)

[8] Undoubtedly, the term "sustainability" is fraught with contradictions and has been criticized for its ambiguity (Lélé, 1991; Redcliff, 1992; 1994). However, it is still widely used in the international water community, and "sustainability" – used in to reference to environmental, social and economic dimensions of the term – is a "central facet" of Mexico's 2030 Water Agenda (Conagua, 2011: 10). In this document, Conagua (2011) interprets environmental sustainability to mean that, "aquifers are not overdrafted, environmental flows of surface water bodies are respected and water pollution is controlled" (Conagua, 2011: 8).

Despite these efforts to develop and implement a comprehensive and coordinated water policy framework, Wilder (2008a) has observed that water reforms in Mexico have led to “a more fragmented national and regional politics – and especially, party politics – that has made it more difficult to push a unitary decentralization and sustainability agenda forward” (p. 3). This is particularly true when different levels of government are governed by distinct political parties, which often politicizes water management decisions. In the analysis section, I examine the degree to which desalination is part of a comprehensive and coordinated water policy framework.

Guiding Policy Principle #2: Decentralization

Decentralization is the “transfer of power from the central government to actors and institutions at lower levels in a political-administrative and territorial hierarchy” (Larson and Ribot, 2004: 3). In various natural resource sectors, reforms emphasizing decentralization have been justified by promises of “increased efficiency, equity and inclusion that should…result in better and more sustainable management (Larson and Ribot, 2004: 2). The concept of decentralization is closely related to the principles of privatization and public participation. Some observers of decentralization processes have expressed concern about the authenticity and effectiveness of participation; others are concerned that decentralization is often conflated with privatization (see discussion below). An additional critique is that co-management is often just “a form of deconcentration where elected local authorities are used by central government and donors as local administrators to implement outside agendas” (Larson and Ribot, 2004: 5).

Given the various forms that decentralization has taken in different contexts, Ribot and Larson (2004) distinguish between “administrative decentralization” and “political” or “democratic decentralization” (p. 3). In the former, power is transferred to local administrative units under the assumption that local actors are better able to read local preferences and mobilize local resources. The latter has a greater emphasis on integrating local actors into the decision-making process through better representation and more empowered local governance bodies which are able to act autonomously and implement meaningful decisions. The ability of local-level administrative bodies to effectively make decisions is influenced by the overall capacity of the administrative unit, local power relations, the structure of resource management incentives, and the dominant ideologies related to environment and society (Ribot and Larsen, 2004).

In Mexico, the momentum towards decentralization was already underway before the passage of the 1992 reforms (Whiteford and Melville, 2002; Wilder, 2005). In urban areas, the operation and management of potable water and sanitation systems was administratively decentralized to the municipal and city level in the 1980s. However, following the 1992 NWL reforms, more funding was transferred from the federal to local governments and urban utilities were expected to operate without subsides (Whiteford and Melville, 2002). The World Bank supported decentralization as one of its principle guidelines, providing both ideological and financial support for such reforms (Whiteford and Melville, 2002; Wilder, 2005).

When the NWL was modified in 2004, a key aim was to “strengthen the decentralization and sustainability aspects of the water law” (Wilder, 2008a: 6). However a weaker version of the modification bill was passed, which ultimately resulted in the deconcentration of the national water authority into 13 regional headquarters. This has allowed Conagua to maintain a large degree of administrative and fiscal authority, which has stalled the decentralization process (Scott and Banister, 2008; Wilder, 2008a; 2010).

In the analysis section of this paper, I examine whether or not the adoption of desalination technology as a water augmentation strategy achieves the aims of decentralization – that is, the transference of power from a centralized government to local actors.

Guiding Policy Principle #3: Private Sector Involvement

One of the most contentious issues in water management is the privatization of water services (Barlow and Clarke, 2002; Swyngedouw, 2005). Bakker (2010) provides a nuanced discussion of the different models of private sector involvement in the water sector. Private sector involvement can range from privatization (i.e., full divestiture of water infrastructure) to marketization (i.e., introduction of markets), to corporatization (i.e., a publicly owned corporation), or liberalization (i.e., contracts and concessions through public-private partnerships, commercialization of water through full cost pricing, deregulation of water quality oversight to private actors, and/or decentralization).

Proponents of private sector involvement in water supply typically blame inefficient governments for failing to achieve adequate water provision and often point out that many of the world's poorest citizens are already paying more for private, informal, and unregulated water supplies from private actors (Bakker, 2010; Goldman, 2007). This latter argument is used to underscore the inequities of the failure of current municipal water service networks; it is also used to argue that the world's poor are willing consumers and represent "a vast potential market" from which both the private and public sectors could benefit (Bakker, 2010: 254). Proponents further argue that the private sector can provide capital investments that many developing country governments cannot undertake. Additionally, the private sector is assumed to run more efficiently on a for-profit business model and can more easily implement full-cost recovery pricing, achieve a higher cost recovery from consumers, and eliminate the need for subsidies in the water sector. Based on these arguments, and the broader neoliberal push for market-based environmental governance, the water sector was liberalized in the early 1990s and pro-private sector policies allowed for a significant increase in private sector participation in water supply systems. The World Bank adopted a Private Sector Development strategy and there was an increase in foreign direct investment in the private water sector by the International Finance Corporation in the 1990s (Bakker, 2010).

However, the private sector's ability to improve access to water services for much of the world's poor has not matched expectations. Given the disappointing performance of the private sector in water supply, the World Bank made an "abrupt turnaround" in 2005 and acknowledged that "the vast majority of water supply systems would remain publicly owned" (Bakker, 2010: 256). The World Bank argued that "a renewed public-sector effort was necessary to extend the provision of urban water supply services to poor households" (Bakker, 2010: 254).

Critics of privatization maintain that private sector involvement has not achieved the promises of increased efficiency in water supply nor improved access to water services. Privatization of water supply is seen by many as an act of "accumulation by dispossession" (Swyngedouw, 2005: 81). Furthermore, increased involvement of the private sector is considered to reduce the power and involvement of citizens, decrease accountability and transparency and increase opportunities for corporate secrecy, 'hand-greasing,' and corruption (Castro, 2007; Swyngedouw 2005). Castro (2007) argues that the term 'public-private partnership' is a misnomer because "…the public sector is extremely weak and has a low capacity for regulation and law enforcement…" (p. 762). He concludes that policies that have promoted private sector involvement "…have not enhanced good governance and have rather discouraged citizen involvement and accountability…" (p. 767).

In 2001, former Mexican president Vicente Fox established the federal Program for the Modernization of Water Utilities (PROMAGUA) to attract private sector investment in municipal water supply systems in cities of 50,000 inhabitants or more (Conagua, n.d.: 6; Conagua 2010b). PROMAGUA receives federal funding through the National Fund for Investment in Infrastructure (FONADIN), which is under the management of Banobras (the national development bank of Mexico). In 2002, the World Bank loaned $250 million dollars to Conagua to support PROMAGUA (Barlow and Clark 2004; Castro Soto, n.d.). Under PROMAGUA, Mexico has had limited success in attracting private sector investment in municipal water supply systems in urban areas. According to a Conagua report (2010b), there have only been 32 water and sanitation projects with private sector participation (p. 4). This report notes that "These contracts have been effective ways of raising funds for investments in facilities for treating water, treating wastewater, and desalination, but do not improve the level of efficiency of the water and sanitation providers and do increase the cost of service" (p. 5). However, the report highlights three "successful" cases of PPP concessions in Mexico, including services in Aguascalientes, Cancun/Isla Mujeres, and Saltillo and concludes that these three utilities are "among the most efficient water and sanitation providers in the country" and that "their tariffs cover a greater portion of their cost of service than the tariffs for most other water and sanitation providers" (p. 30). The report goes on to emphasize the benefits of PROMAGUA:

> Recognizing the importance of increasing the operating efficiency of water and sanitation providers, and the potential for PSP contracts to contribute to this objective, Conagua and other Federal Government entities are pursuing efforts to increase this type of private management and operation of water and sanitation providers, through the Water Utilities Modernization Program (PROMAGUA), which intends to improve efficiencies, make structural changes and include private sector participation (PSP) in the water utilities (Conagua, 2010b: 30).

In their review of case studies of water privatization and decentralization in Mexico, Wilder and Romero Lankao (2006) conclude that the there is "no clear and direct link between private participation and a more efficient management of water" (p. 1991). Furthermore, their case study analysis shows that:

> Private services present an additional burden for water users in general without significant improvement in water services… privatization appears [to be] not so much an instrument aimed at improving efficiency as it does a channel for preferred treatment for capital accumulation by private entities as well as a legitimized way for the state to transfer the financial and politically charged burden of water management to non-state actors. (p. 1991).

Despite the shortcomings of private sector involvement, the neoliberal logic of private sector efficiency holds strong among many policymakers. In December 2011, the

Mexican Congress approved a new Public-Private Partnership Act (Franck et al, 2011). This legislation is intended to "promote the development of infrastructures projects, at the federal level, by establishing the legal framework for private investment in public sector services" (Mueller, 2010: 1). The legislation is innovative in that it allows for longer-term contracts (i.e., up to 50 years, as opposed to the typical 20 or 30 year contracts) and allows a greater variety in the structure of the contracts (i.e., moves beyond more common authorizations, permits or concessions). It also allows for un-solicited projects (i.e., the private sector can propose partnerships that have not been solicited by the government) and does not limit foreign investment beyond the terms outlined in the Foreign Investment Law (*ibid*). In the analysis section of this paper, I examine how a public-private partnership was used to finance, build, and operate Mexico's first-ever, public, municipal-scale desalination facility located in Los Cabos, BCS.

Guiding Policy Principle #4: Public Participation

Stakeholder participation is promoted in the World Bank's water policy papers (World Bank, 1993; 2004) and is a central component of Integrated Water Resources Management (IWRM) (Conca, 2006). The United Nation's Conference on Sustainable Development (UNCSD) suggested that participation should "bring together all relevant parties and their particular socio-economic and environmental concerns that are bound by freshwater" (UNCSD, 1998 qtd. in Conca, 2006: 158).Von Korff et al (2012) use the term "participatory" to "refer in general to processes that actively involve not only water managers and government officials, but also other interested parties (p. 1). Larsen and Ribot (2004) argue that representative public participation is a key aspect in achieving democratic decentralization. Borisova, Racevskis, and Kipp (2012) differentiate between structural characteristics and procedural characteristics of successful collaborations. The most important structural characteristic is that the project involves diverse stakeholders to ensure a broad representation. Bidwell and Ryan (2006) also emphasize the importance of diverse participation. However, they note that an "“open door” policy on participation is insufficient" (p. 840). They emphasize the need to go beyond "voluntary" participation and actively recruit diverse participants and to consider providing monetary and technical resources to support participation of underrepresented groups.

While participatory processes are encouraged to increase transparency, promote democratic decision-making, and reduce conflict, an ideal form of public participation is hard to achieve. Wester, Merrey, and de Lange (2003) emphasizes the need to distinguish between "…token stakeholder participation and actual control over water management decision-making by water users and citizens" (p 799). Conca (2006) notes that there are doubts about the "self-appointed character of many so-called stakeholders" (e.g., international organization, non-governmental organizations), which have been described as "unrepresentative" and "unaccountable" (see Ottawa, 2001 qtd. in Conca, 2006:386). La Viña, DeRose, Escudero, Ribot, and Hoff (2003) express concern about issues of representation and transparency in participatory efforts more broadly. They raise questions about: Who represents which interests? Who can speak for others? How should consensus be achieved? And is input taken seriously by decisionmakers? As Conca (2006) observes, "...questions surrounding participation often produce fragmentation, dissention and debate" (p. 159).

Increased stakeholder representation and participation, has been identified as one of the successes of the 1992 water reforms in Mexico. Increased water user and community participation in water management decisions was also one of the primary objectives of the 2004 modifications (Ranger, 2004). In the context of irrigation districts in Sonora, Wilder's (2005) study found that the decentralization process resulted in "the creation of new democratized spaces for participatory water management that has given irrigation users in Sonora and other states a potent sense of their ability to influence and direct the course of water management within their own irrigation districts. Even so, Wilder (2008b) cautions that a truly democratic and equitable process depends on the quality of participation and the ability to avoid "elite capture of participatory processes" (p. 101). Furthermore, Wilder (2010) observes that "other decentralization reforms such as the municipalization of water management and integrated management by watershed councils has not been effectively implemented due to lack of resources, limited jurisdiction, and lack of fiscal authority" (p. 2).

Public participation in water management in Mexico has been further institutionalized through the 2011 amendment to Article 4 of the Mexican Constitution. This amendment not only establishes water as a human right, but also guarantees this right through "the participation of the Federation, federal agencies and Municipalities, as well as the participation of citizens for the achievement of these ends" (VI World Water Forum, 2012: 31).

In sum, there is evidence that Mexico has achieved some success in increasing participation of Water Users Associations (WUA) in rural water management.

Furthermore, the State has adopted strong language regarding the importance of citizen participation in water management as part of the new constitutional guarantee of water as a human right. In the analysis section, I examine the degree and quality of stakeholder participation in the planning and implantation of desalination technology in BCS.

Guiding Policy Principle #5: Environmental Sustainability

A major shift in contemporary water management is the consideration of the environmental impacts of water infrastructure development (e.g., dams, canals for interbasin transfers, and groundwater pumping technology), recognition of the environmental services provided by hydrological processes, and legal designation of the environment as a legitimate water user (Bakker, 2010; Postel and Richter, 2003; Whiteley, Ingram, and Perry, 2008).

IWRM is an integrated approach to water management that attempts to mitigate negative environmental impacts associated with water development projects. The discourse emanating from high-level water forums in the last twenty years highlights the importance of achieving environmental sustainability in water management (Conca, 2006). The growing recognition of the negative environmental impacts of many large-scale, supply-oriented infrastructure projects has led to a new focus on demand management and efficiency in water supply systems (Gleick, 2000; 2003; Ingram, Whiteley, and Perry, 2008; Postel and Richter 2003; World Commission on Dams, 2000).

In terms of institutional capacity for environmental regulation in water management in Mexico, the Federation has maintained a central regulatory role through the authority of the Conagua, even after the NWL reforms (Castro, 1995; Hearne, 1998).

This distinguishes Mexico's water plan from Chile's extreme free-market model and brings it more in line with IWRM and the Dublin Principle's emphasis on integrated water management and environmental protection (Mestre, 1997; Saade, 1997). In 1997 the National Water Commission was transferred from the agricultural ministry to the ministry of the environment, which signaled an important change in water management priorities. As Wilder (2010) observes, this administrative maneuver resulted in "wresting water management away from the controlling grasp of the agriculture agency and transforming it into an agency focused on water conservation" (p. 6). Environmental sustainability in water management gained further prominence in the 2004 modifications to the NWL, which recognizes the environment as a legitimate water user (Wilder, 2010). However the regulations to implement its environmental protections have never been adopted (Wilder, 2008a).

In the analysis section of this paper, I outline the institutional and regulatory framework under which desalination is being adopted and examine how the environmental dimensions of desalination are being addressed in the case of desalination planning in BCS.

Analysis of Planning and Implementation of Desalination in BCS, Mexico

Desalination as Part of a Comprehensive and Coordinated Water Policy Framework: A Disconnect in the Discourse and Practice of Desalination at National and State Levels

In this in-depth analysis of how the adoption of desalination technology in Mexico fits within the contemporary water governance framework, I first examine the degree to which desalination is part of a comprehensive and coordinated water policy framework.

Within the national-level 2030 Water Agenda (Conagua, 2011), desalination system build-out is not highlighted as a priority action for achieving balanced water supply and demand in Mexico. Instead, emphasis is placed on agricultural modernization and increasing system efficiencies. As stated in the national-level Agenda:

> In summary, in order to ensure the implementation of the technical solutions and achieve balanced supply and demand for water, it will be necessary to concentrate on four lines of action: increasing the modernization (relining primary and secondary channels) and the technification of irrigation districts and units, even at the level of plots; continuing with the construction of infrastructure to supply areas of growth; boosting the efficiency of drinking water and sanitation systems through sub-division and leak repair programs, and increasing the use of efficient technologies in homes, businesses and industry (p. 18).

In reaching this conclusion, the report analyzed multiple options to bridge the gap between water supply and water demand that is projected by 2030. The various options were assessed according to the cost-benefit ratio (Figure 7). In this graph, the vertical axis indicates the marginal cost per cubic meter of each option. The horizontal axis indicates the potential volume of water that could be saved and/or supplied by each option. The options listed on the left side of the graph have a negative marginal cost, meaning that the revenue generated by the implementation of these options would be greater than the cost of their investment. As the analysis concludes, “considering the marginal cost of implementation, the measures that should be implemented first of all are those with a negative marginal cost, such as repairing domestic, commercial, industrial and municipal leaks, as well as replacing showers” (p. 18). In contrast, desalination is the option that falls to the extreme right-hand side of the graph, indicating a high marginal cost. As shown in figure 8, the national-level 2030 Water Agenda does not envision desalination playing a significant role in closing the gap between water demand and water supply by 2030. Aside from being assessed as one possible water augmentation option among many as analyzed in these figures, desalination does not receive further attention in the national-level document.

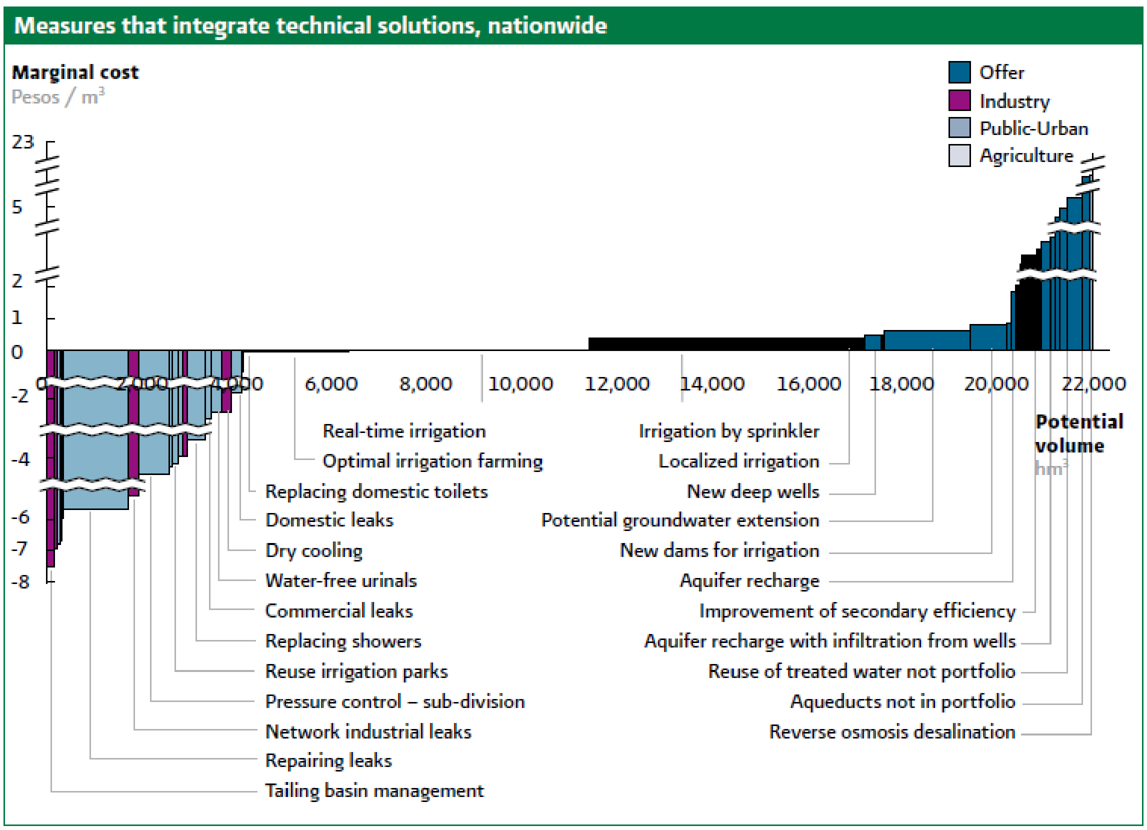

Figure 7. A cost-benefit analysis of various water management options (Conagua, 2011: 18).

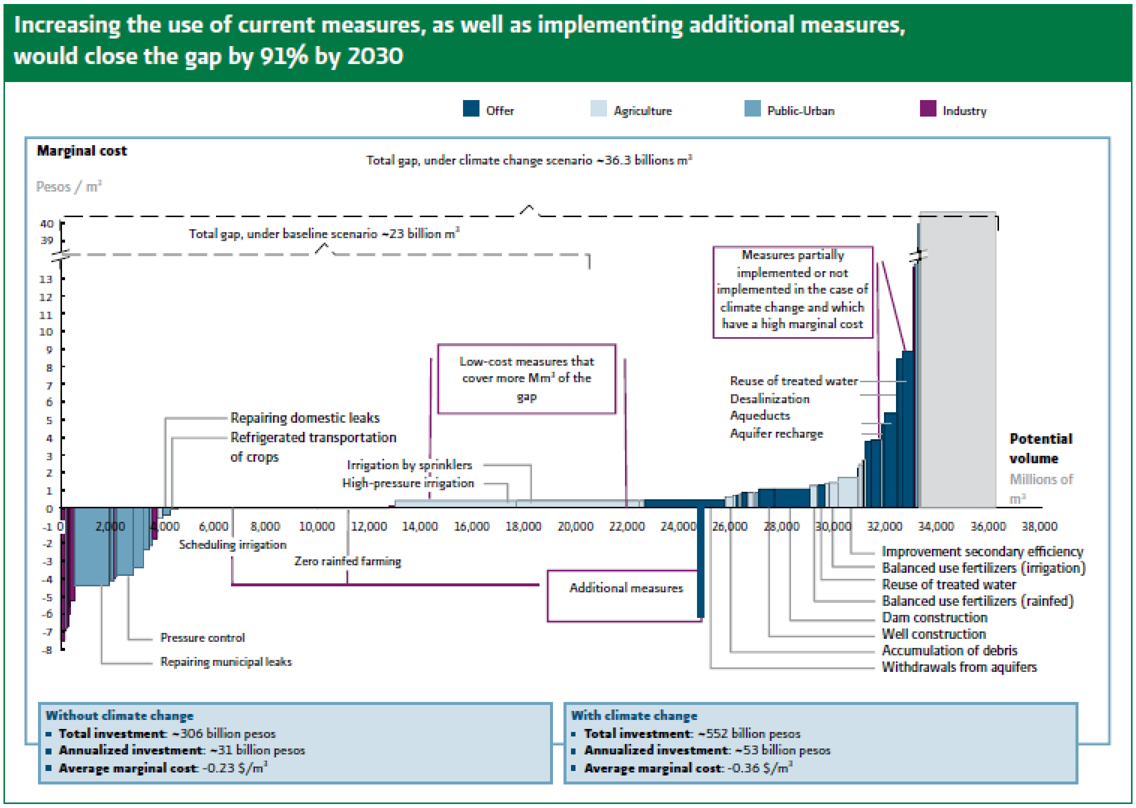

Figure 8. Range of options for addressing the water supply and demand gap by 2030 (Conagua 2011: 20)

In addition to the elaboration of a national-level 2030 Water Agenda, detailed studies have been conducted at 13 regional administrative levels, as well as at the state level to evaluate a range of water management alternatives that could be implemented to achieve water sustainability by 2030 (Conagua, 2011: 10). In contrast to the discourse of desalination in the national-level document, desalination figures prominently in the state-level planning documents that are part of the 2030 Water Agenda. For example, in the *Programa de Acciones y Proyectos para la Sustentabilidad Hídrica: Visión 2030, Baja California Sur* (Program for Actions and Projects for Water Sustainability: Vision 2030, Baja California Sur) (Conagua 2012b), desalination plays a key role in bridging the gap between water supply and water demand in the state of BCS by 2030. As shown in figure

9, desalination (listed as *desalación osmosis inversa)* is expected to make a much more significant contribution to the water supply gap in BCS.

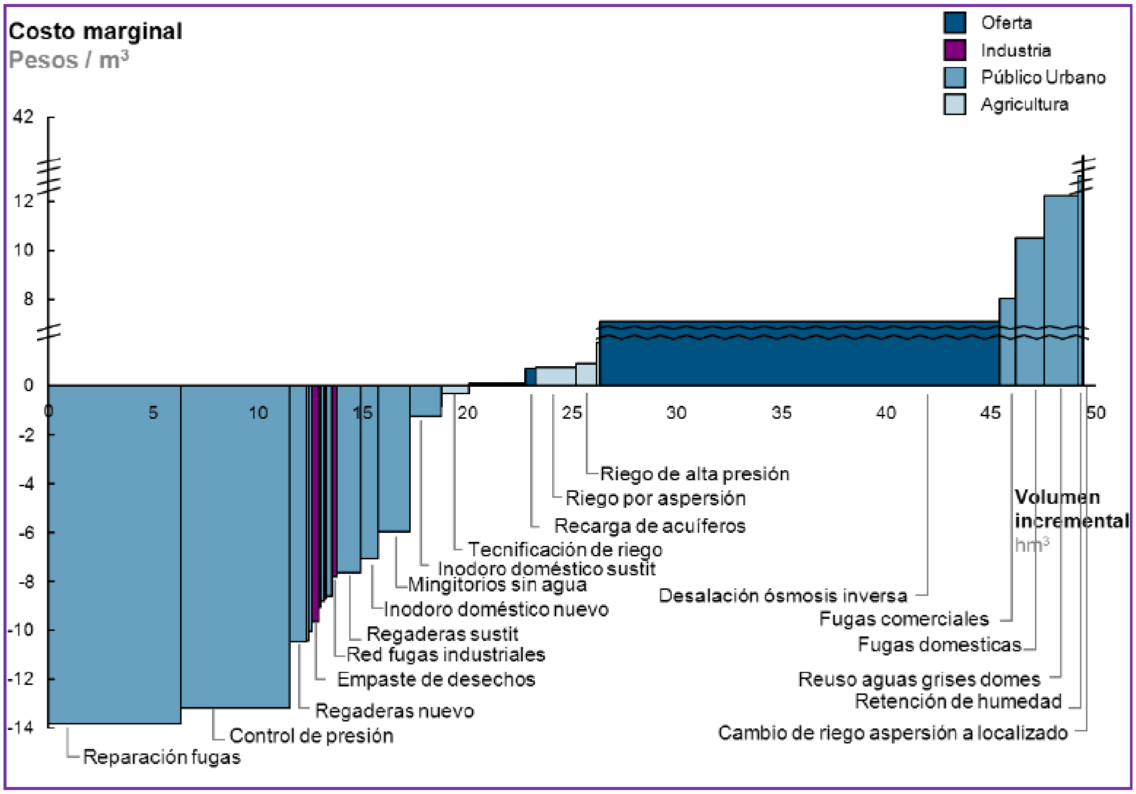

Figure 9. Solutions for addressing the water deficit in BCS by 2030 (Conagua 2012b, p. 21)

In La Paz, the BCS planning document projects a water deficit of 15 hm^3 in La Paz by 2030. Desalination alone is expected to cover 44 percent of this projected deficit (Table 3) (Conagua, 2012b: 25-26).

Measure	**Quantity**	**Unit**	**Contribution to deficit (hm^3)**
Irrigation modernization (parcel)	159	ha	1.10
High precision irrigation	189	ha	0.20
Sprinkler irrigation	347	ha	0.90
Replacing domestic toilets	100,759	person	0.80
Replacing commercial toilets	33,541	person	0.10

New domestic toilets	9,015	person	0.10
New commercial toilets	5,748	person	0.02
Replacing showerheads	78,368	person	0.60
New showerheads	13,431	person	0.10
New low-flow faucets	13,431	person	0.02
Dry urinals (commercial buildings)	2,623	urinal	0.50
Pressure control and sectorization	31,374	connection	1.80
Repairing leaks in the distribution network	1,764	leak	2.10
Repairing domestic leaks	131,141	leak	0.50
Repairing commercial leaks	131,141	leak	0.30
Reusing domestic gray water	65,570	person	0.58
Using reclaimed water to irrigate parks	0.77	ha	0.03
Industrial leaks			0.10
Industrial waste filling			0.10
Water used in industry			0.10
Aquifer recharge			0.20
Desalination plants	2	plants	7.80

Table 3. Measures for covering the water deficit in La Paz, BCS (Conagua, 2012b: 26)
*ha = hectare

The BCS state plan also emphasizes the need for water efficiency, including agricultural modernization, water-efficient appliances in both industrial and commercial settings, and repairing leaks and improving infrastructure. The plan also considers an expanded role for treated wastewater reuse. These efficiency and reuse actions are expected to contribute an additional 42 percent of the water needed to overcome the La Paz's projected water deficit by 2030 (Table 3). Together, desalination, efficiency, and water reuse measures will account for 86% of the expected water deficit by 2030. Similarly, in Los Cabos, expanded desalination is expected to make up 54 percent of the projected 34 hm^3 water deficit by 2030, with other measures making up an additional 37 percent of the deficit (Conagua, 2012b: 28). In sum, there is a disconnect between the discourse of desalination as outlined in the national-level 2030 Water Agenda and the BCS state-level 2030 Water Agenda planning documents.

It is clear that there is a disconnect between the federal and state level policies regarding desalination. However, it is difficult to determine where the core support for desalination as a water augmentation strategy in BCS is coming from. It is possible that core support comes from within Conagua, in a top-down fashion, and in direct contradiction to the broader vision promoted through the national-level *2030 Water Agenda* of achieving balanced water supply and demand through agricultural and system efficiencies. Alternatively, it is possible that core support for desalination emanates from within the regional Conagua office, which suggests that within the same federal organization, there are disparate regional approaches for achieving balanced water supply. There is the possibility that core support for desalination is coming from the local water utilities and local urban planning offices. It is possible that international funding institutions (e.g., World Bank) and/or water policy think tanks are providing the primary impetus for water augmentation via desalination. Also, private firms that specialize in desalination technology may be influential in promoting this technological transition. The evidence gathered through interviews with stakeholders at the federal, regional, state, and local level do not convincingly indicate that the core support for desalination technology is coming from one particular scale of political power. Presented below are excerpts from interviews I conducted with federal, state, and municipal water managers, as well as quotes found in secondary sources (i.e., news reports and government reports) on the role that desalination should play in meeting future water demands in BCS.

The transcript from a local news report on “*Desaladoras en Debate*” (“Desalination Plants in Debate”) captures the differences in concerns and priorities associated with desalination from the perspective of the state Conagua director and the former director of the local water utility in La Paz (SAPA) under the previous administration (2007-2011). The statement by the state's Conagua representative suggests that he not only supports desalination, but sees it as an immediate need to meet growing water demands. He stated, "We have not been able to satisfy this volume of growth, including additional immigration from other states, therefore, this volume must be complemented with desalination" (qtd. in Cuevas, n.d.).

This strong preference for the desalination option is met with reserve from the perspective of the former director of the La Paz SAPA who expresses concern about the high cost of the technology. He stated, "It's a process, which to-date is very expense – it's more than $1 dollar [presumably the unit of reference is $1USD/m^3]. It's not an appropriate water source to incorporate in the urban zone. Who will absorb this cost? This is what I would like to know. I don't think anyone is going to subsidize it" (qtd. in Cuevas, n.d.).

In an interview with the a key administrator in the La Paz SAPA under the current municipal administration (2011-2015), there appears to be a greater interest in desalination, but also an emphasis on the need to implement other water management actions:

> We have so much seawater here, so desalination plants are a valid resource for solving the water supply problem. But I think that we have not done everything that we could do before we reach this point. There are many things we have not done due to lack of resources, or perhaps because of a lack of vision – and we can still do it. We still have time to turn to these alternatives before running to desalination in a massive way. – key administrator, La Paz SAPA (personal interview, Feb. 1, 2012).

This key administrator also expressed concern about the cost of the technology:

> It's no secret. We all know that what you are charged for water does not reflect the real cost. Water is subsidized by the government – and even so, there are people that complain that it's too expensive. So imagine if you have to provide them with desalinated water. Well, there's no money to cover that! – key administrator, La Paz SAPA (personal interview, Feb. 1, 2012).

An email correspondence with a water manager in the Purification and Treatment Department of the federal Conagua office (based in Mexico City) suggests that political disagreements and lack of resources are the greatest barriers to implementing desalination in La Paz. Due to previous fiscal mismanagement and failure to pay Conagua for its water concessions, the La Paz SAPA has accrued a debt of over $23 million pesos (nearly $2 million USD) to the federal water authority. This has limited the federal government's fiscal support for investments in water infrastructure in La Paz (Rubio, 2012). As the Conagua representative explained, "In La Paz, the principle problem, from my point of view, is political. Secondly, it's the lack of resources. La Paz requires water for its population and it's been growing touristically, even with a lack of services, including water supply" (email correspondence, Feb. 23, 2012). When asked to expand upon the political aspects of this problem, he commented:

> The municipal president of La Paz from the previous administration solicited help to build a desalination plant. The former municipal president had a meeting with the governor and with the four mayors of the state. The outcome was that a study was conducted…but La Paz has not paid for its water use rights and for the discharge of residual waters – which has limited the financial support from the Federal government. Furthermore, the municipal president, in agreement with her advisors, decided to take on other development plans, and left the desalination plant aside. The new authorities have not said anything definitive with respect [to the desalination plant] – not the new governor, nor the new municipal

> president. – Conagua water manager (email correspondence, Feb. 27, 2012).

When asked what the relationship is between Conagua and the local water utility in planning for a desalination plant is the Conagua official responded:

> Conagua has offices in each state. Each year, there is a reunion with the State Water Commission (*Comisión Estatal del Agua*, or CEA) and they agree on the projects to carry out. Previously, the directors of the State Commissions got together with the local water utility operators to define the most important actions of the year. They review the actions and programs, and according to the budget, they set priorities. In the case of desalination plants, it's the State government, through the State Commissions, that carry out the competitive bidding process for the projects. – Conagua water manager (email correspondence, Feb. 23, 2012).

When asked what the role of Conagua is in planning and implementing desalination projects at the municipal level, the Conagua official highlighted the federal government's role in financing municipal-scale desalination projects. He stated:

> Conagua has different programs that support the construction of infrastructure for municipalities and states. These programs fall into two categories: 1) where there is private sector participation (i.e., *Programa Fondo Nacional de Infraestructura*, or FONADIN) and 2) where the resources are federal, state, and municipal (i.e., *Programa de agua potable y alcantarillado en zonas urbanas*, or APAZU). The desalination plants fall under the first category of FONADIN with the participation of the private sector, as was done in the case of Los Cabos, BCS. – Conagua water manager (email correspondence, Feb. 23, 2012).

Within the State Water Commission (CEA), there is a special department dedicated to desalination. The director of this department strongly supports further investment in desalination technology, stating, "We believe that it is necessary to cover all of Baja California Sur with desalination plants…for us, the future of potable water is desalination" (personal interview, Feb. 9, 2012).

In the case of the Los Cabos desalination plant, which was built in 2006 for municipal supply, it appears that there was a high level of local interest. I was unable to conduct interviews with the director of the local water utility (OOMSAPASLC), the mayor, or the governor who were involved in the original planning process. But I did conduct an interview with a key informant who acted as a local political leader and served as a city councilman. He also had a position within OOMSAPASLC as an advisor, and thus had been involved with some of the discussion surrounding the decision to pursue desalination as a water augmentation strategy for Los Cabos. He recounted how the decision was made, as follows:

> In 1999, the Workers' Party (Partido del Trabajo, PT) gained political control here [in Los Cabos]. In the first few months they provided benefits for 10,000 families in the working class communities. They started out by providing electricity for Cangrejos [the largest working class neighborhood in Cabo San Lucas]...After that, they solicited potable water. But Cabo San Lucas only received 80 lps for the *colonias populares* (working class neighborhoods) -- and this had to be on a *tandeo* (water sharing) -- one day with water and three days without. So we understood that there was not enough water for Cangrejos… there was a 'boom' in Los Cabos – so there was a need for more water... In the government of Narcisco Agúndez Montaño, with the PT, I was an advisor for potable water in the municipality. And so we proposed the creation of a desalination plant, initially with one private company. [The company] had their proposals for a project – mainly to address the growth, or 'boom' that was happening in Cangrejos. But the project was going to be very expensive with this company. [The company] wanted a contract for 70 years and they were going to charge in U.S. dollars for their service. We thought this would leave a very bad legacy. So we looked for other companies in Europe and Israel. We visited businesses in the U.S. This gave us more ideas and more clear ideas about the economics of the project. And also, it gave us the idea that the local water utility should not operate the same desalination plant. That it should be a private company for 20-30 years (personal communication, 2012).

When asked about how they received information about desalination and who was part of the network he responded:

> Honestly, we thought about the project without really without knowing what was good or bad, but [desalination] was the only *salida* – the only way out. The groundwater was not sufficient. So then we started investigating. And the interest grew from foreign companies…Principally, the proposal that we developed in the administration of Narcisco Agúndez was for modules of 100 lps each. But there was a company that proposed up to 200 lps – and that would totally supply Cabo San Lucas, the hotel zone and everyone with water 24 hours a day (personal communication, 2012).

An interesting aspect of this interview is that the respondent, who was a political leader at the local level, takes pride in claiming that he, along with other members of the local municipal administration, developed the original idea for a municipal-scale desalination plant in Los Cabos. Narcisco Agúndez Montaño, who was mayor (with the PT party) at the time the desalination plant was being designed, went on to become governor of the state of BCS with the Democratic Revolution (PRD) party. Narcisco's gubernatorial term followed the term of his cousin Leonel Cota Montaño. Narcisco's brother, Antonio Agúndez Montaño, was the director of the local water utility while Narcicso was mayor; Antonio went on to become the next mayor of Los Cabos. After his term as governor, Narcisco became the center of a political scandal and was detained and charged with embezzlement and fraudulent sale of public property at well below market rate for personal benefit (de Giusttav, 2011; Porfirio, 2012).

This vignette highlights the complexity of multi-scale governance and the links between land and water development and shows the difficulty in identifying the motivating factors and core supporters for the adoption of desalination technology. This vignette also highlights the role that the larger political economy plays in shaping water demands. The primary development strategy for Los Cabos, and increasingly for La Paz, is based on tourism (Borja Santibáñex, Cruz Chávez, Juárez Mancilla, and Rodríguez Villalobos, 2006). Los Cabos is part of the federal government's National Tourist Development Fund (FONATUR), which is a regional development strategy to create economic centers that attract businesses, industry and foreign investment (Borja Santibáñex, Cruz Chávez, Juárez Mancilla, and Rodríguez Villalobos, 2006). It is responsible for fomenting the development of major tourist destinations in Mexico. Growth in the tourist industry increases the demand for water, directly (i.e., for hotel rooms, golf courses, green areas, and swimming pools) and indirectly (i.e., by attracting labor immigrants to the region. The conservative estimate by the Secretary of Tourism (SECTUR) is that each hotel room generates four jobs. Using this information, a planning document for La Paz estimates that each economically active resident has six family members who don't receive a salary, which means an expected growth in population of 10 residents per hotel room built (Multicriteria S.C., n.d.: 6). A planning document for Los Cabos estimates that each new hotel room will bring 18 to 25 new residents (Plan Director de Los Cabos, 1999). This means a significant burden is placed on the local water utility to provide water to meet increasing demands from industry and residents (see also Pombo, Breceda, and Valdez, 2008). The emphasis on regional growth through tourism in BCS continues to be promoted by federal, state, and local governments. While much of the existing tourism infrastructure and demand in Los Cabos is from four- and five-star hotels (H. XI Ayuntamiento de Los Cabos, 2011), the trend in regional development is in real estate development for villas, condominiums and residential homes (Guido et al, 2005).

Furthermore, this vignette suggests that private desalination companies also play a role in promoting the technology. This assertion is further supported by evidence from a desalination project in Puerto Peñasco, Sonora, Mexico, located on the northeastern shore of the Gulf of California. The *municipio* of Puerto Peñasco petitioned the U.S. Trade and Development Agency (USTDA) to award a grant to a U.S. engineering and consulting agency to conduct a feasibility study for a seawater desalination facility in the region (Wilder et al, 2012a). The USTDA is an agency that "advances economic development and U.S. commercial interests in developing and middle income countries" (USTDA, 2008: 1). Specifically, the agency works with certain countries to enhance the U.S.'s trade and development goals. The USTDA agreed to provide $369,325 in grant monies to fund the feasibility study because the agency had determined that a desalination project in Puerto Peñasco represents "a potentially significant commercial transaction in terms of capital investment and the long-term export potential needed for its expansion. Additionally, there is a recurrent revenue element due to membrane replacement and maintenance activities" (USTDA, 2008: 30). The USTDA (2008) estimates that the total cost of the project would be at least $35 million (USD). Of this, it is estimated that the U.S. could export $15 million to $20 million worth of engineering services for the desalination system design and technology. USTDA (2008) estimates that of the $35 million (USD) for the total project, technology investment would account for about $17.5 million and consulting services would account for $3 million. This represents a substantial trading and export opportunity for American engineering firms and U.S. manufacturers of desalination technology and materials companies. Furthermore, the facility would require frequent replacement of the membranes used in the reverse osmosis process. This recurrent expenditure could be up to $1 million per year. Given that a number of international companies already have a strong presence in the water provision market in Mexico, the USTDA hopes that by funding the feasibility study, the competitiveness of U.S. companies will be enhanced during the competitive bidding process.

In sum, it is difficult to determine where the core support for desalination as the principal means for achieving water balance by 2030 is coming from. As these interview excerpts demonstrate, no clear core source of support was acknowledged by anyone interviewed. Gaining a glimpse into the behind-the-scenes decision-making process was not easy to obtain. While a former advisor to the Los Cabos OOMSAPASLC seemed to take pride in the local government's role in establishing the Los Cabos Desalination Plant, there appears to be more resistance to municipal-scale desalination within the La Paz SAPA, primarily due to concerns about cost, as well as the need to address other water management measures. At the federal level, Conagua provides financial support, and the regional Conagua office has been instrumental in the development of the BCS planning documents for *2030 Water Agenda* that promote desalination as the principal means for addressing the water supply gap. The state water agency (CEA) also supports desalination and has a department dedicated to the development of this technology. The role of international finance capital is also clearly important.

In conclusion, echoing Wilder's (2008a) assertion, my analysis of the discourse and practice of desalination at the national and state level highlights the fragmentation of national versus regional water policy priorities in BCS. However, as the analysis shows, it is difficult to determine where the core support for desalination as the principal means for achieving a balanced water supply in BCS is coming from.

Desalination and Decentralization

My analysis of desalination and decentralization examines the degree to which the adoption of desalination technology in Mexico achieves the aims of decentralization (i.e., transference of power from a centralized government to local actors). Following Ribot and Larsen (2004), I understand successful decentralization to encompass political and democratic transformations, as opposed to simply administrative restructuring or deconcentration. Therefore, I operationalize the concept of power by assessing the degree to which 1) the local population is involved in and represented by the decision-making process for adopting desalination (or not) 2) the degree to which local administrative units are able to act autonomously and make meaningful decisions (e.g., the ability to plan for and implement water augmentation strategies on a regional basis and the ability to implement regulations for desalination facilities) and 3) the degree to which local administrative units are able to mobilize the necessary financial resources for desalination.

Using Spain as case study, Swyngedouw (2013) shows how early water infrastructure development (1939-1975) relied on interbasin water transfers that were "...part of an imaginary link to authoritarian, top-down, and bureaucratic politics" (p.

263). Beginning in 2004, Spain embarked on a new water policy that replaces controversial interbasin transfers with localized desalination plants (Downward and Taylor, 2007). In contrast to the top-down water transfers, Swyngedouw (2013) argues, "…desalination was staged as local, democratic, decentralized, market efficient, and ecologically sustainable" (p. 263). While he challenges the notion of desalination as an ecologically sustainable water augmentation strategy, he notes that desalination is "celebrated as permitting a greater autonomy for the regions of the Levant and guaranteeing their regional economic and cultural independence" (p. 268). His analysis concludes that, "These desalination projects mark the transition from a hydro-structural…to a decentralized, but still decidedly state-led, market environmentalist water framework" (p. 262).

While the regional tensions may not be quite as intense in BCS as they are in Spain, desalination does offer a localized solution to local water demands, thus avoiding more contentious rural-urban or interbasin water transfers. Furthermore, it provides a new source of water to support increased regional development. In the case of Los Cabos, the municipal-scale desalination plant was essential in providing water to the residents who work in the growing tourist industry (McEvoy, forthcoming). Additionally, the use of small-scale, private desalination plants by hotels and developers provides a way to overcome the limited water availability (Pombo, Breceda, and Aragón, 2008).

Furthermore, while the desalination process in Los Cabos is carried out by a private company, the distribution of the desalinated water remains under the control of the local water utility. Thus, it does represent a form of decentralized water management.

Yet, much like the case of Spain, it remains a state-financed and hence federally led action. The Los Cabos Desalination Plant received 30 percent of its funding from the federal government. The remaining funds came from INIMA, a private Spanish firm that was awarded the contract via a competitive bidding process. Private sector participation in various infrastructure projects, including desalination is promoted through federal level programs and policies (i.e., FONADIN/PROMAGUA).

The degree to which desalination is permitted and regulated in Mexico is fairly limited. The permitting and regulation that does occur is primarily through federal-level institutions. In Mexico, water is legally deemed to be the "original" property of the Nation (Article 27 of National Constitution). Its use and exploitation is governed by the Mexican President and more directly by Conagua. This legal claim also applies "territorial" seawater within a 12 nautical mile zone from the Mexican coast. Desalination was first mentioned in Mexican law when NWL was modified in 2004 (Wilder et al, 2012b). This law establishes that the extraction of seawater does not require a concession, "except when it is for the purpose of desalination" (NWL, Art. 17, reformed in 2004). Conagua is the only institution that is allowed to authorize concessions for the extraction of seawater or brackish groundwater for desalination. Concessions may be granted for a minimum of five years and a maximum of thirty years (Art. 24) (Wilder et al, 2012b).

In addition to a concession for seawater extraction, a concession for disposing of the brine discharge is also required. This permitting process takes place through the federal Environmental Ministry (SEMARNAT).[9] SEMARNAT is responsible for monitoring the operation of desalination facilities and the wastewater disposal. Prior to the granting of the discharge permit, an Environmental Impact Assessment (EIA) or *Manifestaciones del Impacto Ambiental (MIA)* must be approved by SEMARNAT (Wilder et al, 2012b). Currently, there is no law governing brine discharge; however the EIA outlines how the discharge will be managed.

Given the increased investments in desalination in Mexico, there is increased interest in developing more formal regulations. SEMARNAT and Conagua are in the process of establishing a new regulation that would set a limit on discharge concentrations. Mexico's National Council on Science and Technology (CONACYT) awarded a grant to a researcher at the Instituto Tecnológico de Sonora to develop a new federal law for desalination. This will primarily be a "technical law" that sets the concentration limits for the discharge water, as well as provides technical guidelines on where to locate the intake pipes (personal communication, January 2012). This provides no regulation for the broader environmental, social, and economic impacts. It does not consider, for example, how increased water availability through desalination might induce urban growth or account for increased energy consumption and carbon emissions.

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[9] In addition to the federal permits required from Conagua and SEMARNAT, the Federal Electricity Commission (*Comisión Federal de Electricidad*, CFE) would have to agree to supply the power necessary for the plant. This is a national monopoly and is, by law, the only power supplier. Also, a land-use permit must also be obtained for the siting of a desalination facility. This approval may occur at the local, state or federal level, depending upon who owns the land (Wilder et al, 2012b).

It also fails to address social aspects of the technological adoption, such as how the costs and benefits of the technology might be equitably distributed within society.

While the regulation of desalination occurs primarily at the federal level, it is important to note that BCS is the first state to address desalination in a state water law (Pombo, Breceda, and Aragón, 2008). The state law allows the state water commission and the local government to establish regulations for the construction, operation, administration, and maintenance of desalination systems; resolve issues related to desalination; and determine the average rate of potable water supply services and desalination (H. Congreso del Estado de Baja California Sur, 2001).

In sum, this analysis of decentralization shows that while the adoption of desalination technology offers a localized solution to local water scarcity, it does not necessarily achieve the aims of decentralization (i.e., transference of power from a centralized government to local actors). The financing and regulation of desalination remains largely in the hands of federal-level institutions. While some of the permitting processes may occur through the state office of the Conagua, this is more a model of deconcentration, than decentralization.

Given that increased involvement and representation of the local population in the decision-making process is one of the key aspects of successful decentralization, I examine this issue in detail (see section on public sector participation). The apparent lack of public participation in the case of planning for desalination in La Paz raises additional questions about the degree to which this technology can be celebrated as a means for achieving decentralized water management.

Desalination and Private Sector Involvement

I now turn to an examination of private sector involvement in desalination in BCS. A public-private partnership (PPP) was used to finance, build, and operate Mexico's first-ever public desalination facility in Los Cabos, BCS in 2006. The public portion of the funding for this project came from the Modernization of Water Utilities Program (PROMAGUA). As a pre-condition to receiving the money, municipalities must facilitate private capital participation. While the World Bank initially provided initial funding for PROMAGUA, the Bank is no longer involved in this program (personal communication, 2013). The Los Cabos Desalination Plant did receive funding through PROMAGUA and is listed as an individual project on the Private Participation in Infrastructure Database, which compiles information on infrastructure projects in 139 low- and middle-income countries (PPI, 2013). However, the Los Cabos Desalination Plant was not a World Bank project and there are no records of the project in World Bank archives (personal communication, 2013).

Official information regarding the project was difficult to obtain. The local water utility directed me to its website, which has limited information (OOMSAPASLC, 2013). Official solicitations for the socioeconomic and environmental evaluations were petitioned from OOMSAPASLC, Conagua, CEA, and BANOBRAS, among others. After 14 months of attempting to obtain this information, I was provided access to a copy of the *Evaluación Socioeconómica* for the Los Cabos Desalination Plant from the Legal Liaison in the Office of Decentralization and Transparency and Access to Public Information, under the direction of CONAGUA (*Enlace de Asuntos Jurídicos, Gerencia de*

Descentralización y de Transparencia y Acceso a la Información Pública, Subdirección General Jurídica, Comisión Nacional del Agua) (Conagua, 2006).

This document estimates the total construction cost of the project to be $307,750,753 pesos (US$25.6 million) (Conagua, 2006: 31). INIMA, the Spanish-based desalination company that won the contract award partnered with Mexican-based associates to form Promoaqua Desalación de Los Cabos. The financing for the project is split between federal and private sources (Figure 10). Sixty-four percent of the funding comes from private resources (31% from credit and 33% from the Promoaqua consortium) (Conagua 2006, p. 31). The remaining 36% of the construction costs come from the federal resources (i.e., PROMAGUA via FINFRA, which is now FONADIN). This is considered a "*fondo perdido*" or "lost fund," meaning that it does not need to be repaid.

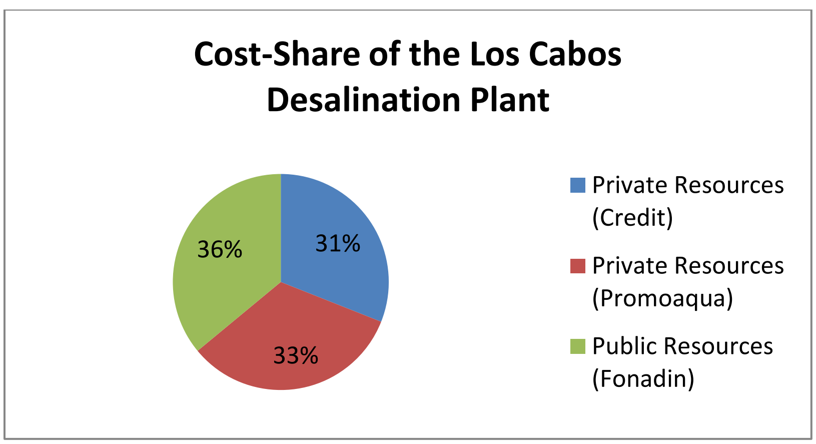

Figure 10. Cost-share for the Los Cabos Desalination Plant (data from Conagua, 2006: 31)

As per the contract, INIMA designed, built and will operate and maintain the Los Cabos Desalination plant for a period of 20 years (Conagua, 2006: 25-26; OOMSAPASLC, 2013) (Figure 11). Currently the plant produces 200 lps of water.

INIMA desalinates the water and pumps it to a holding tank. From there, the local water utility is in charge of distributing the desalinated water to the population (personal communication, 2010).

The local water utility (OOMSAPASLC) buys the water directly from INIMA at a set price. While official information was not made available, data from a local investigative reporter shows that the utility buys the water from INIMA at a rate of 12.50 pesos/m^3 (US\$1.04/m^3) (Gámez Vázquez, 2009). The utility then resells the water at a rate of \$3.3 pesos/m^3 (US\$0.28/m^3) to the public, which means that the desalinated water is subsidized at the rate of 9.2 pesos/m^3 (US\$0.77/m^3) (Gámez Vázquez, 2009). This analysis by Gámez Vázquez (2009) notes that the same year that the desalination plant began operation (2006), the municipality's fiscal surplus disappeared and the municipality registered its first deficit. This raises questions as to the long-term economic viability of desalination as a water augmentation option. Furthermore, it raises questions about the ability of other cities in BCS, and throughout Mexico, to provide subsidies to offset the high cost of this new technology. While the exact mechanism of the subsidy in Los Cabos was not explained by anyone within the utility, other government officials I spoke with assumed that a subsidy for the desalination plant primarily comes from the higher water rate tariffs that are charged to the industrial sector (which includes the hotel and tourism industries) (personal communications, 2012). While Los Cabos has a strong base in mass tourism, other cities, including La Paz, may find it more difficult to provide a subsidy for a similar infrastructure investment.

Figure 11. Photo showing the Los Cabos Desalination Plant with logos of the private firm, the local municipal government and the state government from a presentation by Los Cabos mayor (and former OOMSAPASLC director) Agúndez Montaño at the 2010 Border Governors Binational Desalination Conference (Agúndez Montaño, 2010).

Due to its innovative use of desalination technology and PPP structure, Los Cabos has been described as a "model for the rest of Mexico's tourism developments" (Pombo, Breceda, and Aragón, 2008: 209). According to the 2008 Portfolio of Projects (Conagua, 2008b), several other cities in Northwestern Mexico are likely to receive desalination projects following the PPP model. As indicated in this document a PPP desalination project in Ensenada, Baja California (BC) has been "authorized" (p. 6). This project is estimated to have total investment cost of $351.9 million pesos (US$29.33 million). Forty percent of the funding would come from federal unrecoverable resources and 60 percent would come from a private counterpart. Similar PPP desalination projects in La Paz, BCS; Loreto, BCS; Tijuana, BC (I and II), Puerto Peñasco, Sonora and Bahía de Kina, Son; and Guaymas, Son have all been listed as “susceptible,” meaning inclined or likely (p. 7). The new Public-Private Partnership Act, which was approved by the Mexican Congress in December 2011, is expected to further promote the involvement of the private sector in infrastructure projects (Franck et al, 2011; Mueller, 2010).

The literature on private sector involvement in water services provision raises the concern that private companies tend to “cherry pick” the most profitable projects (Bakker, 2010; Swyngedouw, 2005). This results in an inequitable “archipelago” of water networks within many cities, with networks rarely being extended into poorer and difficult to access neighborhoods (Bakker 2010: 22-23). The concept of “cherry-picking” is applicable to the case of desalination in BCS in that the recipients of the new source of water may be selected based on a perceived ability to pay for the service. For example, in La Paz, a proposed desalination project may be directed toward the benefit of the growing tourist sector, rather than the poorest neighborhoods in the city. As a key administrator of the water utility explained:

> Right now, we have a project in this municipal administration that is considering to obtain the economic resources necessary to install a desalination plant in the northern zone of the city…This would allow us to be able to offer to investors that are interested in development to go ahead and start with their developments in this entire zone near Coyote Beach. There are already important investors who have already invested a lot in basic infrastructure. So they are interested and willing to participate so that this project gets carried out, in order to solve the problem and have access to water to support their developments – key administrator, La Paz SAPA (personal communication, Feb 1, 2012).

But residents have expressed concern about the equity aspects of this approach. As part of the feasibility study for the desalination plant in La Paz (IIUNAM, 2010), public comments on the proposed desalination plant were solicited. As one resident opined, “It’s really unjust to provide water to some developments, when there are working class neighborhoods that lack it” (IIUNAM, 2010: 104). This report also summarized the opinions of a group of water experts and concluded, “The desalination plant is a last resort…if it is installed, it should only be used to avoid further groundwater extraction and maintain hydraulic balance. The plant should not be used to provide water to new developments, since we don’t even sufficient water for ourselves” (IIUNAM, 2010: 105).

In contrast, the municipal-scale desalination plant in Los Cabos was built to provide water specifically for working-class neighborhoods in Cabo San Lucas. Bakker (2010) argues that subsidies are inevitably necessary to achieve equitable access to water resources. She advocates for a new model of water governance that is more open to subsidies. However, as noted by Gámez Vázquez (2009), it is unclear if the subsidy model, as carried out in Los Cabos, is financially sustainable.

Given that privatization of public water services has been a controversial topic, especially in Latin America (Bakker, 2010; Barlow and Clarke, 2002; Goldman, 2007; Swyngedouw, 2005), I wanted to assess stakeholders’ perceptions of the PPP model in the provision of desalinated water in BCS. To this end, I conducted a survey and focus group discussion with 36 individuals. The survey questionnaire explained the PPP structure of the Los Cabos desalination plant and asked: “What could be the benefits and/or problems of this model in La Paz? Respondents were able to list as many comments as they wanted.

There were 17 responses related to the potential benefits of a PPP model for desalination that fell into five different categories. Most notably, “better management and service” was mentioned nine times and “a more reliable, continuous source of water” was mentioned five times (Table 4). There were 56 comments that listed potential problems of a PPP model for desalination that fall into eight different categories. Most notably, there was concern about the “high cost” of the desalinated water (18 comments). There was also notable concern about “lack of law enforcement and corruption” (11 comments). This included references to concerns about whether the concession and contract would be respected, the custom of paternalism and elitism, problems between political parties, and simply corruption. There were also concerns about the “inequitable distribution of benefits” (7 comments), and the perception that “benefits would accrue to the private sector” (7 comments). Some respondents were concerned that because there was only one operator of the desalination plant, there would be “no competition and possibly inefficient service” (7 comments). There were four comments that addressed concerns about the “lack of regulation and environmental impacts” of such a project. Only one person made a specific comment expressing concern about the “privatization of water” under such a governance model (Table 5).

Potential Benefit of PPP for Desalination	**# of times this benefit was mentioned**
Better management and service	9
A reliable, continuous source of water	5
It works in Los Cabos	1
More rational water use due to higher price	1
Could work, but raises equity issues	1
Total # of comments on benefits of PPP for desalination	**17**

Table 4. Summary of potential benefits of PPP Model of Desalination in La Paz, BCS

Potential Problems and/or Concerns of PPP for Desalination	**# of times this problem/ concern was mentioned**
High financial costs	18
Not following laws/contract, Corruption, Politics	11
Inequitable distribution of benefits	7
Benefits accrue to private sector, It's a money-making business	7
No competition, Inefficient service	7
Lack regulation, Environmental impacts	4
Privatization of water	1
By the end of the contract, Municipality will have to re-invest in upkeep	1
Total # of comments on problems/concerns of PPP for desalination	**56**

Table 5. Summary of potential problem and/or concerns related to the PPP Model of Desalination in La Paz, BCS

In sum, given the relatively recent experience with this form of private sector financing and lack of transparency in financial data, it may be too early to determine whether this PPP model represents a viable option for financing desalination projects. This analysis raises questions as to whether the PPP model can provide infrastructure to benefit of the most marginalized citizens who may lack water access to the public network. The analysis also raises questions as to whether local municipalities will be able to provide the subsidies necessary for this model to work equitably. Additionally, the difficulty in obtaining public documents regarding the project raises questions as to the transparency and accountability of PPP projects. This issue is also addressed in the following section on public participation.

Desalination and Public Participation

While the PPP model is an example of an innovative partnership, the collaboration is limited to a narrow range of government and corporate individuals, not inclusive of the broader public. This PPP is limited to select governmental agencies, namely Conagua, the national fund for investment in infrastructure (FONADIN), the state water commission (CEA), the local water utility, and a private company. Aside from a legally required public comment period that is part of the Environmental Impact Assessment process (*Manifestación del Impacto Ambiental, or MIA*) (Uribe Malagamba, 2009), there is little evidence of public participation in the planning and management of the Los Cabos desalination plant.

As part of the state-level 2030 Water Agenda planning process, a series of public workshops were held in an effort to include public participation. However, the process has not been broadly participatory. For example, a representative of one of the principal local NGOs involved in water management in La Paz stated that, despite their efforts to be involved in the process, they were never informed of the public presentation of the final draft of the new state water plan. He felt they had been "*vetados*" or prohibited from participating in this process (personal communication, 2012). Another resident registered a comment in the UNAM (2010) study regarding the La Paz desalination project stating, "There is very little official information available; there has been no public involvement, nor involvement of experts from local institutions" (IIUNAM, 2010: 107).

Even when invited to participate in the meetings, it does not appear that diverse stakeholders' opinions were adequately considered or incorporated into the final documents. As recounted by one water expert who was invited to attend the participatory workshops, he felt that his perspective, and the perspective of others, was not reflected in the final documents and final statements that came out of the participatory process. When asked how participatory the process for the State Water Plan was, he said:

> They invite you to participate, to talk, to give your opinion and to sign an attendance list, so they can justify their actions. They can say, 'We held a workshop, we had the participation of academics, civil society, some functionaries, but in the end, they make the decision. And that's what makes me so upset. This just happened. We participated in workshops to propose projects related to the water problem, organized by the Federal Water Commission. Last year, there were various workshops, where we all participated. But it was clear that there were some projects that were given priority. The final project proposals gave more emphasis to the desalination plants. We agree, but not like that. They are proposing a desalination plant [that would produce] 600 liters per second (lps), three times bigger than the one in [Los Cabos]. That's not ok. So we participated, but they don't take us into account…After all the work we put it, we talked, we came to an agreement. But later, it turns out that the project proposals they sent in, were part [of what we had all talked about], but they gave greater importance to the desalination plants. It's easy to say [let's build] a desal plant of 800 lps…but what problems is it going to cause? *This* is what we discussed -- the problem of the brine discharge, the electricity consumption, the environmental impact, some social problems, the cost of the water. But *this*, *this* wasn't included. [We say], let's improve the wastewater treatment plant, or let's build another dam to capture rainwater, or let's put meters on all the houses and charge people for what they actually use, and let's improve the distribution network. We talked about a lot of things. Let's make sure that the mining companies that want to exploit gold are not allowed here, since this will negatively impact us. But no! So what's the point? We sit down and discuss and plan, but we know that in the end, one or two people will decide for everyone else. This is very bothersome…they put desalination plants as the priority. But we're not in agreement. It's a good option. But there are others. What sense does it make? Let's imagine they build a desal plant – wherever – besides the environmental or social problems, imagine they put the water in the distribution network that is old, deteriorating. There are a lot of

> leaks and water loss in the network, so it doesn't make sense…What happens is, it's a '*cadenita'*, a chain. If the federal government says, 'This year we're going to build desalination plants,' then everyone is in agreement. But it shouldn't be like that…So after a while, you get frustrated. It just wastes your time. And they use you. They say, 'The experts, the academics, they came to the workshop and they all agree with this. Look, here are their signatures on the attendance list.' So now, when I go, I'm not going to sign the attendance list. The last time I went, I didn't sign. But, in the end, whether I'm there or not, it's the same thing. But at least I'm paying attention to how things are done (personal communication, 2011).

In conclusion, while there is a performance of public participation (i.e., workshops to solicit input from stakeholders), the final documents and decisions do not always or adequately reflect the public's opinion. There is a veneer of public participation, but my research provides evidence that stakeholder concerns and priorities are not reflected in the final list of priorities for water management. This is what Wester, Merrey, and de Lange (2003) refer to as "token stakeholder participation", rather than "actual control over water management decision-making by water users and citizens" (p. 799).

Desalination and Environmental Sustainability

Desalination poses a disconcerting conundrum to the contemporary approach to water management and environmental governance. On one hand, desalination is framed as a "sustainable" or "green" technology (Lattemann, Kennedy, and Amy, 2010; Swyngedouw, 2013). Under the appropriate institutional and regulatory framework, augmenting water supply through desalination has the potential to redress the environmental impacts associated with the overpumping of aquifers and interbasin water transfers.[10]

On the other hand, desalination is not a benign technology. As a National Research Council (NRC) (2008) report of desalination technology concluded, there is a "limited amount of long-term research" and a "considerable amount of uncertainty" about the environmental impacts of desalination (p. 144). The limited research conducted on the impacts of seawater desalination has mainly focused on the direct environmental impact of the saltwater concentrate or brine discharge on marine ecosystems (NRC, 2008). Findings from existing studies are inconclusive, with some studies indicating minor to major impacts on marine ecosystems, while others found no significant impacts (NRC, 2008: 130). McEvoy and Wilder (2012) provide a critical risk assessment of desalination that considers a wider range of potential environmental impacts and vulnerabilities, including energy use and greenhouse gas emissions, discharge of brine and chemical pollutants, as well as shifting geopolitics and equity issues that may arise with the adoption of desalination technology. Swyngedouw (2013) also raises concerns about equity issues due to the high price of the technology and the "multiscalar financial flow and support mechanisms" that are necessary to support desalination (p. 268). The California Coastal Commission concluded in 2004 that "a desalination facility's most significant effect could be its potential for inducing growth" (qtd. in Cooley, Gleick, and

[10] Desalination is also promoted as a drought-proof water source that can buffer against uncertain water availability and climate change impacts on water resources. This is discussed at length in elsewhere (see McEvoy 2013a and McEvoy and Wilder 2010).

Wolff, 2006: 67). However, less research and policy attention has been given to this potential impact.

While desalination has the potential to reduce pressure on groundwater resources or eliminate the need for interbasin transfers, an appropriate and effective institutional and regulatory framework must be in place in order to realize this “green” potential. Cooley, Gleick, and Wolff (2006) note that it is necessary to have an “explicit mechanism” to ensure that desalted water will be used in wetter-than-normal years for environmental purposes (i.e., releasing water from dams). Otherwise, following Jevon’s paradox, it is likely that surplus water will aid further growth, rather than conservation (Alcott, 2005). Thus, the degree to which desalination will help achieve sustainable water management remains questionable. As Swyngedouw (2013) observes in the case of water management in Spain, desalination is “increasingly seen as a socionatural fix that permits a productivist water logic to remain the bedrock of Spain’s global eco-modernization projects so that ‘nothing really has to change’ (di Lampedusa 1960)” (p. 268). Swyngedouw (2013) describes desalination as a “scalar fix” – that can “allegedly contain conflict by including the sea as an integral component of national water management strategies” (p 262).

In this section, I analyze how the feasibility study for a desalination plant in La Paz addresses the potential environmental impacts of the project (IIUNAM, 2010). Given that aquifer recover is a central goal of the La Paz desalination proposal, I also examine the degree to which explicit mechanisms have been implemented to achieve these goals.

The primary environmental concern associated with desalination is the direct impact of the brine discharge on marine ecosystems (NRC, 2008). As noted, SEMARNAT and Conagua are in the process of establishing a new regulation that would set a limit on discharge concentrations. But this new regulation does not taken into account the broader potential impacts of desalination (i.e., growth inducement, chemical pollutants, increased energy consumption, or equity issues). While desalination projects are required to undergo an Environmental Impact Assessment (EIAs), lawyers with the Mexican Center for Environmental Law (CEMDA) have observed that the EIAs do not always adequately address the impacts of desalination technology (personal communication, 2011). In many cases, a large-scale urban or tourist development can submit an EIA for the development, in which a desalination facility is built to "offset" the negative impacts of the development on water supply. When worded as such, the construction of a desalination facility is considered to be a "solution" that "mitigates" the potential negative impacts of the development and there is little or no examination of the impacts of the desalination plant itself (personal communication, Dec. 13, 2011). In cases where just a desalination plant is proposed, then a more comprehensive examination of the impacts of the technology on the marine ecosystem, social and economic impacts are considered (IIUNAM, 2010).

It is beyond the scope of this research to assess the impact of the brine discharge on the marine ecosystem. Rather, the aim of this analysis is to understand how environmental impacts are being considered and evaluated in the planning process. To do this, I analyze the feasibility study for a proposed desalination facility in La Paz which considered three different site locations for a 200 lps plant (and the associated brine discharge pipe) and analyzed the socioeconomic and environmental impacts of each of the three scenarios (IIUNAM, 2010). Once a scenario is selected, an EIA will be conducted and approval solicited from SEMARNAT.

In considering the potential environmental impacts, it's important to recognize the richness of the marine ecosystem of the Gulf of California – the location for at least five proposed desalination facilities in Northwestern Mexico (Conagua, 2012a) (Figure 1). The Gulf has been described by legendary oceanographer Jacques Cousteau as the "aquarium of the world" (Kamp, 2005: 4; see also Wilder et al, 2012a). It boasts more than 2,000 marine species (Young 2001: 288). It contains 39 percent of the world's marine mammal, one-third of the world's cetacean species, and 891 species of fish (90 of which are endemic). The ecosystem supports 181 bird species and 695 vascular plant species (28 of which are endemic) (Kamp, 2005: 3). The Gulf is also home to a number of charismatic species, including the endangered vaquita (in the northern Gulf), the whale shark, sea turtles and gray whales (at the southern tip). As noted in the UNAM (2010) study, the marine ecosystem adjacent to the city of La Paz is important for both tourism and commercial fishing, including 216 species of mollusks that have commercial and historical value, as well as many endemic species (IIUNAM, 2010: 59-61).

The majority of the environmental analysis in the study (IIUNAM, 2010) focuses on the impact of seawater intake and brine discharge. The report states that the main environmental (and social problem) is the brine discharge. However, the report is optimistic that this problem can be mitigated with proper siting and plant design, which should include diffusors (i.e., small fan-like mechanisms on the end each discharge outlet that helps to disperse the saline concentrate) and dilution (i.e., pre-mixing the concentrated brine with less saline seawater to reduce the salinity level of the discharge prior to dispersal) (p. 397).

The report reviews studies on the impact of brine discharge worldwide and concludes that, if the appropriate location is selected and the implementation and operation of the plant follow appropriate technical measures to control and mitigate environmental problems, there is little significant environmental impact (p. 7).

The UNAM (2010) study considers discharge regulations in other countries, as a guideline for establishing discharge concentrations for La Paz, BCS. It notes that the mostly widely accepted discharge standard is that of the U.S. Environmental Protection Agency (EPA), which recommends that the natural level of salinity should not increase by more than 4,000 parts per million (ppm) (p. 400). However, this is significantly higher than standards in Spain (which limits salinity increases to 2,000 ppm), Australia (1,500 ppm) or Japan (3,000 ppm) (p. 401).

The study analyzes two possible discharge locations: 1) the Ensenada de La Paz and 2) La Bahía de La Paz (Figure 13). These locations have natural salinity levels of 38,000 ppm and 36,000 ppm, respectively. The models for this study were designed to limit the concentration to 40,000 ppm to avoid negative environmental impacts[11] (p. 404).

[11] The study concluded the brine discharge poses the greatest to the benthic marine organisms and marine vegetation. While the model that this study was based on did not have a complete list of marine organisms that can be found in area, the study lists 40 of the most important marine species that could be impacted (p. 404). However, the maximum limit of salinity tolerance for 27 of the 40 was unknown. Twelve of 40 listed

Because the Ensenada is a closed bay with shallow water and very little ocean circulation, this location was determined to be more "conflictive" because it is a natural protected area where various social and economic activities occur (p. 431).

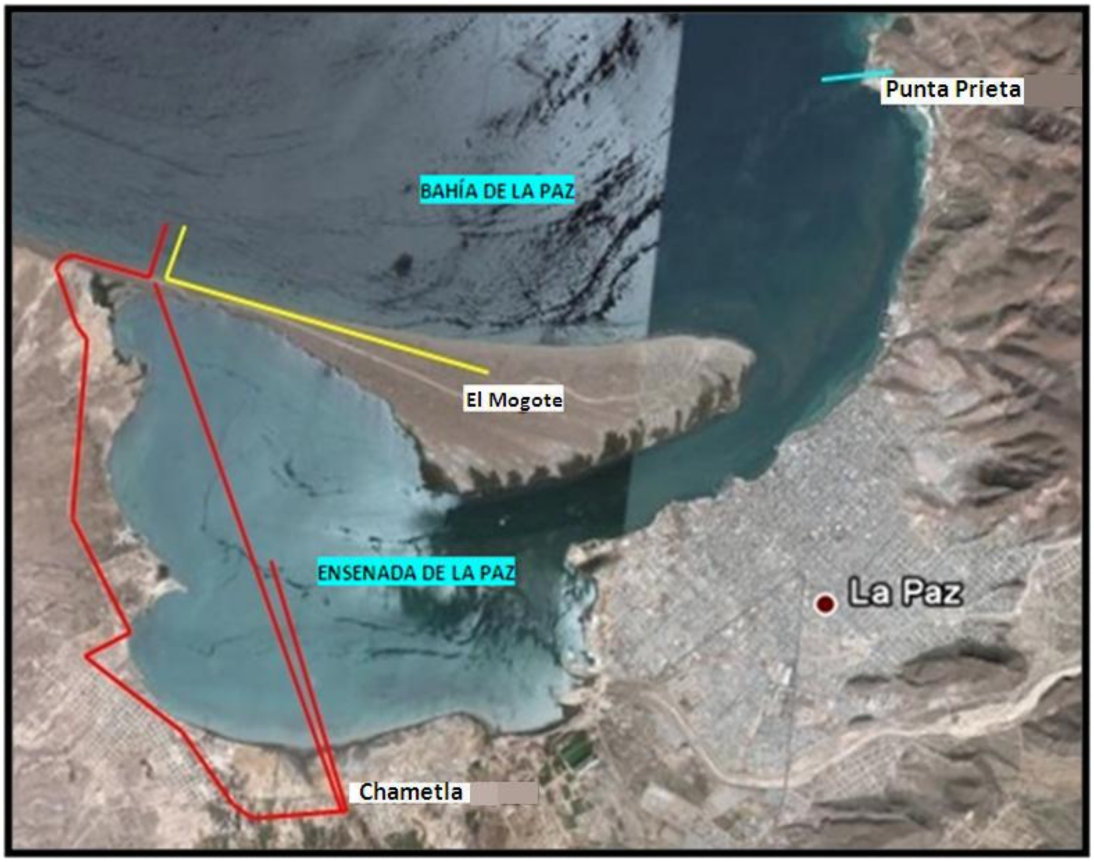

Figure 13. Map showing three possible locations for siting the plant (Punta Prieta, El Mogote and Chametla) and two possible locations for discharge of brine concentrate from the plant (Bahía de La Paz and Ensenada de La Paz). Red line indicates two possible routes for discharge pipes from Chametla. Yellow line indicates discharge pipes from El Mogote. Blue line indicates discharge pipe from Punta Prieta (IIUNAM, 2010: 406).

The environmental impact assessment of brine discharge concludes that the installation of diffusers would improve the mixing process. Also diluting the discharge water (i.e., mixing it with seawater with regular saline concentrations) will keep the

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species have been shown to tolerate salinity levels of 40,000 ppm or greater. One species showed a maximum salinity tolerance of 38,0000 ppm. So the model was designed to limit the concentration of ppm to 40,000 ppm to avoid negative impacts.

discharge within the limits established by the U.S. E.P.A., and mitigate the negative impacts on marine biota in the area of discharge (p. 431).

The introduction to the report purports to consider a wide range of impacts, including abiotic, biotic, and socioeconomic elements of the land and marine components, including the impact on the aquifer (p. 7). There is recognition of the threat of urban growth, the growth of tourist developments and demographic growth (p. 26). The study notes that, because BCS has more than 3,000 species of flora, 20 percent of which are endemic (and of the cactus, 70 percent are endemic), the viable sites for locating a desalination project should be carefully evaluated "in order to not run into environmental controversies or confrontations with civil society, given the important of this vegetation and it's correlation with the presence of emblematic fauna species of the region" (p. 26). Beyond this mention, however, there is limited discussion of these broader environmental impacts and there is no analysis of how additional water availability could affect urban development. The study mentions the energy demands of desalination, but only in terms of how it relates to operation costs. There is no mention of the environmental impacts associated with the increased energy demands. The final models and conclusions do not incorporate these broader concerns. In sum, while the feasibility study provides analysis of the potential impact of the brine discharge on the marine ecosystem, it does not address environmental sustainability more broadly.

The second part of the analysis of the environmental sustainability of desalination is to consider the way(s) in which, under certain institutional arrangements, the technology could reduce the pressure on groundwater aquifers. As stated in the study report (IIUNAM, 2010), aquifer recovery is a central goal of the desalination initiative in La Paz. On the opening page, the report states:

> There are diverse desalination schemes that have been successfully implemented in coastal zones with water supply problems, similar to the case of La Paz, BCS. But these schemes must be analyzed in conjunction with the dynamic behavior of the aquifer in order to *find a suitable alternative that allows for the correction of this problem [of overexploitation and saline intrusion] and achieve not only the necessary water supply, but also the recovery of the aquifer*, at least in the areas where saline intrusion and depletion of the water table, caused by excessive pumping, have significantly impacted the groundwater (IIUNAM 2010: 1, emphasis added).

The document goes on to state:

> The National Water Commission (Conagua) considers the installation of a reverse osmosis seawater desalination plant of 200 lps (6.3Mm3/year), as a vanguard technological option that would satisfy the excessive short-term water demands for potable water for the population; it would also contribute to the control of the overexploitation and accelerated depletion of the aquifer and saline intrusion (IIUNAM, 2010: 7).

While aquifer recovery is a central goal associated with the adoption of desalination technology, an “explicit mechanism” is needed to ensure environmental benefits of desalination (Cooley, Gleick, and Wolff, 2006). In order to achieve the potential environmental benefits of desalination (e.g., aquifer recovery or water for environmental needs), new rules and regulations regarding the use and management of aquifers would need to be implemented. Given the growth-inducement potential of desalination, integrated land-use and water policies would also need to be adopted. Otherwise, following Jevon’s paradox, it is likely that surplus water will promote further growth, rather than resource conservation.

In BCS, there has been surprisingly little institutional development associated with desalination technology. As discussed above, the only federal-level laws regulating desalination are the requirements for an Environmental Impact Assessment (EIA) and permits for seawater extraction and brine water discharge (as per the EIA), along with the necessary land-use permits for facility siting and power supply from CFE. While BCS is the first state to address desalination in its State Water Law, there is no specific regulation that ensures aquifer recovery or integrated land-use and water planning.

Urban development in La Paz and Los Cabos is guided by master plans, known as a *Plan de Ordenamiento Ecológico Local* (POEL). The POEL is one institutional mechanism that could possibly serve as a mechanism through which integrated land-use and water planning could occur, although enforcement is difficult to ensure. Currently, according to the La Paz POEL, "In La Paz, freshwater is the limiting factor, therefore it is the quantity of groundwater of each unit of environmental management (*Unidad de Gestion Ambiental, UGA*) that determines the maximum population" (p. 3). In other words, the "carrying capacity" of each parcel is determined by the availability of potable water. As one stakeholder commented in the UNAM study, "The POEL insists that there should not be one more development, not one additional hotel room, until there is a new source of water" (IIUNAM, 2010: 109).

The UNAM study itself provides a strong critique on the lack of adequate zoning laws and enforcement, stating:

> The current situation [in La Paz] shows an aggravation of the availability and efficiency of water in the area, with respect to the 1970s in which the social, politic and economic development of the area began, which led to the accelerated urban and demographic growth that has occurred in the

> area since the 1990s, with a 380% increase in population and *anarchic expansion of the urban footprint*, principally in the southern zone of the city, an area of aquifer recharge. *The 1983 Plan de Desarrollo Urban has not been updated*[12]*, and this plan is not respected or followed because there is a lack of regulation in the land-use, which has allowed and encouraged irregular human settlements and tourist real estate development in federal coastal zones and natural protected areas* (IIUNAM, 2010: 22, emphasis added).

The 1995 Los Cabos POEL (which also has not been updated) encouraged new tourist developments to provide their own water supply through desalination (POEL 1995). The wording in the planning document specifies that new developments must also be able to provide water for the associated population growth. As the 1995 Los Cabos POEL reads:

> The planned tourist developments in [specified] units *must secure their own supply of water, as well as water for the population centers that they will generate*, without impairing the resource for other surrounding locations, preferably by the establishment of desalination plants or other technologies for water utilization (H. Ayuntamiento de Los Cabos, 1995: 17, criteria A1, emphasis added).

While there are now 22 private, small-scale desalination plants in Los Cabos (Pombo, Breceda, and Valdez Aragón, 2008), new tourist developments do not provide water for the growing resident population. This remains the task of the municipality. Furthermore, the 1995 master plan's recommendation for self-supply applies only to tourist developments, not to residential developments. Despite the limited water supply in both Los Cabos and La Paz, developers are still able to obtain the necessary permits to

[12] There has been an effort to update the POEL, but it was not approved by the previous municipal administration, and was currently undergoing review by the new administration (personal communication 2011).

build, highlighting a lack of coordination between the urban planning office and the water utility. As one stakeholder commented in the UNAM study:

> There are new *colonias* and settlements. They let them build – they do not require the developers to guarantee water availability for 20, 50 or 100 years. The only thing that matters is economics of it…But if we build a desalination plant, will there be a reduction extraction from the groundwater aquifers? No! With the new plant they will build two or three new developments…[A developer] comes with a housing project for 5,000 homes in El Centenario. [The government] only cares if they pay taxes. But what about the *colonias*, like Lázaro Cárdenas, that only receives water every four days, or once a week (IIUNAM 2010, p. 111-112)

To address the lack of coordination, Los Cabos established a Municipal Institute of Planning (IMPLAN), a public planning consultancy, in 2009. IMPLAN provides advice and coordination among various agencies, including the urban planning office and the water utility.[13] While it may be too soon to assess the effectiveness of this nascent institution, it appears to be a step in the right direction. Without such an institution, it is likely that, as Smith (2009) notes, desalination can allow arid regions to "have limitless development 'cake' and eat it too" (p. 77).

Another potential mechanism for ensuring aquifer recovery in BCS would be to improve the monitoring and enforcement of regulations regarding groundwater extraction. At present, the water networks in La Paz and Los Cabos lack full-metering, including both macro-meters at the extraction wells, as well as micro-meters at the level of the individual user (see McEvoy, forthcoming; Carrillo Guer, 2010; Valdez Aragón, 2006). This would allow the water utilities to better detect leaks, improve system

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[13] This new institution is also designed to compensate for the rotation of directors of key administrative offices when there are new municipal elections every three years This is discussed at length in McEvoy, forthcoming (see also Pineda Pablos and Briseño Ramírez, 2012).

efficiencies, and encourage conservation through education and the implementation of progressive tariffs. A program that provides full and accurate accounting of water withdrawal and delivery, as well as leak detection would be an important first-step in ensuring aquifer recovery.

Additionally, new rules for how groundwater can be used may need to be drafted. For example, in the southwestern United States, the Bureau of Reclamation threatened to withhold funding for the Central Arizona Project (CAP), if the state did not impose restrictions on groundwater use. This spurred Arizona to adopt its first groundwater code. While the ultimate effectiveness of regulatory efforts to restrain groundwater pumping is debatable (Hirt, Gustafson, and Larson, 2008), at least there was a recognition that if new groundwater regulations were not implemented, it was unlikely that the new water provided by the CAP would be used to address the existing groundwater depletion problem.

A fourth potential mechanism for ensuring that the adoption of desalination technology achieves additional environmental benefits would be the pre-conditioning of desalination adoption upon the successful implementation of a range of water conservation and system efficiency measures. For example, the 2030 Water Agenda planning document for BCS lists a range of water conservation measures that should be implemented, including the installation of water efficient showers, water faucets, toilets, and urinals (Conagua, 2012b) (see Table 3 above). More stringent codes for new buildings could require new homes, hotels, and industries to install efficient appliances. Rebate programs could be implemented to incentivize the replace of older infrastructure.

There is the potential for achieving both environmental and social equity goals by subsidizing efficient appliances for poorer households. As Bakker (2010) notes, this type of subsidy program would not only supply poorer households with the basic infrastructure they need, but would also reduce their water expenditure by increasing household water-use efficiency (p. 204).

However, even if municipalities were to adopt new rules and regulations regarding development planning and aquifer management, there remains the concern about the strength of these institutions to enforce such rules. This is particularly true in the context of developing countries, where weak institutions are even more susceptible to corruption, or simply lack the resources necessary for enforcement.

As part of the survey I conducted as part of the focus group, I asked respondents about their perception of their city's ability to enforce rules governing urban development. Survey results indicate that respondents have very little trust in the ability of the local government to effectively regulate urban growth. Respondents were asked whether they strongly agree, agree, disagree, strongly disagree or are neutral regarding the following statement: The government institutions that regulate urban growth are strong enough to deal with greater development pressure. Seventy-eight percent of the respondents either strongly disagreed or disagreed with this statement. Eleven percent were neutral and only six respondents agreed. Nobody strongly agreed with this statement and two respondents did not answer (Figure 12).

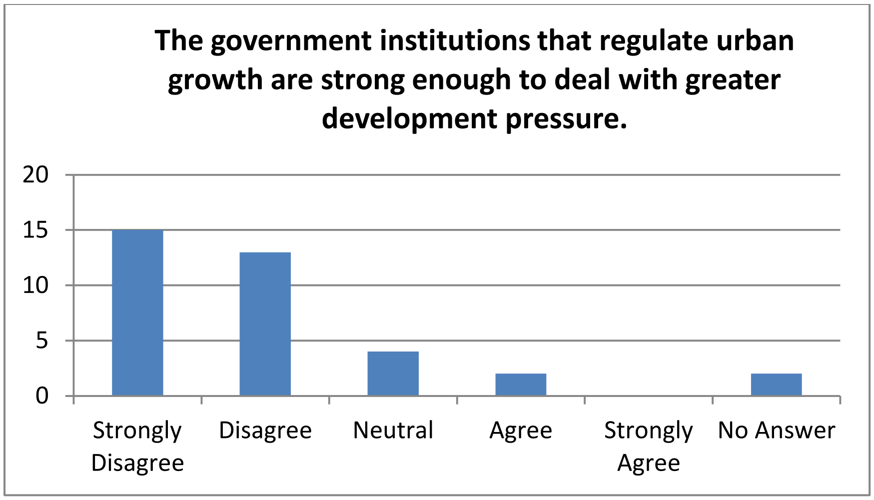

Figure 12. Graph of survey responses to question about trust in government institutions to regulate urban growth.

In sum, in exploring the contradictions of desalination as an environmentally sustainable water augmentation strategy, I conclude that the existing institutional arrangements are insufficient to achieve the purported environmental benefits of desalination technology. Despite the central goal of achieving aquifer recovery through the adoption of desalination technology, there is little evidence of the development of appropriate and sufficiently effective institutions that can provide an explicit mechanism by which the potential environmental benefits of desalination might be realized. Without such a mechanism, it is likely that desalination will, following Jevon's paradox, result in "business as usual" development in which increased water availability encourages additional growth, rather than resource conservation. This type of hard-path, technical solution creates a form of technological obduracy or path-dependency, making it more challenging to implement alternative water management solutions (Hughes, 1983; Gleick, 2003). Instead, continued efforts to strengthen institutional capacity within water management and urban development institutions, particularly at the local level, are necessary.

Conclusions and Discussion

This paper has argued that, while discursively, an emphasis is being placed on demand management and environmental sustainability as part of the contemporary water governance framework in Mexico, the preference for seawater desalination, as an innovative, supply-side water augmentation option is gaining traction among water managers, urban planners, and decision-makers, particularly in arid northwestern Mexico. Using two large-scale desalination projects in BCS as case studies, this paper examined how municipal water supply by desalination fits within Mexico's contemporary water governance framework. Specifically, the analysis assessed the degree to which the planning and implementation of desalination technology facilitates and/or deviates from the key environmental governance principles of implementing a comprehensive and coordinated policy framework, decentralization, private sector involvement, public participation, and environmental sustainability.

The findings of this analysis suggest that adoption of desalination technology in BCS facilitates some key policy principles, but also deviates from others in important ways. There is a clear disconnect between the discourse and practice of desalination at the national and state levels. In contrast to the national-level 2030 Water Agenda which places little emphasis desalination, the planning documents that are part of the state-level 2030 Water Agenda in BCS identify desalination as the principal means by which the cities of La Paz and Los Cabos will overcome the projected water deficit in 2030.

However, it was difficult to determine where the core support for desalination in BCS was coming from. Evidence gathered through interviews with stakeholders at federal, regional, state, and local levels illustrates the complexity of factors that influence water governance decisions. Furthermore, the scenario of desalination in Los Cabos highlights the role that the larger political economy plays in shaping regional water demands (e.g., there is a clear link between land and water development and private desalination firms are important actors in financing in desalination infrastructure). The analysis of the degree to which desalination is part of a comprehensive and coordinated water policy framework indicates that current water management in Mexico is fragmented. This case study provides a textured example of how and why achieving a coherent and unitarily decentralized national and regional water strategy is difficult.

The analysis of desalination and decentralization focused on the degree to which desalination facilitates (or constrains) the transfer of power from a centralized government to local actors in order to achieve more robust political and democratic transformations (as opposed to simply administrative restructuring or deconcentration). I conclude that, on one hand, desalination facilitates democratic decentralization by offering a local solution to water scarcity. This allows for increased regional development, while avoiding contentious rural-urban or interbasin water transfers. The local water utility is part of the public-private partnership and maintains control over the distribution of the desalinated water, representing a form of decentralized water management. However, the public portion of funding for desalination comes from federal sources and most of the permitting and regulation for desalination remains in the hands of federal-level institutions. This suggests that despite involvement of local actors, desalination remains a federally-led activity, which reinforces the state-led hydraulic paradigm.

The analysis of the private sector involvement in desalination concludes that the PPP model is an important source of funding for desalination. But, given the relatively recent experience with this form of private sector financing and the lack of transparency in financial data, it is difficult to determine if this PPP model represents a viable, long-term option for financing desalination projects. While the Los Cabos desalination plant provides water to residents of working-class *colonias*, the mechanism for subsidizing the cost of desalination through higher tariffs on the hotel industry may not be feasible in other cities. Furthermore, analysis of the planning process for a municipal-scale desalination plant in La Paz raises concerns about whether desalination technology will be used to meet the needs of the most marginalized residents, or whether it will further contribute to the 'archipelagic' nature of urban water infrastructure that primarily benefits the tourist sector and wealthier residents who are perceived to be able to pay the higher cost of desalinated water. Lastly, the difficulty in obtaining public documents regarding these desalination projects raises questions about the transparency and accountability of PPP projects.

Given that increased involvement and representation of the local population in the decision-making process is one of the key aspects of successful decentralization, the analysis of the level and quality of public participation in planning for desalination raises additional questions about the degree to which this technology can be celebrated as a means for achieving decentralized water management. The evidence from interviews with stakeholders and excerpts of community opinions from the feasibility study for the La Paz desalination projects indicate that stakeholder input has not been adequately incorporated into the evaluation and prioritization of water management alternatives. Rather, this appears to be a case of token participation and thus limits the degree to which democratic decentralization can take place. This finding contradicts the discourse that promotes public participation in water management as part of the new constitutional provision to water and sanitation as a human right.

The analysis concludes that desalination poses a disconcerting conundrum to the contemporary water governance framework in terms of the degree to which it can contribute to environmentally sustainable water management. While augmenting water supply through desalination has the potential to redress the negative environmental impacts associated with the overpumping of aquifers and interbasin water transfers, the analysis indicates that current institutional arrangements in Mexico are insufficient to achieve the purported environmental benefits of desalination technology. The only federal-level laws regulating desalination are the requirements for an Environmental Impact Assessment (EIA) and permits for seawater extraction and brine water discharge (as per the EIA), along with the necessary land-use permits for facility siting and power supply from CFE. A new federal regulation is being developed to regulate desalination. However, the new regulation focuses narrowly on limiting the brine discharge concentration and fails to address other potential environmental impacts associated with the technology. Similarly, the feasibility study for the La Paz desalination plant considers the potential impact of the brine discharge on the marine ecosystem; it does not address environmental sustainability more broadly. While an EIA is required for desalination projects, the Mexican Center for Environmental Law has observed that the EIAs do not adequately address the environmental impacts of desalination technology. As I have argued elsewhere (McEvoy and Wilder, 2012), new desalination projects may, in fact, contribute to socio-ecological vulnerability rather than reduce it, and thus desalination may be understood as a maladaptive strategy for addressing future water supply rather than an appropriate adaptation.

Lastly, the paper offers policy recommendations for the types of specific institutional mechanisms that may be necessary to ensure that desalination contributes to sustainable water management, including integrated land use and water planning, improved monitoring and regulation of groundwater extraction, and the pre-conditioning of desalination upon the successful implementation of a range of water conservation and system efficiency measures. Without such mechanisms, it is likely that desalination will result in "business as usual" development in which increased water availability encourages additional growth, rather than resource conservation and environmental sustainability. As I have argued previously (McEvoy, forthcoming; McEvoy and Wilder, 2012), there is a need to focus on institutional development and capacity building, especially within local water utilities and urban planning agencies. These recommendations are applicable to the management of desalination, and other supply-side water management strategies, particularly in developing countries.

In conclusion, Mexico is an example of a country grappling with modernization and seeking to grasp the mantle of sustainability in water management. While the discourse surrounding desalination offers promises of decentralized water management and environmental sustainability, the institutional arrangements to implement the discursive ideals remains incomplete. Desalination, as a water augmentation strategy presents many contradictions and inconsistencies to the contemporary water governance framework, creating a disconnect in both in the rhetoric and practice of environmental governance and contemporary water management in Mexico.

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