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Water History
All Volumes & Issues
ISSN: 1877-7236 (Print) 1877-7244 (Online)

In this issue (7 articles)

Water Hist (2017) 9:169–187
DOI 10.1007/s12685-016-0180-z

Urban water development in La Paz, Mexico 1960-present: a hydrosocial perspective

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Received: 21 March 2016 / Accepted: 31 August 2016 / Published online: 15 September 2016

Abstract The impact of human activity in the terrestrial water cycle is not contested, yet social data are not fully explained, observed, or shared. This is especially true among low- and middle-income countries. This paper enters the conversation on hydrosocial systems to diagram a watershed in urban Mexico which highlights the historical, biophysical, economic, and cultural relations embedded in the development of urban water infrastructure. Our critical hydrosocial perspective, situated in political ecology and hydrology science, addresses the challenges of managing water resources for a growing population in a desert city. We integrate hydrological and historical data to show how broadening the scale of study from the political boundary of the city to the physical boundary of the watershed identifies human impacts on the water cycle and exposes uneven water allocation under drought conditions. An inclusive review of the historical development of urban water infrastructure in the city challenges the traditional ideas of separation of urban and rural water users in the production of sustainable communities and waterscapes.

Keywords Hydrosocial · Urban · Water · Infrastructure · Inclusive cities · Mexico

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Introduction

Hydrological cycles are often depicted by diagramming water flows, but recent calls to reflect the social dimensions of water have been made (Linton and Budds 2014; Sivapalan et al. 2012). In this paper, we build on the scholarship of critical geography, political ecology, and hydrology to offer insights into the social construction and power relations of urban water provision through the lens of decision-makers involved in water management. We approach our case study qualitatively as 'hydrosocial,' defined as the socio-natural process by which water and society make and re-make each other (Linton and Budds 2014). Using interviews of experts in five sectors of water policy, operations, and cultural influence, we outline the development of one urban hydrosocial cycle to reveal the hidden ways in which different social groups are involved in the framing and re-framing of priorities for water provision and to suggest how connecting these groups may lead to the production of sustainable communities and waterscapes. Because urban water infrastructure links people and the built environment, we seek to reveal the hydrosocial relations of production and how these relations shape and are shaped by the people who manage water in the La Paz municipality. In other words, we are trying to piece together, in the words of Maria Kaika, the "(hi)story of a city of flows" (2005, p. 25) for the City of La Paz by examining agents who live and work within the decision-making structures of water management.

Research related to the social influences and impacts of urban water infrastructure is expanding. Wittfogel (1959) linked the ability of ancient empires to control rivers with opportunities for despotic government. Although his work inspired research on the political and social aspects of water resource management, he has since been criticized for being too deterministic in suggesting that controlling water (e.g., through irrigation networks) is a direct form of social control (Banister 2014). Others have looked at water as a common pool resource, arguing that institutional arrangements accompany engineering designs and operations, calling attention to allocation and decision-making control over the development and use of supplies (Freeman 2000; Ostrom and Ostrom 1972). Swyngedouw (2004) later loosened the reigns of Wittfogel's linkage—while still yoking society to hydrology, he recognized the subtle fluxes and feedback loops between different actors as they struggle for power and access. He insisted that the understanding of hydrosocial systems must include, among other things, explanations of natural resource accumulation processes, material and ideological practices, and the impacts of these on cultural practices and social relations. Further, he encourages us to remember the critical inquiry of political ecology: 'for what' are we building urban water infrastructure, and 'for whom'? After all, every new pipe or sewer line that is placed is likely to "negatively affect the control over place of some while extending the control and power of others" (Swyngedouw 1993, p. 322). Likewise, Graham (2000, p. 115) finds evidence that urban water infrastructure grids connect practices of production and consumption that are unevenly disbursed.

Scholars have described in great detail the 'hydraulic mission' of irrigation districts and bureaucracies in Mexico to control and centralize hydrosocial networks through water reform (Molle et al. 2009; Wester et al. 2009). Other researchers have shown how federal water reform impacts were present on the Baja peninsula in fits and starts to spur economic development (Cariño and Monteforte 2008). However, a focus on the history of the development of the capital city of Baja California Sur is warranted, as it presents an example of a second-tier global city in the most arid state in Mexico. Like many global cities today, it contends with population growth amid limited resources. La Paz, capital of

both the state of Baja California Sur and the La Paz *municipio* in Mexico's northwest, is in a period of socio-spatial structure transition which has made it one of the fastest growing cities in the country. It is the most populated city in a state of about 712,000 inhabitants (INEGI 2016). Since water scarcity is tightly related to the way the city grows and depends on rural areas, La Paz becomes an example of how decisions about urban development affects sustainable management practices, a phenomenon which is experienced in many other cities around the world (Peck 2009).

The "Research study" section explains the methods of data collection and analysis of the research study. The "A hydrological narrative of the La Paz watershed" section shares hydrological data to diagram water flows in the watershed, while the "A social narrative of the La Paz watershed" section provides a social narrative of recent historical processes of natural resource accumulation, the material and ideological practices, and the impact on cultural practices and social relations. The "Hydrosocial narrative of the La Paz watershed" section integrates the hydrological narrative of the water cycle with the social narrative of the water cycle to diagram a hydrosocial representation of the watershed. The "Conclusion" section concludes with how the La Paz case study compares with other urban water histories and how future hydrosocial research can investigate the role of subject matter experts in decision making and framing water use as agents embedded in the structure they seek to change.

Research study

Data were collected through three site visits, each lasting 1–8 months in duration over the course of 3 years. Hydrological data were collected through federal, state and municipal documents regarding drought regulation, water law, state vision statements, city and municipal planning, and scientific assessments of the La Paz aquifer, including: federal documents concerning drought declaration (Diario Oficial 2012), federal water reform documents, (National Water Program 2007–2012, SEMARNAT), federal drought relief reform documents (Guide for the Formulation of Programs of Preventative Measures and Mitigation of the Drought 2013), federal disaster declarations (FONDEN), federal climate change guides (Meterological guide for the evaluation of the vulernability to climate change 2013), state plans (Oasis, Vision 2030), local aquifer estimations (Diario Oficial de la Federacion 2009), and municipal watershed diagnostics (OOMSAPA 2011).

Social data on urban water infrastructure in La Paz were gathered from stakeholder interviews from federal, state, and local levels of management from April–September 2013, the year following a federally declared drought. Stakeholders were selected for semi-structured interviews representing different aspects of water management, use, and behavior to understand how water has been diverted, stopped, imagined, and re-imagined in the past 40 years. More than one source is needed to construct a holistic narrative, as Mannheim claims, thought is a product of position in society: "In accord with the particular context of collective activity in which they participate, men [sic] always tend to see the world which surrounds them differently" (Mannheim 1954, p. 3). Therefore it is necessary to collect different angles on the same topic. At the same time, Mannheim (1954, pp. 3–4) states that patterns of thought are passed down through generations, making the historical-social situation important for studying the patterns as well as the "inherent connections which always exist in reality between thought on the one hand, and groups and activity on the other." For this analysis of the perceptions and collective activities of urban

water development, five sectors of water management were identified, guided by the socio-technical systems outlined by Geels (2004), to gather discursive characteristics of the recent social history of the water cycle in La Paz. Informants were recruited using the 'purposive snowball' technique in which subject matter experts were targeted for their unique perspective and subsequently asked to use their social networks to help us locate other potential informants. This non-probability sampling method has been used in the social sciences to collect knowledge-specific data that cannot be acquired from a random sample (Campbell 1955). The method elicited a total of 19 interviews (four women and 15 men): two respondents each in the technological and distribution sectors, four each in the science and socio-cultural sectors, and five in the policy sectors (Table 1). The sample reflects the male—dominated space occupied by water managers and influencers in La Paz, Mexico. Federal and state hydrological and meteorological agencies were contacted to reflect the views of the technological sector. Scientists from two local universities and municipal research practitioners were contacted to represent the science sector. Federal and state water and planning agencies were contacted to speak from a policy sector point of view. Municipal water operators for urban and rural water delivery were approached for comments about the distribution sector. University professors in the social sciences and local non-profits were contacted to represent the socio-cultural sector. An interview guide was used to systematically collect data on water and drought issues while giving the informants freedom to address topics in their own way. Interview questions clustered around themes designed to elicit data on water policy, infrastructure, behavior and use (Appendix 1). All interviews were conducted by the first author who speaks native English. Most of the participants spoke fluent English, but a professional bilingual translator was hired for simultaneous translation when the participant requested the interview in Spanish. A professional bilingual transcriber was hired for verbatim transcription in the original language and translated from Spanish to English when necessary. To prepare the data for pattern recognition, transcriptions were reduced through coding (Dunn 2010). Content was

Table 1 Table 1 Interview participants were selected using purposive snowball sampling to represent a range of perspectives from five sectors involved in water management in distribution, policy, science, socio-cultural, and technological (Geels 2004)

Sector	Scale
Technological	Federal
Technological	Federal
Science	State
Science	State
Science	State
Science	Local
Policy	State
Policy	Federal
Policy	Federal
Policy	State
Policy	State
Distribution	Local
Distribution	Local
Socio-cultural	State
Socio-cultural	State/Local
Socio-cultural	Local
Socio-cultural	Federal

validated for use to analyze urban water infrastructure through frequency analysis of key words such as "urban," "water," and "infrastructure" and by using key word cluster analysis by sector around the word "water." Words and phrases were selected from the content described above around significant events to develop a timeline. Stakeholder views and public document data were butressed with participant observation in the field from February–August 2013. Analysis was iterative, defined as beginning with concrete observations (interview content) with the goal of developing an abstract description (of the hydrosocial cycle) (McAdams 2012). The purpose of this project was not to pinpoint areas of agreement or disagreement between sectors, but to construct a narrative that included perspectives from many angles of water management in the area. Quotes are used to emphasize the concerns that decision-makers have when trying to balance mandates with reality.

A hydrological narrative of the La Paz watershed

Urban water infrastructure is often designed based on the water cycle. In its simplest form, water budgets are calculated where outputs (e.g., evaporation, condensation, runoff) are subtracted from the inputs (e.g., precipitation) to estimate the change in storage (e.g., reservoirs, aquifer). To use such an equation, hydrologists need to understand the interactions and mass transfers (water in different states) that occur between the atmosphere, land surfaces and oceans. Processes include water inputs from precipitation, outputs from evaporation, flooding hazards from runoff and streamflow, percolation and storage in aquifers (and in cold climes, snowpack), and soil moisture accounting. Recently, these approaches have been criticized for leading to uncreative solutions to dwindling inputs, in particular, increasing inputs by drilling deeper or exploiting more sources.

As a city in the desert, La Paz faces a tight water budget with threats of decreased inputs due to recurrent droughts, overuse, and climate change. Baja California Sur has the lowest annual precipitation of any Mexican state, an average of 160 mm/year between 1971 and 2000 (CONAGUA 2010). The City of La Paz records an average of 18 rainy days per year for an average of 169.2 mm of rain, most of which occur in the months of July, August, and September (Organismo Operador Municipal del Sistema de Agua Potable 2011). Monsoons are primarily driven by the El Niño-Southern Oscillation (ENSO) phenonmenon (Cavazos and Hastenrath 1990), yielding a mean of 14.6 storms per season (Farfán and Fogel 2007). Climate change scenarios show that the peninsula may be subject to an overall drying trend, predicting more severe and frequent droughts in the future (Cavazos and Arriaga-Ramírez 2012).

The mountainous area to the southeast of the city receives more rain per year than the City of La Paz, with 400–440 mm at the highest elevations (Fig. 1 in red), and 300–350 mm at lower altitudes (Fig. 1 in orange). This area has been identified as the water recharge zone for the aquifer, that is, precipitation percolates to an underground reservoir. The area is located outside of La Paz city limits but within the municipal boundaries and is inhabited by rural ranching households scattered near riverbeds and roads. Because rainfall is low, groundwater provides a more predictable source of water for La Paz. In Baja California Sur, three aquifers are considered "over drafted" and four are affected by salt water intrusion (CONAGUA 2010).

On mainland Mexico, as much as 80 % of water is dedicated to agriculture (Wilder and Lankao 2006, p. 1982). In the La Paz municipality of Baja California Sur, however, the

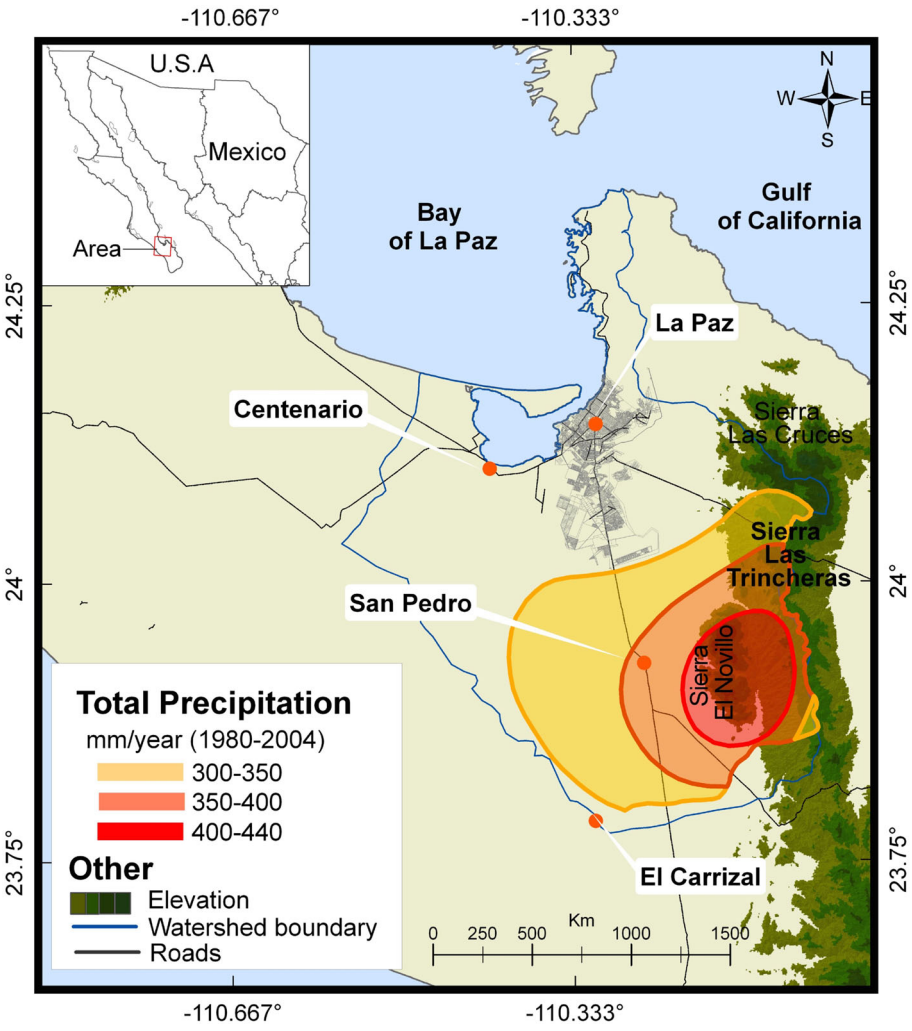

Fig. 1 Map showing elevation (*green*), watershed boundary (*dark blue*) roads (*gray*) and annual mean precipitation (*red* high, *orange* medium, *yellow* low). The La Paz watershed is bounded by topographical characteristics which define the runoff surface *Source* (Niparajá 2014)

proportion of water in the agricultural sector accounts for only 35 % of usage while the urban sector consumes 63 % (the rest is used by industry and other uses) (Organismo Operador Municipal del Sistema de Agua Potable and PO 2011). The City of La Paz currently depends on one aquifer for potable water, delimited by geophysical features that define the movement and storage of underground water. Despite a 1951 decree banning new development of this source, over-concession of extraction rights via wells and lack of accurate measurement has resulted in overexploitation (CONAGUA 2004, DOF, 8 October 1951). Pollution and salt water intrusion further aggravate water stress (CONAGUA 2001).

Recharge of the aquifer occurs through rainwater percolation with an estimated 47 % infiltration in the high altitude El Novillo sub-basin, an area inhabited by dispersed rural ranches (Fig. 1). The area of both the watershed and the aquifer vary from study to study

based on the methods used, complicating accurate estimates of available water (CONAGUA 2002; Cruz 2007). All of the studies agree that the aquifer is operating at a deficit, although at differing degrees of significance.

As social scientists, we must add a caveat when presenting numbers like those listed above. Quantitative measurements dominate the hydrological dialogue, but these numbers should not be presented uncritically. Data for statistical analyses are gathered under social conditions for specific social purposes and are subject to human error. It should not be assumed that the hydrological data described above is void of social comment or controversy. The comment below illustrates the social challenges of financial and human capacity in collecting local data in the La Paz municipality:

> …the hydrological data are not very good. For example, the climatological station measures rainfall, temperature, humidity, evaporation, solar radiation and some other physical parameters, but that was at the beginning (in the 1970s). Then, the sensor broke down and people didn't check the data and…the data reporting is very primitive. There are few new stations and I do not have very high confidence in the data recorded from the 1980s or 90s to now. The first step is to install new climatological stations, but CONAGUA [federal water agency] does not have the people or the resources.
> (*science sector participant*, English original, 2013)

We present the quote above not to undermine the important work that scientists are doing, but to shed light on the social in the hydro. We seek to emphasize the need for a critical understanding of who are producing data and why, a social understanding of the urban demand on the hydrological cycle, and the social meanings of drought and water scarcity.

Generic hydrological diagrams of water cycles typically include information on precipitation, evaporation, groundwater storage, and surface flows. Using the hydrological information provided in official documents, nearly 80 % of potential water in the system is lost to evaporation, the majority of the rest that falls as rain runs off to the ocean (OOMSAPA 2011). Therefore, a schematic of the La Paz water cycle might be drawn as Fig. 2, where few ephemeral streams collect water draining to the ocean, but the primary water storage system is the groundwater aquifer.

A social narrative of the La Paz watershed

We argue that the current urban water infrastructure system in the La Paz municipality is built on a history of social interactions with the water cycle. Human-built water diversion is nothing new on the Baja peninsula, however, the few sources that are available referring to pre-1960s development document only small-scale, contained productions (Crosby 1994). The following integrates a number of histories from different sectors of water management in La Paz across different operating scales to create one post-colonial narrative of the hydrosocial cycle. Three lines of inquiry emerged from the social data in describing the development of urban water infrastructure in La Paz that can be categorized as (a) a series of processes of natural resource accumulation, (b) shifts in material and ideological practices, and (c) impacts on traditional cultural practices and social relations between urban and rural water users.

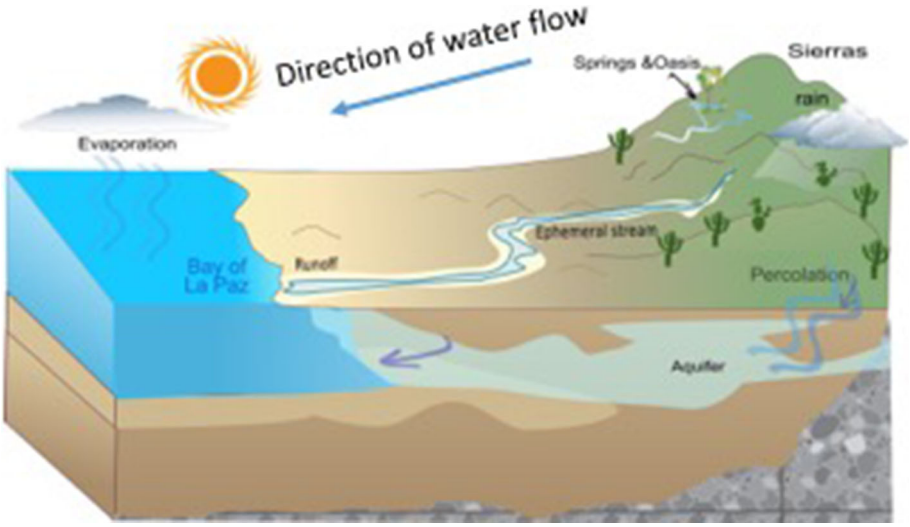

Fig. 2 Diagram of hydrology-focused water cycle of La Paz. Freepik and IAN symbols were used

Process of natural resource accumulation

The social data below present a narrative that exposes how human activity has fundamentally altered the watershed. Until the early 1960s, households on the La Paz coast relied on windmills to pump the shallow water table, earning the nickname "City of Windmills." The last 40 years have seen substantial urban population growth and a redefinition of human-water interactions. The interviews elicited a set of specific concerns and events that informants felt were relevant to how they performed their work given their positions in water management. Informants tended to tell their stories in chronological order, moving through decades beginning with the 1960s. Merging these social data in the same format, we identify overlapping and mutually dependent phases that describe a process of natural resource accumulation (Table 2).

Piecing together the participants' statements, a phase in La Paz's contemporary urban water infrastructure development can be perceived as a period driven by an urgency to reduce urban vulnerability by delivering fresh water supplies and building infrastructure to reduce hazard impacts. The first major population thrust was driven by transportation links with the mainland, specifically a ferry in the 1960s and later a highway connecting the peninsula to the United States in 1973. Beginning in the 1960s, pressure from the growing number of wells drew saltwater from the Bay of La Paz into coastal water supplies, contaminating drinking water quality. At the same time, the city installed sewer lines to serve a military hospital. This event marked a gradual transition away from septic tank use in government buildings and eventually residences. The natural topography of the land was considered as an amenity by draining runoff directly into the Bay without having to build ditches. This period coincided with a development boom on the mainland and throughout Latin America in general. In La Paz alone, the population doubled from about 46,000 in 1970 to about 91,500 in 1980 (INEGI 2012). Summer storms are normal in Baja, and the rain is usually a welcome relief after a long dry season. But in 1976, Hurricane Liza hit La Paz. The hurricane is said to have only brought light-to-moderate rains. To protect the downtown from flooding, the military detonated a dike, flooding an area with poor quality

Table 2 Transitions in La Paz, Mexico's urban water infrastructure development based on social data

Years	Phase	Example
Pre-1960s	Colonialism, development as a Mexican territory	Human-environment interactions based on small, private means of water use
1960–1970s	Public delivery of fresh water supplies	Transition from private household wells to pipe and sewer network
1970–1980s	Awareness at the local and state levels	Scientific assessments of the La Paz aquifer
1980–1990s	Top-down water reform	National Water Law Article 27, amended in 1992
1990–2000s	Reliance on municipal capacity	Introduction of locally bound greywater markets
Present–Future	Attempts to align municipal with state and federal goals	Federal, state, and local sustainability goal, Water Agenda 2030

housing and resulting in deaths. Some say that people had been warned but dismissed the call, and it is still regarded as one of the worst disasters in Mexican history (*science sector participant*, 2013). In response, a new dam was built to prevent flooding in that area and has not failed to date.

A second phase in La Paz's history is an *internal* awareness at the local and state levels of the growing water quality and quantity problems resulting from reactive infrastructure design. At the state level, the Secretary of Agricultural and Natural Resources initiated the State Water Plan in 1980 to address the imbalance of the aquifers through treatment, reuse, and improved agricultural technology. The Plan incentivized less water-intensive crops, subsidized irrigation technology, and encouraged greywater reuse. The State Plan is generally regarded as primarily responsible for the municipal shift in water use from agricultural to urban (*political sector*, 2013; Cariño and Monteforte 2008). Meanwhile, the City installed collection tanks to capture and treat wastewater before entering the Bay. The population rose to 165,000 residents (INEGI 2012). Scientists were commissioned to estimate the water balance. Their reports identified potential groundwater sources, found overexploited aquifers and confirmed saltwater intrusion in several public wells (Organismo Operador Municipal del Sistema de Agua Potable 2011).

A third phase was marked by broad decentralization and *top-down* water reform from the federal level. Before the National Water Law Article 27 was amended in 1992, land and water within the national territory belonged to the Mexican United States. The 1992 reforms changed that, essentially de-linking groundwater from land rights by allowing private entities to trade water (Shah et al. 2004). This new legal framework precipitated a number of operational and administrative changes within water decision-making at the federal level, including consolidating all water business and permitting under the agency Comisión Nacional del Agua (CONAGUA). The reform to the Constitution Article 27 in 1992 allowed, in the case of *Aguas Nacionales*, the private sector to build and manage hydraulic infrastructure and participate in municipal water and sewage service, and also the creation of a market ruled system of national water concession. For *ejidos* (a system of cooperative land tenure) and indigenous communities, the constitutional amendment adversely affected their water rights. It also allowed external (public or private) parties to acquire water titles and concessions, among others, on streams, rivers, lakes, mangroves, and coastal zones within their territories. The impacts of this decentralization of environmental policy signaled a shift in water management that was felt throughout the country and have been criticized for transferring the financial burden from the federal government to irrigation water users and creating more inequity (Wilder 2009;

Wilder and Lankao 2006).[1] This restructuring of existing water institutions was followed by water quality and wastewater regulations and put pressure on the management of La Paz's water cycle as well.

A fourth phase from the late 1990s through the early 2000s can be conceptualized as La Paz acting in a more local, *muncipal* capacity, encompassing the surrounding peri-urban and rural mountainscape. In some ways, this could be due to the political landscape. Before 1988, with the exception of some deputies from opposition parties, the Partido Revolucionario Institucional (PRI, Institutional Revolutionary Party) had assured the presidency, all governorships, all Senate seats and a majority in Congress. Although the results of the 1988 election were tempered by the electoral recovery of the PRI in 1991, they marked a watershed in the political history of Mexico.

A new political landscape emerged with the massive presence of opposition political parties in Congress because PRI did not receive, for the first time, a majority of two-thirds to implement amendments to the Constitution. In subsequent years, the right-of-center Partido de Acción Nacional (PAN, National Action Party) won some governorships over PRI and later, so did the social democrat Partido de la Revolución Democrática (PRD, Democratic Revolution Party). While the Presidency was held by PAN from 2000 to 2012, PRD governed Baja California Sur from 1999 to 2011 as shown in Table 3.

There were shifts in political leadership at both the federal and state levels, but not in the same way. This context explains this interviewee's comment:

> Del año 1998 al 2010, las administraciones del municipio fueron diferentes colores, no fueron las del PRI entonces eso contrajo la inversión, o sea, los programas federales no llegaban como antes entonces eso reflejo una mala infraestructura urbana, porque no había dinero, eran PAN después PRD, entonces los recursos simplemente no llegaban por eso es que hay un pico en la infraestructura, por eso no hubo crecimiento en sistema hidráulico, agua potable, drenaje, etc.
>
> From 1998 to 2010, the administrations of the municipality were different [political] parties [than the federal government], so federal programs failed… we now have a poor urban infrastructure because there was no [federal] money. [Baja California Sur elected] PAN and then PRD, so resources simply did not arrive…for this reason there was no growth in the hydraulic system, drinking water, drainage, etc. (*technological sector participant*, 2013)

During this time, La Paz created a new source of municipal income from the sale of greywater, re-defining this product from waste to one of economic value. By the end of the nineties, La Paz was selling by some reports 100 % of its greywater to private entities, mainly to hotels for watering lawns and golf courses. The State passed a water law in 2001 which opened the space for citizen participation in water operations in the form of domestic user representation on the Board of Governors, which had not previously existed (*distribution sector*, 2013). Equally important in this time period was the evolution of the environment as sacred, even in the face of potential development. In 2008, an activist group called *Colectivo Balandra* collected over 18,000 signatures to petition the designation of a culturally and ecologically valuable beach as a Natural Protected Area. The initiative passed, and effectively removed 2000 hectares of beachfront property from the real estate market. This signaled a paradigm shift in Mexico's

[1] Amidst social criticisms, the Mexican Congress approved the removal of regulations in 2015 that prevented full participation of the private sector, arguing that private participation is needed for water service improvement, i.e., preventing water transfers between basins without natural connections.

Table 3 Baja California Sur (Mexico) Source: Instituto Estatal Electoral de Baja California Sur (2016). *Resultados electorales*, IEEBCS, La Paz, BCS. Retrieved from http://www.ieebcs.org.mx/resultados.php

Period	Municipal president	Political party at *municipal* level	Political party at *state* level	Political party at *national* level
1999–2002	Alfredo Porras Domínguez	PRD	PRD	PAN
2002–2005	Víctor Guluarte Castro	PRD	PRD	PAN
2005–2008	Víctor Manuel Castro Cosío	PRD	PRD	PAN
2008–2011	Rosa Delia Cota Montaño	PRD	PRD	PAN
2011–2014	Esthela de Jesús Ponce Beltrán	PRI[a]	PAN[a]	PRI
2014–2015	Francisco Javier Monroy Sánchez[b]	PRI	PAN	PRI
2015–2018	Armando Martínez Vega	PAN	PAN	PRI

La Paz municipal presidencies /political parties, 1999–2018

[a] A one-time 4 year period to synchronize electoral processes

[b] Substituting his predecessor for a 6-month period, after her resignation

tourism strategy that was otherwise known for promoting industry in Acapulco, Cancún, and most importantly for Baja California Sur—Los Cabos. Following the global crisis in 2008, economic growth in the city was severely compromised. In 2010, there was a recovery in the level of output but unemployment fluctuated between 6 and 7 %, one of the highest percentages in the country (Angeles 2012). By 2014, the economy was improving through the growing construction of resorts and second homes for tourism along the coast, and –within the city– gated communities, shopping malls and the gentrification of some of its districts. The expansion of the urban area was also made possible by means of the construction of modest housing. The development has resulted in urban sprawl away from the piped central city toward the unconnected areas along Bay of La Paz (El Centanario) and south along the highway (towards San Pedro) (Fig. 1). These rapidly growing settlements largely depend on water delivered via truck from commercial and public entities. Also in this period, in terms of the water cycle, Hurricane Odile made landfall in 2014. Strong winds caused widespread power outages in La Paz.

According to informant statements, La Paz can be said to be entering a new phase, or at least vision, that attempts to *align* with state and federal goals. Water Agenda 2030 at the federal level aims to mitigate drought impacts along four axes: universal coverage, flood and natural disaster risk, clean rivers, and water balance. Each state in Mexico was charged to comment on the document in recognition of the unique climatological, ecological, and socio-cultural contexts in Mexico and re-structuring the traditional top-down approach of federal mandates. In Baja California Sur, around 120 decision-makers in various sectors weighed in on actions and strategies to meet these goals in this state. Comments were delivered to CONAGUA, and was presented at the conference of parties (COP) 16 United Nations Climate Change Summit in 2010. At the same time, Baja California Sur created the State Water Plan Vision 2030 to outline specific state-wide actions, including constructing five new wells, an aqueduct, two new dams, and a municipal desalination plant (Castro 2014). To modernize water delivery and partly to encourage household water conservation, the municipal water management agency has begun to install water meters, with 29 % household coverage (Organismo Operador Municipal del Sistema de Agua Potable and PO 2011).

Material and ideological practices

The material practices of the extension and expansion of development seem to be aligned with the ideological practice of supporting growth in La Paz. Today, the 220,000 inhabitants of the City of La Paz are serviced by 33 deep wells in which water is delivered by three aqueducts, connected by 367 km of pipes, and stored in 37 tanks (Organismo Operador Municipal del Sistema de Agua Potable and PO 2011). Desalination is a popular technical solution suggested to meet growing demand, but building new infrastructure is costly and requires traversing difficult terrain. Desalination is the conversion of seawater or brackish groundwater into fresh water, globally touted as a "drought-proof" solution to water insecurity (McEvoy and Wilder 2012, p. 354). Some environmental concerns are that the process is energy intensive and that disposal of the residual brine into the sea may harm marine life. A social concern of desalination is that the high price of converting seawater renders it cost-prohibitive to offer it to the public. La Paz's southern neighbor Los Cabos installed Mexico's first municipal desalination plant. However, reports claim that even with subsidies and a public–private partnership to keep prices affordable, the municipality is losing money (selling at 8 pesos/m^3 compared to 16 pesos/m^3 to produce, *technical sector*, 2013). If desalinated water were publicly available, delivery would be problematic. A plant was proposed on the northeast side of the city with marine sustainability in mind (for releasing brine into the ocean), but population density is growing in the opposite direction—to the south and west (Fig. 1). Either new pipe infrastructure would have to be built to deliver desalinated water to households or zoning laws need to be established in order to encourage denser development in the city center where delivery systems are already in place (*political sector*, 2013). In addition, desalinated water in La Paz would likely be offered for sale to private entities such as those in the tourism industry instead of the public in order to be cost effective (*technical sector*, 2013). Despite excitement for building the La Paz plant, the State governor Carlos Mendoza Davis later canceled the desalination proposal in favor of building the aqueduct to develop the El Carrizal water source (Fig. 1), moving the desalination plant to Los Cabos and increasing La Paz's reliance on groundwater (Aviles 2016).

The impact on cultural practices and social relations

Location within the watershed shapes how households manage their water supply. As a direct result of the historical stages described above, there exists a class-based, spatially explicit gradient of water consumption. Power relations exist between these groups within the structure in which they live. This could not be made clearer than in Baja, where the action of accessing drinking water takes multiple forms. Availability depends on the day, and requires different equipment based on where in the watershed one is located. For example, one family may drink water directly from an indoor tap connected to a personal treatment system, another family buys water from the market, and yet another family keeps a ceramic pot to collect rainwater. In this way, the La Paz municipality exists in the space where the domestication of water has not been fully realized (Kaika 2005, p. 53). But as more and more people depend on indoor systems and expect water to appear when they turn a knob, the less likely they are to connect their personal water use with the overall supply. Hence, a local water conservation NGO finds

it necessary to remind urban residents that "water does not come from the tap, it comes from the mountains" (Niparajá 2014).

The built environment presents daily concerns for both water quality and quantity. Upper and middle class families do not drink water from the tap, they either install household purification systems or buy *garrafons* (5L bottles) from private companies that drive trucks through the city. Municipal tap water is delivered by pipe by a *tandeo* system—1 day on and 1 day off. Urban households have adapted by collecting water on the "on" days in a cistern to be able to use on the "off" days. Because the growing number of people drawing from this network decreases the pressure in the system, the city sometimes has trouble pumping and delivering water even on "on" days. Private developers are now required to provide up-to-code infrastructure for new developments to help the city meet demand (*distribution sector participant*, 2013).

Meanwhile, the upstream users in the rural mountains (Sierras) primarily continue to access ephemeral streams (*arroyos*) and springs (*ojos de agua*) when water is available. However, the lowering water table and saltwater intrusion is impacting their ability to capture groundwater in wells (*pozos*) even further inland (*science sector participant, 2013*). Some rural households can obtain a permit with the federal agency CONAGUA to receive truck delivery of freshwater from the municipality which households store onsite in a tank. Other rural households, generally if they are close to the main highway, can access the municipal pipe network where they can receive water from 6 am to 6 pm. The following respondent describes how residents in one rural locality received less water than urban users during the end of the federally declared drought:

> La verdad es que en algunos de los casos donde se tiene servicio más continuo en la ciudad rebasan los 250 litros. Hasta 300 litros llegan algunos, y esto es un abuso. En el caso de las comunidades rurales pues no, porque los tenemos acotado para proteger la fuente de abastecimiento y no damos todos los días, no proporcionamos el servicio todos los días. Por ejemplo, en el caso de [peri-urban], ahí les damos dos veces por semana y en un promedio de 12 horas, el problema ahí es que la distancia de la fuente de abastecimiento, hay que transportar el agua 18 km. Y la fuente de abastecimiento es un pozo a cielo abierto que está a la margen de un arroyo..., si no hay lluvia se va para abajo el nivel. El año pasado tuvimos una experiencia muy fuerte porque tuvimos que racionar el servicio a través de pipa y darles 600 litros por semana, por familia no por persona. Se nos seco el pozo.
>
> The truth is that in some cases where you have more continuous service in the city they exceed 250 L (versus the 117 L per day granted to each person). Some use up to 300 L, and this is an abuse. In the case of rural communities they cannot use this much because we do not provide service every day. For example, in one [peri-urban] case, we gave them water two times per week for 12 h on average. The problem there is the distance from the source - we transport the water 18 miles. The source of supply is an open well, which is near the bank of an arroyo. If there is no rain, the level is low. Last year [2012] was severe because we had to ration the service through pipes and give them 600 L per week, per family not per person. We dried the well.
> (*distribution sector,* 2013)

A hydrosocial narrative of the La Paz watershed

Combining the five perspectives of urban water infrastructure development in La Paz with the hydrological data into one storyline, La Paz's modern water history can be told as a story of defying gravity to support a growing population in the desert, a 'flipped' hydrology serving urban residents first and rural residents last. A recount of the history of La Paz from 1960-present shows how human activity has altered this system by pumping inland groundwater, piping it to the coastal city to be treated, and then delivered back 'uphill' to the urban residents by pipe or through commercial entities, then to peri-urban and rural residents by truck. Incorporating social data with technical data, the water cycle of La Paz may be drawn as Fig. 3.

We also find that water distribution in the La Paz municipality is a two-tiered system. For rural water users who wait in line for water delivery through the altered hydrosocial system, water use comes to consciousness in daily practice. For those in the city center, who can (sometimes) turn on a tap and expect water, use is becoming more and more an unconscious activity that fades into the background of daily life. Yet, many native urban residents have not entirely converted to modern water use practices but continue traditional customs developed to adapt to precipitation and temperature variability. For example, *paceña* (City of La Paz residents) households tend to keep a bucket in the shower to collect greywater for plants. Walking down the street on a hot day, one may come across locals wetting down the sidewalks, a practice the rural households also use to cool off in hot temperatures. These and other rituals suggest that urban design and regulation alone will not alter human behavior without a deep understanding of the culture. The rural identity and the collective perception of them as water conservers are deeply embedded in the urban mentality and ideas about what it means to live on the peninsula. Linking this conservation identity to urban messaging might be one way to promote a locally-based ethic while bridging the urban–rural divide.

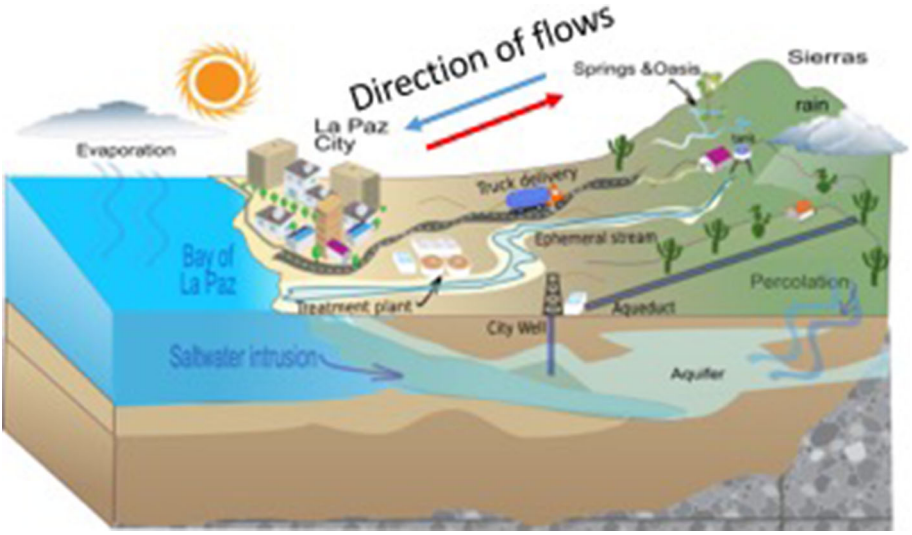

Fig. 3 Diagram of hydrosocial based water cycle of La Paz. Freepik and IAN symbols were used

Lastly, the rural ranching community that lives on the recharge zone for the city's aquifer but physically outside the political boundaries of the city presents an opportunity for engagement in water conservation that can be beneficial to both urban and rural users. In other words, sustainable ranching practices to increase soil absorption and rainwater percolation into the aquifer ultimately benefits both parties. This prospect that has not gone unnoticed by local non-profits who are currently devising water conservation programs. State public officials also recognize what a more inclusive approach to water management could mean for sustainability, while acknowledging that the reality of a long-standing cultural divide complicates an idyllic future:

> …The key question is: can we [urban and rural] live together? Can we learn and understand the [urban] lessons for the communities in the [rural] Sierra and can we learn lessons that the communities in the Sierra give to us and integrate those ideas in the city?
> (*political sector participant*, English original, 2013)

Reality will likely present a water future causing new, but not immediately apparent transitions for the five sectors of water management from which we interviewed and for many urban and rural social groups in the watershed. We argue that although water operators in the La Paz municipality struggle to meet minimum delivery goals, an inclusive sustainable watershed is not out of reach. This paper has pointed out how cultural drivers can be be seen as positive instigators for restoration and conservation. As its Los Cabos neighbor to the south develops desalination for public consumption, how La Paz learns from that experience and adapts it for their own use will determine how inclusive and sustainable La Paz can become as their hydrological footprint expands. The City of La Paz, Mexico is a site that provides unique insight into the development of urban water infrastructure to promote economic growth in a desert, where the politics of water are evident, and where critical hydrosocial issues raises questions of the sustainability of waterscapes.

Conclusion

Integrating hydrological with social data, this paper shows how a second tier global city in the desert defies gravity to move water to certain populations at certain times. Unlike Reisner's *Cadillac Desert* (1993) in the American West in which "water flows uphill towards the rich," water in this desert is pumped downhill towards the rich and trickles back up if enough resources exist to complete the cycle. The City effectively 'flipped' the hydrology of the watershed by reversing the flow of water from a gravity-fed model to a delivery system that feeds the coastal city first and high altitude users last. Where water once ran off mountains to supply the shallow water table of the coast, the city now drills inland to access an aquifer to pipe groundwater directly to the coast for treatment, for delivery to urban then, later, peri-urban and rural users. Today's urban water infrastructure network transforms hydrology through massive human activity of extraction and transportation. The analysis leads to the finding that the radical re-direction of water involves adjusting water flows from its ecological context to a social one as the expanding city reaches farther into the hinterland to access fresh water sources. The analysis revealed how recent developments in urban water infrastructure has impacted the hydrology of the water cycle as well as the culture of users in terms of their water behavior. The result is a

demonstration of a shift in water use as the sophistication of the system grows and as the urban population demands more water based on non-climatological factors.

Despite the unique differences, the La Paz experience also shares similarities with other transitioning cities. Like Strang (2004, p. 21, 36) found in an urbanizing United Kingdom, the residents of La Paz have been moving through their own stages of civic disenfranchisement from a very intimate, hands-on labor involvement with water to 'passive recipients' of an alienated industrial product. Before the 1960s, urban water was a *private* problem handled by individual households pumping their own water with power generated by personal windmills. The City of La Paz has effectively re-educated its public away from the idea that water comes from the sky or ground, and towards a reliance on a pipe system. This feat was not accomplished by a top-down directive, but by a combination of many different actors in different sectors reacting to external forces. These actors are simultaneously decision makers that impact others and who are embedded actors in the process they are affecting. Stakeholders are agents within the structure they are trying to shape. Therefore, it becomes increasingly important for future hydrosocial research and the growing case studies of urban water histories to investigate how knowledge experts make meaning of their plural roles in water management, how their efforts translate across scale and time to impact different social groups in their abilities to access water, and how cumulative decisions push water management in different directions.

Acknowledgments Parts of this work have been submitted by Melissa Haeffner in partial fulfillment of the requirements for a PhD at Colorado State University under IRB 12-3573H. We would like to thank Dr. Dennis Ojima, Dr. Michele Betsill, and Dr. Stephen Leisz for substantial feedback, Dr. Fermín Reygadas and Gabriel Patrón for assisting with identifying and contacting potential interview participants in the field, Mabilia Urquidi Gaume for producing the figures and collecting secondary data sources, and to Luz Fabiola Armenta Martínez and Mariana Ledesma for transcribing and translating the interviews. We are grateful to the two reviewers for their insightful comments. Also, we thank participants in the Association for Environmental Studies and Sciences (AESS) Writing Workshop 2016 for their feedback on an earlier draft. Finally, we are especially appreciative of the decision-makers in La Paz for sharing their thoughts on water management.

Appendix 1 : Public official interview guide

Role of organization

What is the role of your agency in water management?
What is your role in the organization?
What do you or your organization think is the major concern about water management in your jurisdiction?
Do you think that environmental conditions are changing in your jurisdiction? If so, how?

Water infrastructure and policy

Which droughts has your organization responded to?
How has your organization responded to drought?
Has your organization learned from past drought and changed its operations accordingly?
Is your policy around water management influenced by other actors (e.g., federal government, state government, lobbyists, civil protests, scientists, etc.)? If so, how?
What do you see are the institutional challenges around drought?
Who do you think should be responsible for responding to drought?

What technology, physical or human capital, has your organization pursued to alleviate water scarcity issues? (e.g., dams, irrigation, desalinization, storage, conservation, economic development/alternative livelihoods)

Water users and behavior

Who is the target population for your services?
What kinds of community relief has your organization devised to respond to drought? What were some the major successes? Were there any failures, if so, have they been addressed?
To what extent do you think government funds influence people's relationship with the environment at the local level? (What influence does it have on people's behavior?)
Do you think that households in Baja California Sur have changed how they use water recently? If so, which households? When? Why? How?
Do you think that households in Baja Califoria Sur move when there is a drought?
Do you feel the water infrastructure is adequate to serve the needs of in-migration in the towns/cities?
Do you feel that water infrastructure is adequate in the rancheros?

Suggestions

If you could suggest a policy to better manage water in your jurisdiction, what would it be?
Which agencies or groups in your area are involved in water management (broadly defined) in Baja California Sur?
Whom should I talk to next?

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