The limits to large scale supply augmentation: Exploring the crossroads of conflicting urban water system development pathways

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Abstract. Managers of urban water systems constantly make decisions to guarantee water services by overcoming problems related to supply-demand imbalances. A preferred strategy has been supply augmentation through hydraulic infrastructure development. However, despite considerable investments, many systems seem to be trapped in lackluster development pathways making some problems seem like an enduring, almost stubborn, characteristic of the systems: over-exploitation and pollution of water sources, distribution networks overwhelmed by leakages and non-revenue water, and unequal water insecurity. Because of these strategies and persistent problems, water conflicts have emerged, whereby social actors oppose these strategies and propose alternative technologies and strategies. This can create development pathways crossroads of the urban water system. To study this development pathway crossroads, we selected the Zapotillo conflict in Mexico where a large supply augmentation project for two cities experiencing water shortages is at stake. The paper concludes that urban water systems that are engaged in a trajectory characterized by supply-side strategies may experience a temporal relief but neglect equally pressing issues that stymie the human right to water in the medium and long run. However, there is not a straightforward, self-evident development pathway to choose from, only a range of multiple alternatives with multiple trade-offs that need to be thoroughly discussed and negotiated between the stakeholders. We argue that this development pathway crossroads can cross-fertilize technical disciplines such as socio-hydrology, and social disciplines based on hydrosocial studies, which both ambition to make their knowledge actionable and relevant.

1 Introduction

Urban water systems ~~around the world are~~, understood as the managerial, technological, and infrastructural configuration of water supply in a city interlinked with its diverse water resources, have become vulnerable in the face of climate change and uncontrolled urban growth (Flörke et al., 2018). This alarming situation poses a risk that may sever water security for billions of people (WWAP, 2019; UNESCO, UNWater, 2020). Historically, water managers have uncritically implemented large supply augmentation projects as their main strategy~~,~~ (Allan, 2003; Molle, 2008; McCulligh & Tetreault, 2017; Boelens et al., 2019), despite the piling evidence of its shortfalls (Gupta & Van der Zaag, 2008; Gohari et al., 2013; Rinaudo & Barraqué, 2015; Purvis & Dinar, 2020). ~~Some of these shortfalls arise because some problems consist of more than just issues of disparity~~

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between water supply and water demand laid out on a spreadsheet. A more nuanced analysis of urban water systems shows that there are problems of over-exploitation and pollution of water sources, low investment capacity due to leakages, non-revenue water and low water tariffs to improve the water utility´s performance, sustainability, and equitable service, expressed in persistent situations where poor users face constant disruptions of the water service and poor water quality (Biswas et al., 2018). Adding new sources of water to the system will likely not solve these issues (von Bertrab, 2003; von Bertrab & Wester, 2005), nor make urban water systems more prepared for future stressors and shocks (Leach et al., 2010; Di Baldassarre et al., 2018).

The preference for large supply augmentation solutions is based on the sanctioned discourse and vested political and economic interests linked to the hydraulic mission that started at the beginning of the previous century and still continues as the main water paradigm in many countries (Allan, 2003; Boelens et al., 2019). This discourse has set an urban water system trajectory whereby water managers underestimate the potential of alternatives and trivialize negative social and environmental effects of large infrastructure (GWP, 2012). At a local level, water utilities are often risk-averse and tend to opt for solutions contained within their own legal framework and engineering capacities confines (Lach et al., 2005).

Therefore, water authorities and managers seem unlikely to change the course of the strategies and policies they have implemented. Against the continuation of this trajectory based on large supply augmentation projects, social actors have long criticized this sanctioned discourse that conceals and neglects more complex issues that are more difficult to tackle in urban water systems (COMDAHowever et al., 2019). In addition, affected communities have constituted grassroots movements and a strong opposition against the implementation of these projects (Godinez Madrigal et al., 2020).. In some cases, these movements have been effective in delaying or even cancelling these projects (Ahlers et al., 2017; Godinez-Madrigal et al., 2020), while demanding the need to search for alternatives (Ochoa-García, 2013; Ochoa-García et al., 2014; Ochoa-García et al., 2015; Ochoa-García & Rist, 2018).

In fact, there is a wide rangeHundreds of available alternativeswater conflicts have emerged in the past decades, many of which are related to the implementation of large water infrastructure for securing urban water security (Larsen et al., 2017). However, their potential in local contextsdevelopment (EJOLT, 2021). The importance of these conflicts is that they have played a key role in redefining the decision space of cities and basins to address pressing problems like water shortages and poor water quality (Rodriguez-Labajos & Martinez-Alier, 2015; Ochoa-García & Rist, 2018). The decision space in such conflicts is disputed preciselycharacterized by the water managers who aim to implementcompeting approaches either based on business-as-usual pathways like large-scale infrastructure. or transitioning to alternative pathways (Godinez Madrigal et al., 2018a; 2020). This has generated an impasse, whereby large infrastructure isprojects are stalled due to the conflict, but alternatives remain untested. We call this situation characterized by conflict and indecisiveness in troubled urban water systems a development pathway crossroads, in which the actors in conflict will either define a new pathway or reinforce the current one. Overcoming this crossroads is of extreme importance since it will imprint long-lasting consequences for the urban water system in questionwater security and water justice expressed in institutional arrangements and infrastructural configurations of the urban water system in question. For instance, in business-as-usual scenarios based on large infrastructure, Kallis (2010) observed a recurring phenomenon in the co-evolution of cities and water systems dubbed the ‘supply-demand cycle’, in which additional sources of water supply fostered a societal response that increased water demand. Thus, a larger water demand warranted developing new sources of water supply, fuelling the cycle, externalizing social and environmental costs to rural populations (Kallis, 2010), and exacerbating uneven water access in urban and sub-urban populations (Savelli et al., 2021). Moreover, a high dependence on reservoirs may render cities more vulnerable to hydro-climatic variations (Kuil et al., 2016; Di Baldassarre et al., 2018). Therefore, if water conflicts and grassroots movements can redefine the decision space of urban water systems, they will also interfere with the socio-economic, political and hydroclimatic dynamics that reproduce the supply-demand cycle.

~~We chose~~ To understand the ~~Zapotillo conflict in Mexico as an ideal case study of a~~ origins, extent, and possible consequences of this development pathway crossroads~~.~~, it is necessary to study both the interdependent relationship between the coupled human and water systems, and the power dynamics that configure the decision space within the urban water system. To test this approach, we draw on empirical work on the Mexican urban heartlands of León and Guadalajara suffering from water shortages and overexploited water resources, and their water security strategy of increasing water supply through an intra-basin water transfer. This ~~case is~~infrastructure project has caused a 15 years-old intractable water conflict between ~~two urban regions seeking to increase their water supply through a large dam and intra-basin water transfer, while communities fight~~the cities and three villages within the projected reservoir’s site who have fought not to be relocated ~~and farmers want to protect their water reserves in the donor region. Due to the resistance of the opposing actors, the infrastructure project has~~ . The villagers formed a grassroots movement that has been ~~indefinitely stalled, and the challenging actors are~~ successful in stalling the implementation of the infrastructure project and lobbying for the implementation of alternatives ~~to the Zapotillo project~~ strategies in the two recipient urban water systems ~~suffering water shortages, overexploited water resources and an increasing water demand.~~

~~An effective analysis of this kind of development pathway crossroads would require a transdisciplinary approach, since there are constant feedbacks between the narratives, framings and social capitals that actors push forward to mobilize a particular pathway over others, and the technical and biophysical reality that constrains the range of options available to actors. Therefore, contrasting disciplines such as socio-hydrology (a technical discipline) and hydrosocial studies (a social discipline) may find fertile ground to make their knowledge actionable and relevant to social actors.~~

. In this paper, we aim to ~~analyse if and how~~explore the concept of development pathway crossroads to visualize the role of water conflicts and grassroots movements as a heterogeneous social response in coupled human-water systems characterized by the supply-demand cycle. We first ask what hydrological, technical, and socio-economic and political factors are triggering the supply-demand cycle in León and Guadalajara. Then, we describe and analyse how grassroots movements can ~~contribute to cross-fertilizing socio-hydrology and hydrosocial studies. Since the Zapotillo case is considered an emblematic and highly intractable water conflict in Mexico (Godinez-Madrigal et al., 2020), its development pathway crossroads analysis should inform and help understand other water conflicts in similar situations but different contexts.~~ redefine the decision space of urban water systems to address water shortages, and act as a feedback mechanism that could disrupt the supply-demand cycle of urban water systems.

The paper is organized as follows. First, we discuss the relevant literature ~~on socio-hydrology and hydrosocial studies that aim at improving~~to develop our ~~understanding of the coupled human-water systems, and the knowledge gap to improve the cross-fertilization between both disciplines to enhance their social impact~~concept of development pathway crossroads in urban water systems. Second, we describe the methodology, which involved ethnographic techniques and ~~the development of a water resources model to elicit~~conducting participatory ~~processes and test scenarios~~modelling. Then, we present the results, and finally discuss the relevance of the case to the understanding of development pathway crossroads.

2 ~~Integrating disciplines to understand the development pathways of~~Development pathway crossroads in urban water systems

With habitual news headlines of cities reaching tipping points and 'day zero´s' in ~~their~~urban water systems (Maxmen, 2018), academic articles and reports calculating future billions of people without access to water (~~Vorosmarty~~Vörösmarty et al., 2010; Schlosser et al., 2014; Mekonnen & Hoekstra, 2016; WWAP, 2019), and the incorporation of water in the investments of commodities of futures due to the growing fears for its scarcity (Bloomberg, 2020), water managers keep implementing a limited number of tried-and-tested strategies based on large infrastructure that no longer respond to emerging drivers of change (Leach et al., 2010; Larsen et al., 2016). In contrast, water managers underestimate the potential of alternatives and trivialize negative social and environmental effects of large infrastructure (GWP, 2012; Godinez Madrigal et al., 2020). This phenomenon is relevant because this decision-making pattern often triggers unintended consequences in urban water systems such as contributing to a more pronounced water scarcity in the future (Gohari et al., 2013; Kuil et al., 2016; Li et al., 2019). ~~professionals look to implement tried-and-tested strategies based on their "technical expertise and the professional cultures that have developed over decades in line with the dominant urban water management system" (Larsen et al., 2016: 930). However, what if those tried-and-tested strategies have inadvertently contributed to the present situation?~~

~~In the past years, the understanding of hydrological~~ With a systems ~~has incorporated society as a system that co-evolves with hydrological systems to the point of switching the analysis from the hydrological cycle to the hydrosocial cycle (Linton & Budds, 2014). This new understanding has shed light on feedback loops between society and water systems which constitute repetitive cycles causing unintended consequences. For example, one of these cycles, relevant to this paper, is that of the '~~approach, Kallis (2010) conceptualised this phenomenon as the supply-demand cycle~~´ (Kallis, 2008).~~

~~Most human systems are dependent on water for their proper functioning, but since some systems are incentivized to keep growing, their~~ , which describes locked-in urban systems engaged in a constant dynamic of supply augmentation strategies followed by an increased water demand ~~tends to overshoot~~in different economic sectors that overshoots again water availability ~~even when new water supplies are added (Gohari et al., 2013). Therefore, following~~. Moreover, Di Baldassarre et al. (2018)

further developed this ~~strategy continuously makes the system dependent on developing new sources of water, and then, more vulnerable when these eventually fail. This is known as the 'reservoir effect' (Di Baldasarre et al., 2018).~~

~~Although the 'reservoir effect' has been documented in many cities throughout the world, it is still unclear "how diverse combinations of hydrological, technical, and social factors play a role in accelerating or mitigating the underlying feedback mechanisms [of~~ concept by describing the reservoir effect, in ~~different contexts]" (Di Baldassarre et al., 2018:621). Answering this question is of utmost importance if we want~~which urban water systems ~~across the world to avoid development pathways that set~~become more vulnerable by increasing their dependence on external water sources that can be affected by future droughts.

This systems ~~into~~approach has been the foundation of socio-hydrological scholarship, which has mostly intended to understand what is happening with coupled human-water systems and why, instead of focusing on what should be done (Sivapalan & Blöschl, 2015). As a result, socio-hydrology has advanced the understanding of the prevalence of this large supply augmentation strategy in terms of co-evolution of human and water systems, infrastructure path-dependence, locked-in systems, and feedback mechanisms of coupled human-water systems (Kallis 2010; Gohari et al., 2013; Di Baldassarre et al., 2018; Li et al., 2019). However, there is a paucity of literature that has focused on case studies where the status quo has changed, especially through the emergence of grassroots movements (Rodriguez-Labajos & Martinez-Alier, 2015), and the emergence of water conflicts, a research topic that remains underresearched (Di Baldassarre et al., 2019).

Kallis (2010: 807) glimpsed the potential to break the supply-demand cycle through "environmental changes, social and technical experiments, social movements and coalitions and innovations." However, few studies have analyzed cases of social movements and water conflicts that have exerted a crucial change to a water system by widening the decision space to implement alternatives and interfere with pernicious supply-demand cycles~~. However, perhaps~~ (i.e., Platt, 1995, is a good example). A challenge to analysing complex cases involving water systems and human agency is that it requires a sound interdisciplinary integration (Wesselink et al., 2017; Rusca & Di Baldassarre, 2019; Di Baldassarre et al., 2019). For instance, Savelli et al. (2021) addressed how the lack of understanding of power relations and heterogeneity in socio-hydrology may lead to overlooking differentiated responses and distribution of risks for diverse social groups in the case of Cape Town during the Day Zero drought. Societal responses and agency in contexts of power asymmetry need to be unpacked to better capture the diverse feedback mechanisms of coupled human-water systems.

To fill this gap in the natural sciences, critical studies developed the concept of the hydrosocial cycle (Swyngedouw 1997; 2004; 2009, Boelens, 2014, Linton & Budds, 2014, Schmidt 2014), which internalizes the interplay of water and social power as a dialectic inherent to the cycle (Linton & Budds, 2014). Specifically, this approach has investigated how different distributions of water, authority, and knowledge in each society (re)produce several forms of exclusion and asymmetrical risks in different groups of society (Zwarteveen et al., 2017). In the case of the recurring decision-making pattern of large infrastructure implementation, critical studies have mobilised diverse approaches to understand how sanctioned discourses align the practices of decision makers, political economy of water management favouring the interests of prominent economic and political actors, psychological biases in decision making and power embedded in knowledge asymmetries (Allan, 2003, Lach et al., 2005; Molle, 2008; Molle et al., 2009, Budds 2008; Flyvbjerg et al., 2003: Flyvbjerg, 2009; 2014; Hommes et al 2016; 2019; Hommes & Boelens 2017; Boelens et al., 2019). However, few critical studies engage in interdisciplinary research, which limits their transformative potential (Rusca & Di Baldassarre, 2019).

This is an even more important question to ask is how can water systems transit from a pathway characterized by the supply-demand cycle to an alternative one with, hopefully, better sustainable, and social outcomes?

Many natural and social scientists around the world acknowledge a need for a larger scientific effort to actively get involved in solving intricate water problems (gap that needs to be addressed, because, as discussed by Castree et al., 2014). Exponents of the highly technical discipline of socio-hydrology have expressed their aim at contributing to science-policy processes to achieve the sustainable development goals (Di Baldassarre et al., 2019); while social scientists have expressed their objective in not only studying water conflicts, but also contributing to transform them (. (2014), Zeitoun et al., 2019).. (2019) and Rusca & Di Baldassarre (2019), scientists have a moral obligation to change (not only to interpret) the world. Moreover, Lave et al. (2014) considersconsider it imperative that more scientists “combine critical attention to relations of social power with deep knowledge of a particular field of biophysical science or technology in the service of social and environmental transformation”. Therefore, innovative frameworks and methods are needed to engage socio-environmental transformation by addressing the interplay between a diversity of actors that frame differently how to address the many challenges facing urban water systems and hydrological flows. Leach et al. (2010) offers a promising approach based on the concept of development pathways, understood as: “particular directions in which interacting social, technological and environmental systems co-evolve over time.” Key elements of this approach are acknowledging the power dynamics and feedback mechanisms behind a current development pathway of a coupled nature-human system and unearthing marginalized alternative narratives. This is critical since it highlights the possibility of change by emphasizing a need to widen the decision space to include these marginalized alternatives into negotiation and decision-making processes. A key question is to find which tools are appropriate to support unearthing and supporting alternative narratives that can compete with dominant development pathways.

However, this willingness may be futile if3 Methodology

Considering the two research questions driving this paper regarding the multiple factors behind the supply-demand cycle in León and Guadalajara and investigating the role of water conflicts and grassroots movement in interfering with this cycle by showcasing alternative pathways, we conducted an inter and transdisciplinary research continues to be discouraged (Krueger et al., 2016). Scientific endeavour may be handicapped to exert social impact, as explained by Lane (2017), since science is increasingly characterized by a frenzy of over-production of publications and of brutal competition that disincentivize scientists to be more reflective and formulate research questions “beyond the confines of the simple cause-effect models that it so often espouses” (Lane, 2017: 93). Moreover, it is still unclear how the social and natural sciences can collaborate in advancing both the understanding of complex phenomena while addressing societal challenges, since both differ in their ontologies -how reality is perceived-, and epistemologies -how can reality be apprehended (Wesselink et al., 2017). This still constitutes a knowledge gap and a source of debate in academia (Di Baldassarre et al., 2019).

As a way out of this conundrum, Wesselink et al. (2017) suggested a modular approach, where both social and natural sciences can complement each other rather than compete, by means of developing social narratives from case studies that can benefit the exercise of socio-hydrological modelling and recognizing patterns in those case studies (e.g., Srinivasan et al., 2012). In addition, Miller (2008) proposed an epistemological pluralism approach in which the methodology would be negotiated among the actors involved. Lane (2017) urged to conduct 'slow science', as a departure of a kind of science that privileges impactapproach. First, we employed socio-hydrological and political ecology perspectives to analyse the long-term interplay of qualitative and quantitative factors, and instead produce knowledge that is useful for the objects of its research when they are allowed to 'talk back' and influence research questions and how to answer them.

A promising framework to conduct transformative research is that of development pathways (Leach et al., 2010). This approach engages with both the actions of actors and the narratives that frame how the coupled human-water system works, and collectively define what would be a sustainable pathway to undertake. Therefore, this approach brings about the politics between the actors and their strategies, which summon different social capitals to prioritize objectives akin to their interests and their vision for the future. This partly explains path-dependencies and lock-in systems, since actors in power keep making decisions and investing in the same development pathway (more than a pathway, it rather may be seen as a "motorway" say Leach et al., 2010), until they are challenged by conflicts or crises (Godinez Madrigal et al., 2019). Thus, to change course, scientists may need to conduct "empowering designs", to broaden out issues and problems, and opening up the decision space (Leach et al., 2010).

The development pathways approach further internalizes the "essential [task] to recognize the roles of public deliberation and negotiation – both of the definition of what is to be sustained [explicit qualities of human well-being, social equity and environmental integrity] and of how to get there – in what must be seen as a highly political (rather than technical) process." (Leach et al., 2010: 5). Water systems and their internal feedbacks and patterns cannot be fully understood without a thick comprehension of human agency and the multiple actor/power configurations that shape society (Rauschmayer et al., 2015). In this way, following the approach of development pathways, socio-hydrology and hydrosocial studies can increase the deliberation and negotiation, and thus, the potential of exerting much needed change in urban water systems.

3 Case study and methodology

3.1 Case study

To facilitate the reading of the paper and bring some context, in this section we briefly describe the Zapotillo project and introduce the nature of the conflict. The Zapotillo project is in México and centers around a proposed water transfer from the Verde River Basin to the cities of León and Guadalajara. Figure 1 illustrates the project and the three regions involved. First, the donor region of the Verde River basin has an area of more than 21,000 km2 and is primarily located in the State of Jalisco;

the basin has a semi-arid climate in the northern half with an average precipitation of 330 mm/year and a sub-tropical climate in the southern half with an average precipitation of 900 mm/year. Then, the recipient regions are the cities of Guadalajara and León, with a population of more than 4.5 million and 1.5 million inhabitants, respectively.

The water transfer would start at the Zapotillo dam in the Verde River basin. The dam is currently built at 80 m height with a storage capacity of 411 million m3, but the states of Jalisco and Guanajuato are lobbying to increase its height to 105 m (with a storage capacity of 990 million m3) to secure water for both Guadalajara and León. However, the reservoir would need to relocate hundreds of people. Since the project announcement, the dam-affected communities, and many farmers from the region fearful of possible water scarcity derived from the project have resisted the implementation of the project. This has created a 15-year-old conflict that has polarized sectors of the society and added numerous actors intervening in the conflict (Godinez Madrigal et al., 2020). Since 2013, the reservoir construction has been interrupted at the original 80 m high and it is unclear if the project will ever be finalized and implemented.

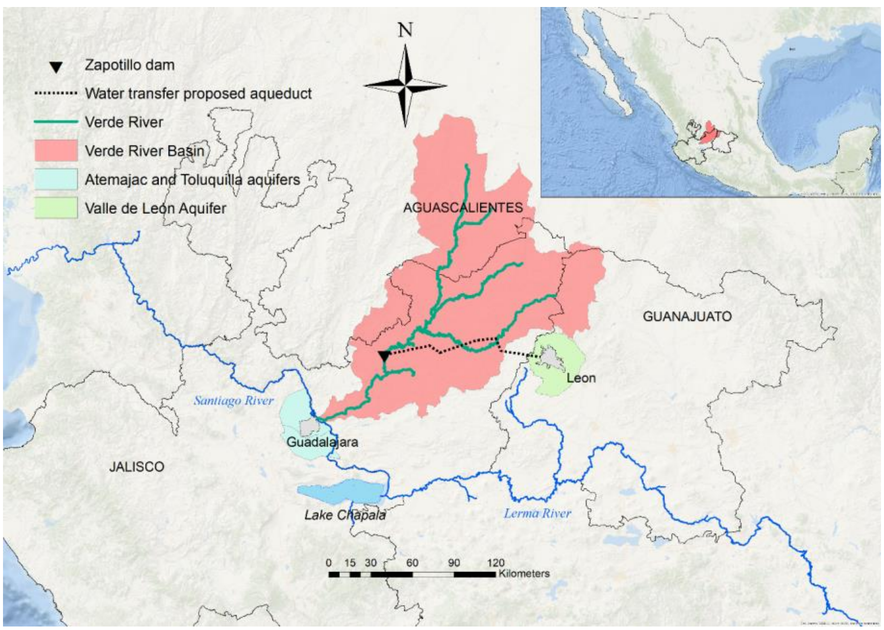

Figure 1: Map of the Verde River Basin and main cities (Source of GIS layers: © 2018 Conagua, and © 2019 Esri, Garmin, GEBCO, NOAA NGDC, and other contributors).

~~3.2 Methodology~~

~~Our research objective is to improve our understanding of what we have conceptualized as the development pathways crossroads of urban water systems. To achieve this, first, we ask what is the role played by hydrological, technical and social factors in a development pathway characterized by supply-side policies in Guadalajara and León, which would also contribute to the understanding of the reservoir effect (Di Baldassarre et al., 2018). Second, we ask how can water systems transit from a pathway characterized by the supply-demand cycle to an alternative one with, hopefully, better sustainable, and social outcomes?~~

~~To answer the first question, we analysed the co-evolution of the water system and society in both Guadalajara and León to delineate what the current development pathways of these cities are. To answer the second question, we analysed how the decision space opened up to include alternatives to the current development pathway of Guadalajara and León; then, we explored and analysed the new decision space, which considers the alternative development pathways proposed by some of the actors in the conflict. Our methodology is further explained in detail below.~~

~~3.2.1 Analysing~~ that steer the co-evolution of the ~~human and~~urban water systems

~~First, we traced back the evolution~~ of ~~water use and population dynamics in both~~ León and Guadalajara ~~and León as far back in time as possible. For Guadalajara we found data since 1900, while for León data was available only since 1988. Then, we normalized the data according to its initial value, following the same procedure as Di Baldassare et al. (2018).~~

~~To complement this analysis, we~~. We took inspiration from similar works that accounted for the political and socio-technical history behind these developments, ~~a method inspired by the works of~~ such as Kallis (2008) on the co-evolution ~~in~~of water resources development in Athens, ~~and~~ Molle & Wester (2009) on the longitudinal in-depth historic analysis of specific basins known as River Basin Trajectories~~.~~

~~3.2.2 Influence~~, Hommes & Boelens (2017) on the role of ~~conflicts~~imaginaries of modernity and progress in ~~opening up the decision space~~

~~We~~justifying rural-urban water transfers, and Savelli et al. (2021) on the interplay of society and hydrological flows of Cape Town. In the context of the Zapotillo conflict, we conducted ~~22 in-depth~~29 semi-structured interviews with key ~~actors in the conflict during the first half of 2017 and organized a stakeholder workshop with some inhabitants of Temacapulín in July~~stakeholders and decision makers of León and Guadalajara between 2017 ~~to explore the root causes of the conflict~~and 2020. During that time, we also conducted participatory observation in meetings, forums, and other workshops to which the first author was invited until the end of ~~2019~~2021. We chronicled those meetings in fieldnotes which were commonly shared with the authors. We complemented these perspectives with official statistical data of both cities and requested unpublished information to both water utilities to understand the co-evolution of their infrastructural configuration and socio-political dynamics.

Then,Second, as a method to analyse the perspectivesshowcase marginalized alternative narratives and perceptions of key actors to a larger decision space, by the end of 2018, the first three authors organizedtheir role in exerting a development pathway crossroads, we tested participatory modelling during a stakeholder workshop with the most important actors in the conflict in Jalisco. during December 2018. Several studies have analysed the role of participatory modelling as an empowering design (Stirling et al., 2007) in contributing not only to our understanding of coupled human-water systems, but also to benefit social processes like conflict resolution (Basco-Carrera et al., 2017; 2018, Van Cauwenbergh et al., 2018). Nevertheless, participatory modelling remains largely unexplored by socio-hydrology and hydrosocial studies to account for diverse social values in water systems and unveil power and knowledge asymmetries between actors (Melsen et al., 2018; Srinivasan et al., 2018). To the best of our knowledge, in the context of supply-demand cycle and the emergence of water conflicts and grassroots movements, this tool has not been used yet. We invited representatives of in favour of the of the supply augmentation project of El Zapotillo — Conagua (the national water authorityNational Water Commission), IMTA (Mexican Institute of Water Technology, the technical branch of Conagua), Jalisco´s government, the college of civil engineers —, actors of the grassroots movement — community members of Temacapulín and affected communities downstream, IMDEC (Mexican Institute of Community Development, a prominent NGO working with the dam-affected communities of Temacapulín, Acasico and Palmarejo), Tómala (a civil society group involved in facilitating dialogue around important societal challenges in Jalisco), college of civil engineers, and academics of local universities.

The workshop was structured around the interaction of the participants with a water resources model of the Verde River Basin (the donor basin of the Zapotillo project) and Guadalajara and León (the recipient regions) developed by the authors (Godinez Madrigal et al., 2018). The model, which was based on the model developed by UNOPS (Godinez-Madrigal et al., 2020) incorporated alternative urban water supply strategies to the Zapotillo dam, such as demand management, reallocation of water rights and decentralized water supply augmentation (Supplementary material describes the model in detail). These strategies were previously proposed by the actors in conflict, but not yet formally developed in a water resources model. The model was controlled through a user-friendly interface developed in VBA, which of this paper describes in detail the variables and development of the model, which we dubbed SimVerde (Craven, 2018; Godinez Madrigal et al., 2018). The actors randomly organized themselves in four groups to toy with the model, which allowed the generation of scenarios based on the discussion between the members of the group. To analyse the actors´ experience of a larger decision space through a boundary object such as the SimVerde, we debriefed the participants on their impressions of the workshop's experience on participatory modelling and how it changed their perspectives on the conflict.

Finally, in the last quarter of 2019 the first author conducted participatory observation in a series of workshops on alternative solutions to the Zapotillo project, one facilitated by the ministry of natural resources in Mexico City, and two others in Guadalajara organized by IMDEC.

3.2.3 Influence of conflicts in opening up the decision space

To analyse a larger decision space itself, we explored most of the combinations of the four main strategies mentioned before: (1) demand management, (2) reallocation of water rights (3) decentralized supply augmentation and (4) large centralized supply augmentation infrastructure. The first three strategies are composed of several measures, and the last one only of the Zapotillo project. The demand management strategy was composed of reclaimed wastewater for industrial water demand, implementation of water-saving devices, limiting urban growth, and reduction of physical losses in the distribution system. Reallocation of water rights was composed of water reallocation from agriculture to supply urban water demand. Decentralized supply augmentation was composed of implementation of rainfall harvesting systems and stormwater infiltration to different degrees. Finally, the Zapotillo project could be implemented by either of its four possible configurations (105 m dam, 80 m dam, 60 m dam, and decommissioning the dam; for details see supplementary material).

Our approach was informed by a 2019 stakeholders' workshop, where key actors explored a maximum of three alternatives. To make the exercise manageable, for each alternative we limited the number of possible combinations to one measure of each of the four groups (demand management, reallocation of water decentralized supply augmentation, and large supply augmentation infrastructure2018b).

4 Results

4.1 The co-evolution of the urban water systems of León and Guadalajara

With a population of approximately 1.5 million in the city of León and 4.5 million in Guadalajara, these are the two most important cities of Western Mexico (Fig. 1). Due to the water shortages and groundwater overexploitation experienced in both cities, Conagua developed the intra-basin water transfer Zapotillo project, a large-supply augmentation infrastructure to increase urban water supply. The sub-sections below describe the urban water system development pathways of León and Guadalajara to understand how certain hydrological, technical, socio-economic and political factors explain the development of this infrastructural solution.

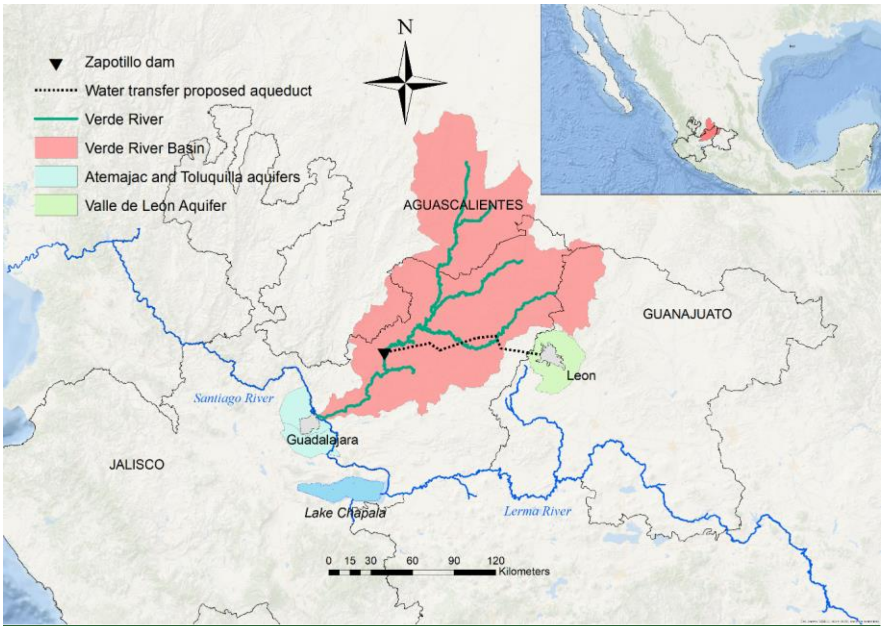

Figure 1: Map of the Verde River Basin and main cities (Source of GIS layers: © 2018 Conagua, and © 2019 Esri, Garmin, GEBCO, NOAA NGDC, and other contributors).

4.1.1 León

Currently, León's water system appears to be in a dire situation. Local and national authorities recognize a severe over-exploitation of groundwater averaging a decline rate of 1.5 m/year (SAPAL, 2015). This level of overexploitation has had increasing negative consequences for the water quality of its aquifer (Villalobos-Aragón et al., 2012; Cortés et al., 2015). Despite this, León is the most economically vibrant city of Guanajuato producing 25 % of its GDP, partly due to its vibrant leather industry (Herrera, 2017: 86), and with the largest population, which grows at a rate of 2 % per year (Fig. 2). This constitutes a water challenge (or a dilemma),) since this level of growth and groundwater over-exploitation seems untenable in the long term.

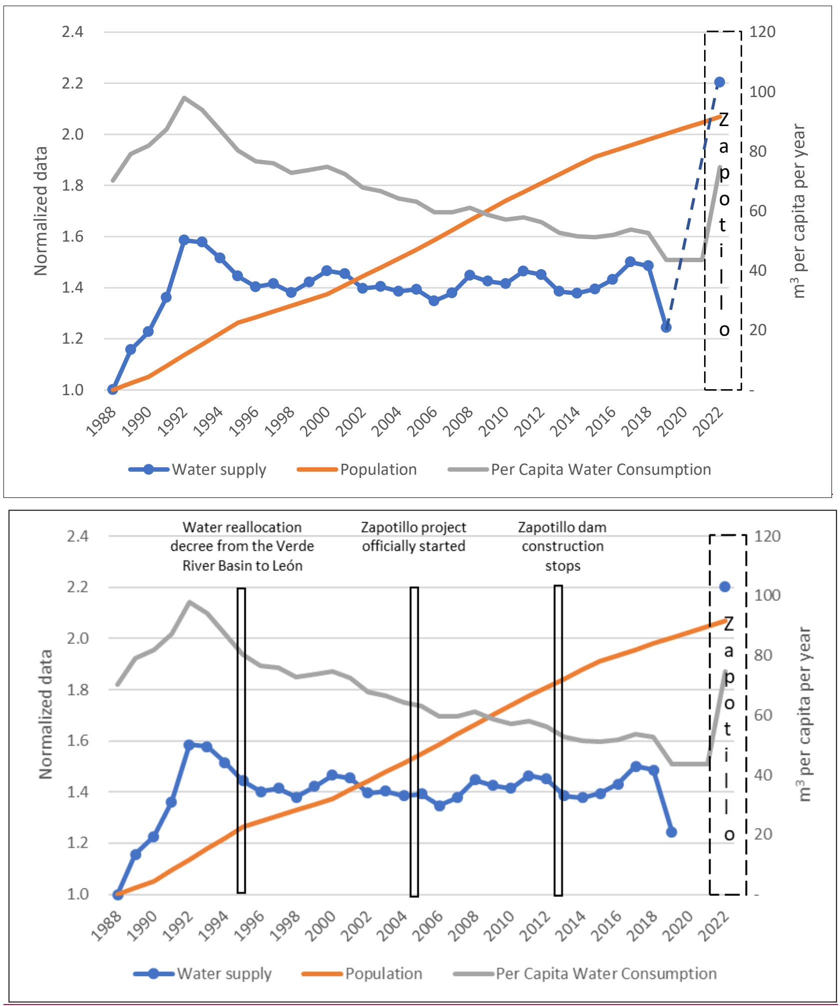

Figure 2: The reservoir effect in León (the dashed ~~line~~rectangle denotes the projected new water demand of a large new supply-augmentation scheme). Sources of data: INEGI, 1990, 1995, 2000, 2005, 2010; 2015; CONAPO, 2015; CEA-Guanajuato & Conagua 2018; SAPAL, 2020.

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~~Leon's~~The history of León's water utility ~~has focused~~can be divided in two periods. One, where the local government ran the water utility until 1988, and a second one where the water utility became autonomous under the rule of an administration committee formed by representatives of various sectors of society, especially businesspeople. In the first period, pork-barrel politics characterized the water utility's administration, a common practice during the authoritative regime of PRI (Partido Revolucionario Institucional) (Costa-i-Font et al., 2003). Keeping a low-cost, albeit crumbling, water service was important for the political aspirations for the city mayors. Non-revenue water reached 60%, and neglected infrastructure caused high levels of physical losses and poor bookkeeping and corruption led to high commercial losses (Herrera, 2017). As a result, only 37% of users enjoyed daily water service while poor neighbourhoods would suffer no water service for days (Herrera, 2017).

The second period started during the late 1980s, when, under the influence of international organizations like the World Bank and the IMF, Mexico began adopting neoliberal privatization policies as a remedy to the overall perception of the state inefficiency. In 1988, under the notion that water shortages were limiting their growth, several business organizations in León coalesced under the banner of democratizing the municipality of León and improving its ~~efforts~~water service by giving autonomy to the water utility. During the 1988 local elections, this coalition ran under PAN (Partido Acción Nacional) a pro-business political party and won the election.

In the 1990s, the city sought to invigorate its vibrant leather industry and, with the new free trade agreement with the United States and Canada, to attract foreign investment. This also marked a political transition to favour industrialization and export agro-export businesses as a vehicle to development, leaving traditional farming as a thing of the past (Godinez Madrigal et al., 2019). However, politicians and business organizations recognized that limited water availability in the region and severe groundwater overexploitation represented a limiting factor for a sustained economic development of León and Guanajuato (Rodriguez, 2004; 2008; Herrera, 2017; Pastrana et al., 2017).

To solve this problem, the business-led water utility aimed at running the water utility as a business and relied on two strategies~~.~~ to improve the water service of León. One, depoliticizing the prices of the water service to increase physical and commercial efficiency ~~and achieve~~beyond cost recovery ~~since the early 1990s (Herrera, 2017).~~ (Tagle-Zamora & Caldera-Ortega, 2021). Two, since the 1990s, lobbying for a ~~supply augmentation solution to Conagua, the national water authority~~large water transfer (Godinez Madrigal et al., 2020). ~~With these~~These two strategies ~~Leon's and Guanajuato's authorities have aimed at solving what they think is the limiting factor for their economic development: water scarcity (Rodriguez, 2008; Herrera, 2017; Pastrana et al., 2017).~~were interlinked, since with the financial surplus of the utility's efficiency the water utility could partially afford the high costs of the water transfer.

~~The first strategy started after 1988, at a crucial point where the water utility (run by the municipality) had more than 60 % non-revenue water, and only 37% of its users enjoyed daily water service while poor neighborhoods would suffer no water service for days (Herrera, 2017). The system was in shambles since the water utility could not invest in infrastructure due to its below cost recovery water tariffs. These were kept low to avoid a politically costly decision of raising tariffs.~~

~~Since business organizations considered this situation a limit to their expansion and were the best organized civil society associations in León, they decided to organize a political opposition against PRI (the then ruling party). They found a powerful~~

~~social cause and political flag in the improvement of León's water system. With this platform they gained powerful political traction to force the democratization of the city and force PRI out of the municipality and the water utility (Herrera, 2017). This would result in the decentralization of the urban water supply and the creation of SAPAL, a parastatal water utility.~~

~~The main objective of the newly elected water utility administration was to make the utility independent from politics by involving influential citizens as members of its administrative board and to consolidate the utility's efficiency. They aimed at reducing non-revenue water by means of renovating built infrastructure and achieving cost recovery by increasing water tariffs.~~ ~~This~~The first strategy made León´s water tariffs the highest in the country and, consequently, per capita water use became one of the lowest in the country (Consejo Consultivo del Agua, 2011). This strategy was so effective in improving the utility's efficiency (reducing non-revenue water from more than 60% to less than 35% and water coverage improved to almost 95%), that Conagua awarded them with the prize of the best managed utility in the country in 2012. However, the ~~social~~public perception of the utility´s price hikes was that the utility ~~was managed~~operated as a business ~~when it should provide~~instead of a ~~public service~~steward of the human right to water (Caldera-Ortega, 2009; 2014; Lozano, 2014).

Domestic water users experienced a sudden hike in their costs, with the poorest users struggling to pay the water bills, while large automotive industries were attracted with water access subsidies (García Garnica & Martínez-Martínez, 2017; García Garnica 2018). This strategy has also brought about unintentional consequences, since it led many industries, especially the small units of the leather industry, to resort to the black market, where they would buy water tankers from farmers engulfed by the city sprawl (Caldera Ortega & Tagle Zamora, 2017; Hernández-González, 2020). This also indicates that SAPAL´s (~~León's water~~León'swater utility) official water demand might be underestimated. Despite this, the policies of the city and the state have incentivized the formation of long-term large industrial clusters in the region by promising secured water supply (García-Garnica, 2017).

~~In early 2000s, this strategy alone proved insufficient for the objective of continued economic development. In 2004,~~With the second strategy (the Zapotillo project), León and Guanajuato's authorities sought a water reallocation from the nearest sub-basin, the Verde River Basin, which Conagua awarded in 1995. However, the materialization of an infrastructure project was delayed until 2005, when the then Mexican president (Vicente Fox, a former governor of Guanajuato) and the governors of Jalisco and Guanajuato belonged to the same political party of PAN. The importance conferred to this project was such that SAPAL´s director mentioned that "[I]f we do not undertake a [supply augmentation] project in the coming five years […], we will not be able to have the same growth in León as we have today. We need to bring water, because we can still grow for five more years; afterwards, although we can sustain the supply to the city, we would need to halt its growth." (Rodríguez, 2004).

~~Therefore, in 2004, the national water authority announced the San Nicolas project in the Verde River basin, but a fierce and swift local opposition forced the authority to cancel it. In the same year, the water utility tried to acquire agricultural water rights from a neighbouring aquifer, but the local farmers resisted the project, ensuing a water conflict that ended with the cancellation of the project (Caldera Ortega, 2009). Finally, in the second half of 2005, the Zapotillo project was approved and publicly announced.~~ However, since 2013 the project and dam construction have been stopped because of a social conflict of the dam-affected communities (~~Section 4.2 describes the conflict in detail).~~Godinez-Madrigal et al., 2020). In response ~~and~~ to

~~supply~~ the growing water demand of the rapidly growing city, SAPAL~~ has~~ expanded its groundwater supply network to the aquifer of León as well as in the neighbouring aquifers of Silao-Romita, Turbio River and La Muralla. The number of deep tube wells of SAPAL grew from 124 in 2008 to 196 in 2019 and is pumping at ever increasing depths in all aquifers (Konijnenberg, 2019), in a context in which groundwater use for agriculture (accounting for up to 80% of all extracted groundwater~~) has gone by-and-large unchecked (Hoogesteger and Wester, 2017). In 2018, in view of the problems with the Zapotillo dam, CONAGUA declared the aquifer of Silao-Romita as having water availability (after years of deficit and declining water tables) to enable the institution to grant additional groundwater concessions to SAPAL (Hoogesteger, 2018). Additionally, SAPAL has explored the possibility to use the small Palote Dam (now only used for flood control) for domestic water supply while also working on the further improvement of their distribution network, the re-use of treated wastewater for watering the green areas of the city, supporting the reduction of industrial water use especially the leather industry and stimulating a reduction in domestic water supply through public water awareness campaigns (Konijnenberg, 2019). ~~, from more than 18,000 wells) has gone by-and-large unchecked because of toothless demand management institutions and weak and incomplete administration and regulatory systems (Hoogesteger and Wester, 2017).

Although it is still unclear whether the project can be finalized, SAPAL and Guanajuato's government consider ~~it~~the Zapotillo project not only the preferred but the only solution to bring water security to León (SAPAL 2009, 2012, 2016, CEA-Guanajuato & Conagua 2018). However, it is still uncertain if the objective of the Zapotillo project ~~will~~is to contribute to the sustainability of the water system~~,~~, or to a sustained capitalist expansion since Guanajuato's water authority expects water demand to almost double when the Zapotillo project is implemented (see Fig. 2's dashed ~~line) due to increased domestic and industrial water demand.~~

~~In conclusion, although León has implemented promising strategies regarding cost-recovery and reclaimed wastewater, they have been limited in scale, partly due to the expectancy of the Zapotillo project, which has disincentivized the implementation of upscaled demand management strategies (Caldera-Ortega et al., 2020). In the meantime, Leon's increased demand for water has been supplied through the expansion of the groundwater pumping network.~~rectangle). Thus, even with the new water transfer the authorities do not expect a reduction of the groundwater overexploitation, since the 3.8 m^3/s water transfer will not completely satisfy the new expected water demand of around 5 m^3/s (CEA~~-Guanajuato & Conagua 2018).~~ Guanajuato & Conagua 2018). This provides evidence of a future supply-demand cycle triggered by the Zapotillo project that will not reduce groundwater overexploitation because of an increased water demand.

In conclusion, although León has implemented promising strategies regarding cost-recovery and reclaimed wastewater, they have been limited in scale, partly due to the high expectations of the Zapotillo project to provide water security once and for all (Caldera-Ortega et al., 2020), which is a problematic expectation in light of the demand-supply cycle. Furthermore, León's and Guanajuato's authorities have passively accepted groundwater overexploitation by focusing on the Zapotillo project and overlooked an increased accumulation of groundwater rights in the hands of few powerful farmers, agro-export businesses, and industries that perpetuates a severely unsustainable groundwater dynamic (Hoogesteger & Wester, 2015; Hoogesteger, 2018).

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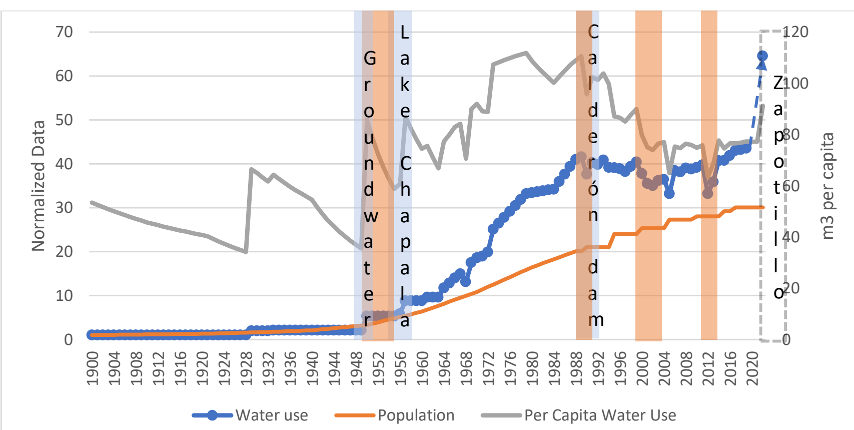
4.1.~~1~~2 Guadalajara

At the moment of writing this paper (2021), Guadalajara is suffering from a water shortage. The Calderón dam, a key water source contributing 14% of total water demand, is running dry and Jalisco´s politicians demand for the continuation of the Zapotillo project as the only solution (Del Castillo, 2021). This is the latest event of a controversial issue that has characterized Guadalajara for the past decades: ~~how to secure the city with sufficient water supply for its increasing population of more than 4 million inhabitants (Godinez Madrigal et al., 2020). This issue is controversial because, although Guadalajara has benefited from three large supply augmentation projects in the past (Fig. 3), water managers have striven to continue adding even more water sources to the city (Flores-Berrones, 1987~~expanding its water sources to further regions to keep up with the apparent ever-increasing water demand (López-Ramírez & Ochoa-García, 2012). The urban dynamics of Guadalajara have been characterized by a relentless urban growth that outpaces the capacity of the local governments to regulate it, and the water utility to incorporate new urban stretches into the networked system (Castillo-Girón et al., 1994; Del Castillo, 2018; Gleason & Casiano, 2021). Consequently, the urban water system of Guadalajara resembles an infrastructure archipelago (Baker, 2003; Allen et al., 2017), with approximately a hundred of non-networked neighbourhoods with scarce water access (Greene, 2021), hundreds of networked but intermittent neighbourhoods with low water quality (Pérez-Peña et al., 2009; Rubino et al., 2019) and high-income neighbourhoods and large industries with an independent and secure groundwater source (González-Valencia, 2020). As a result, the city faces a precarious and low-quality water access for hundreds of thousands of people, and over-exploited aquifers (Pérez-Peña et al., 2009; Rubino et al., 2019; Greene, 2021).



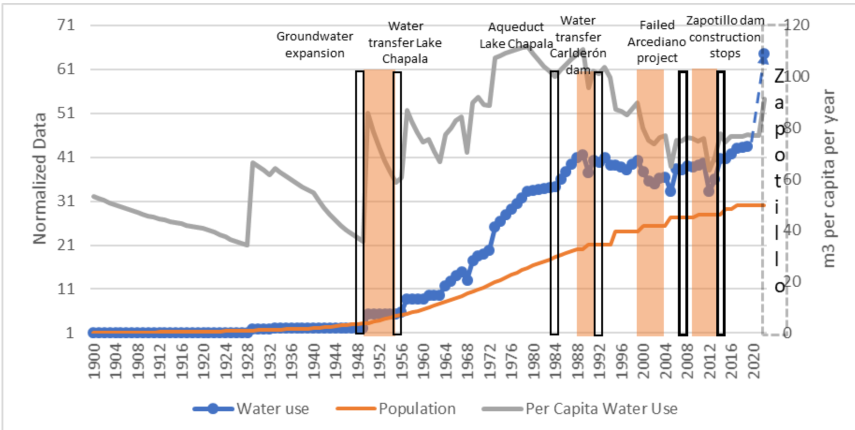


Figure 3~~:~~. The reservoir effect in Guadalajara (the blue bars denote the implementation of a large supply augmentation schemes in 1947, 1956, and 1991; red bars the presence of droughts; and the dashed ~~lines~~rectangle the official projected new water demand for the proposed large supply-augmentation scheme). Sources of data: INEGI 1900, 1910, 1921, 1930, 1940, 1950, 1960, 1970, 1980, 1990, 1995, 2000, 2005, 2010; 2015; Duran Juárez & Torres Rodríguez, 2001; Jalomo Aguirre, 2011; Torres Rodríguez, 2013; Conagua 2015; SIAPA, 2014b; Gómez-Jauregui-Abdo 2015; CEA-Jalisco & Gobierno del Estado de Jalisco, 2018; SIAPA 2020.

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~~The first~~ Historically, Guadalajara has benefited from three large supply augmentation ~~project~~ projects in the past (Fig. 3). The first was ~~implemented during the late 1940s and installed a network of wells to use~~ based on groundwater supply augmentation in the late 1940s that has continuously ~~been~~ expanded until today. ~~That new water source increased water demand to around 280 l/d/cap (SIAPA, 2016).~~ However, the accelerated population growth (higher than 6 ~~%)~~% per year) typical of Latin-American cities of the time (Camisa, 1972~~)~~), and a severe drought ~~that almost desiccated Lake Chapala (Godinez-Madrigal et al., 2019),~~ created an image of acute water scarcity. This generated a pressure to ~~expand~~increase water supply sources. Therefore, in 1956 when the drought ended ~~and the lake recovered, Guadalajara~~ , Guadalajara's government decided to build the Atequiza sluice ~~in~~ to make use of the ~~Santiago River (which originates from~~largest natural lake in Mexico, Lake Chapala~~), that would become the main water source for the city~~. The city also built a large drinking-water plant with an installed capacity of 9 m3/s (more than twofold of what was needed) to increase water supply from the lake on demand. ~~This infrastructure confirmed not only a dependency relation of Guadalajara to Lake Chapala, but it also allowed urban growth and a higher water demand per capita (Fig. 3). Such growth was fostered by a combination of weak urban planning, and public policies to attract investment (Castillo-Girón et al., 1994).~~ The governor of Jalisco considered this project "monumental" and a permanent solution to water scarcity for Guadalajara (Pérez-Peña & Torres-González, 2001). Moreover, the project was embedded in a larger policy of the hydraulic mission to make water available as much as possible for economic and urban uses (Boehm-Schoendube, 2005), a tendency that later led to basin closure and water conflicts between Jalisco and Guanajuato (Wester et al., 2005; Godinez-Madrigal et al., 2019).

~~During the 1980s, Guadalajara had already incorporated three adjacent municipalities as a unified, albeit chaotic, urban mass.~~However, the “permanent” Lake Chapala solution lasted only a couple of decades, because during the 1970s and 1980s Guadalajara’s increased water demand did overshoot water availability again. Therefore, the local authorities created SIAPA ~~an~~ (Sistema Intermunicipal de Agua Potable y Alcantarillado) in 1978, an intermunicipal water utility~~. SIAPA´s main mission was to expand water supply infrastructure to keep up with the urban expansion, rather than maintaining and improving the distribution network.~~

~~By the early 1980s the state and local governments increasingly developed groundwater, abstracting more than 2 m3/s of groundwater with 181 wells. Consequently, this level of abstraction started to present signs of over-exploitation in local aquifers.~~ to increase the water management capacity of the growing city. However, expert engineering and management knowledge have always been secondary to varied vested interests of Jalisco´s government (Del Castillo, 2018). Therefore, ~~in the late 1980s, an aqueduct directly from Lake Chapala replaced the Atequiza sluice, which was prone to surface contamination. And, projecting a continued water demand growth~~the water managers and engineers needed to solve water problems without affecting the status quo of a continuous expanding city and a large per capita water consumption (≈ 300 l/cap/day). Next, water engineers of Jalisco and Conagua ~~(the federal water authority)~~ developed a basin development plan of the Verde River Basin, known as Zurda-Calderón, to build more than 15 dams to expand Guadalajara´s water supply ~~(Ochoa-García et al., 2014).~~

~~By early 2000s,~~to meet an estimated future water demand of Guadalajara of 24 m^3/s by the year 2000, more than double the city’s actual water use in 2021’s (Flores-Berrones, 1988; Cabrales-Barajas et al., 1993; Ochoa-García et al., 2014). To date, only Calderón dam (1.5 m^3/s) has been implemented.

Although integrating urban planning with water management would have contributed to alleviate the increasing pressure over Guadalajara´s water supply sources, the city´s dynamics (as in many other cities in Mexico) has been characterized by a deregulated urban planning and an unrestrained urban speculation fostered by national neoliberal policies (Pérez-Peña et al., 2009; Pfannenstein et al., 2017, Reis 2017; Greene 2021). “Guadalajara´s business model is to expand horizontally and vertically” (Del Castillo, 2018). As a result, SIAPA was perceived as a water utility mainly managed to generate political and economic gains rather than a good service based on technical and administrative sound decisions (Del Castillo, 2011).

In the last 30 years, the network system deteriorated to a point where water service became intermittent and poor water quality led to the bottled water industry completely replacing tap water for human consumption (UASLP & CEA Jalisco, 2010; Greene, 2018; 2021; McCulligh et al., 2020). Under the neoliberal sanctioned discourse, this does not represent a problem since the market provided a solution to an inefficient public water utility. With this perspective, affluent neighbourhoods and large industries were also allowed to develop in protected natural areas and managed their own (secure) groundwater supply systems (Pérez-Peña et al., 2009; González-Valencia, 2020). Despite this, the focus has always been on the gap between demand and supply with the recurring threat of water scarcity. This threat was especially tangible when in 2004 Lake Chapala suffered again a water crisis that threatened 70% of Guadalajara's water supply that depended on ~~Lake Chapala~~it (6 out of 9 m^3/s of Guadalajara´s water demand). SIAPA suspended water service in several parts of the city (Flores-Elizondo, 2016). ~~To safeguard the lake, and more importantly, Guadalajara's main water source, Conagua mobilized resources and its authority to decrease the water use upstream in Guanajuato (for a more detailed description of this event, see Godinez-Madrigal et al., 2019).~~

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~~As consequence of the drought, in 2004,~~Continuing with a techno-managerial solution approach to solve the crisis, in 2004 Jalisco spent millions of dollars in prospective studies for an intra-basin water transfer project from the Santiago River called Arcediano, which would supply as much as 10 m^3/s to Guadalajara. The government had such high hopes that this project would solve the increasing water demand of Guadalajara in years to come that Jalisco´s government ordered SIAPA to grant any new ~~housing~~domestic water~~ use~~ request: "We can´t stop the city from growing" mentioned a high-ranking civil servant (Del Castillo 2018). Whereas the water transfer was not yet concretized, it had already increased water demand. Ultimately, the Arcediano project fell apart due to geological complications (López-Ramírez, 2012), prompting the search for a new supply augmentation project. In the meantime, the distribution network continued to deteriorate and water losses persisted, despite having the technology to swiftly repair leaks (Delgado-Aguiñaga et al., 2017).

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~~The city´s dynamics (and many other cities in Mexico) has been characterized by a deregulated urban planning and a vigorous urban speculation (Pfannenstein et al., 2017, Reis 2017). This urban dynamic was further fuelled by cheap water tariffs set at lower than~~Currently, the ~~cost of production. This situation undermined Guadalajara's urban water system, unable to invest in an aging and faulty distribution~~entrenched faith on large supply augmentation infrastructure ~~(non-revenue water higher than 35% and most~~ continues while pressing issues of highly unequal access to water of ~~its distribution system reaching 80 years-old (Gómez-Jauregui-Abdo, 2015)). As a result, SIAPA was perceived as a~~ poor quality, over-exploited groundwater and unabated urban growth are neglected, as are the high levels of unaccounted-for-water of the water utility~~ mainly managed to generate political gains rather than a good service based on technical and administrative sound decisions (Del Castillo, 2011). Ultimately, the Arcediano~~. This omission could rapidly offset the benefits of a large supply augmentation project~~ fell apart. Technically, the project was considered unfeasible due to geological complications (López-Ramírez, 2012). And, socially, civil organizations considered that the decision-making process simulated public participation, lacked transparency, and broke political promises to constituents and stakeholders (Lopez Ramirez & Ochoa Garcia, 2012).~~

~~Jalisco´s government current position is that the water resources of the Verde River basin are the only solution to the water shortage problem and increasing water demand of Guadalajara. Should~~, because should the Zapotillo project be implemented, the state water authority expects water demand to ~~continue the growing trend from before the 1980s drought and reach almost 17 m3/s~~grow to a level that would equalise the new water supply (represented by the dashed ~~bar~~rectangle in Fig. 3; CEA-Jalisco & Gobierno del Estado de Jalisco, 2018~~), and there will be no incentive to improve the current rate of non-revenue water caused by a lack of investment and low water tariffs.~~).

4.2 Opening up the decision space

The pastprevious subsection shows that the growth of both cities´ urban growth hashave increased water demand beyond current water supply and for both cities the Zapotillo project is perceived not as the main but the only viable strategy to bridge that gap. Although León has focused on implementing some alternatives to However, both cities experience water problems beyond a gap between supply and demand that a large supply augmentation, like reducing its non-revenue water to 32% and fostering reclaimed water for agricultural use, the continuing groundwater over-exploitation is their bottom line to lobby for the Zapotillo. Guadalajara has invested so many resources for the past three decades on developing the Verde River basin, that the Zapotillo project seems like the only option left will not fix. On the contrary, there are indications in both cases that it could further foster a supply-demand cycle (Kallis, 2010), and possibly the reservoir effect by increasing their dependence on the Zapotillo reservoir (Di Baldassarre et al., 2018). Therefore, considering the conflict that has put the Zapotillo project indefinitely on hold, the urban water systems of Guadalajara and León are facing a crossroads that warrants the question of what alternatives solutions can address León's and Guadalajara's water problems, and what are their challenges, obstacles, and potential.

However, a local network of social actors has lobbied to stop the Zapotillo project and proposedThe grassroots movement consisting of the dam-affected communities along with an international network of academics, practitioners and experts have been developing and proposing a portfolio of alternative strategies with fewer socio-environmental externalities than the Zapotillo project (Godinez Madrigal et al., 2020). Although these actors have deployed a variety of legal, social, communicational, and political strategies to achieve these goals, they have only been successful in temporarily stopping the Zapotillo project by producing a cohesive narrative on how the Zapotillo will not fix the root causes of the problem. On the other hand, these actors have not been able to bring about viable and actionableThe main alternatives.

Social actors developed a narrative consisting of how Jalisco's government has neglected the chaotic urban growth that has caused negative effects such as impermeable soils that obstruct groundwater infiltration and urbanized natural areas with high storm flow that are now causing recurring floods (CIESAS, 2018). In addition, they argue that SIAPA has not been able to further reduce its non-revenue water of 33% due to its obsolete leak detection methods, despite the local availability of advanced technology to swiftly localize them (Delgado-Aguiñaga et al., 2017). Related to water quality, water for domestic use does not meet drinking standards (McCulligh et al., 2020), forcing its population to depend on bottled water (Greene, 2018). Furthermore, most of its wastewater is untreated and currently affects the health of hundreds of thousandshave been debated in the southern part of the city (McCulligh 2017), which in turn cannot make use of that surface water to alleviate water shortages due to its high concentration of industrial and domestic pollutants (UASLP & CEA Jalisco, 2010). Turning to León, experts and social actors have criticized that the utility has not been able to reduce its 32% of non-revenue water nor increase water reclamation for industries (Tagle-Zamora & Caldera-Ortega, 2021). Moreover, urban floods are common due to increasing surface impermeability, insufficient wastewater treatment that pollutes downstream ecosystems (Tagle Zamora et al., 2015), and a costly water service that privileges efficiency for the sake of economic growth over affordable water access

~~to households (Tagle-Zamora & Caldera-Ortega, 2021). In conclusion, both actors from Guadalajara and León argue that the Zapotillo project does not consider nor aim to address the issues depicted above, because more water will not fix a broken system.~~

~~However, these criticisms do not directly translate into reliable alternatives, as the communities find it difficult to source sound expert opinions. The lawyer of the communities elaborated that: "A problem we often face is access to information; it has been opaque, not transparent and very technical […] another difficulty is to offer expert opinions; we have no one to do that. For example, a proof of environmental impact in anthropology, geology, engineering, etc. These are expensive [scientific] proofs. Sometimes we reach universities, colleagues, acquaintances. The communities cannot pay for those expert opinions". Therefore, although alternatives like~~media and the public agenda are rainwater harvesting, limiting urban growth, reclaimed wastewater reuse for industrial water demand, implementation of water-saving devices, reallocating water from agro-export businesses to domestic uses and reduction of physical losses in the distribution system ~~have been discussed on the media and the public agenda, they are yet to be developed into cohesive implementable plans due to lack of resources.~~

~~Water~~. However, local and state governments and water engineers ~~further antagonized the actors against the Zapotillo project as only opposers without a constructive criticism: "It´s so difficult to deal with these 'oposi-todos´ (anti-everything people)." (Anonymous~~conceived these alternatives as distractions to the only feasible solution, the Zapotillo project (anonymous interview with a retired water engineer of the state of Jalisco, 25 May 2018). ~~This lack of development of alternatives has become a talking point for actors supporting the Zapotillo project:~~ "Many organizations say they have been fighting for 10, 15 years for a position related to different alternative solutions for water [supply]. I think that if we continue like this for another 10, 15 years, then that method [sic] cannot deliver. It is just not possible to continue in the same situation for another 10 or 15 years." (~~Transcript~~transcript of a public talk of the Head of the civil engineer college of Jalisco, 22 Nov 2018). ~~The head of~~Even when the ~~Water Council of Jalisco added:~~alternatives´ potential is acknowledged, they are dismissed as unfeasible because "If we would consider implementing these projects [i.e., reducing physical losses and rainwater harvesting], it would take years and be very costly" (~~pers. comm. 22 December 2020).~~ interview with the head of the Water Council of Jalisco, 22 December 2020). Nevertheless, these negative assessments of alternatives are not backed up by thorough studies, but based on a priori judgements on water knowledge and dubious expert opinions (interview with local academic, 8 December 2018).

~~Considering these narratives, we found that a more quantitative approach was needed for a larger social impact, specifically in quantifying the potential of alternative solutions as viable pathways for the urban water systems of Guadalajara and León. Therefore, the authors improved the UNOPS model of the Verde River basin by adding the other two concerned regions: Guadalajara and León. The model was designed to answer a critical question: how does the Zapotillo project compare to alternative solutions for creating a sustainable and socially just urban water system? In early December 2018, we organized a participatory modelling workshop in Guadalajara attended by representatives of seven organizations with opposite positions vis-à-vis the Zapotillo project.~~

~~Through a debriefing session, the outcome of the workshop can be summarized as follows: the participants chose to run scenarios based on their own interests. Social actors comprised of NGO and dam-affected communities sought for evidence~~

that the Zapotillo project would not represent a solution; therefore, they tested scenarios with the Zapotillo infrastructure at 105 m without any alternative. Indeed, the model confirmed that scenario fared poorly in all its indicators (see Table 1). This group of actors sought to test the other 80 m, 60 m and decommission scenarios of the Zapotillo dam, but the model running time (≈ 30 minutes) limited the number of scenarios to run within the workshop´s timeframe.

Participants from the national water authority sought to test the effect of alternatives to produce good results for urban water supply and showed scepticism of the model and the developed alternatives:

"YouHowever, these negative assessments have become a talking point for actors supporting the Zapotillo project. Water engineers have depicted the actors against the Zapotillo project as bad faith opposers without a constructive criticism. In engineering circles, they are known as 'oposi-todos´ (anti-everything people). (Anonymous interview with a retired water engineer of the state of Jalisco, 25 May 2018).

Conscious of how the governments and experts portrayed the grassroots movement, members of the movement introduced to the public discussion the need to look for alternatives to large-scale supply augmentation infrastructure besides their main argument that the Zapotillo project was a mistake. However, with limited expertise and scarce resources, the grassroots movement faced limitations to clearly argue which alternatives would be more suitable to Guadalajara and León, and to what extent would they provide a reliable solution to the different needs of each city. Given this void, the authors of this paper collected the dispersed alternative solutions into an integrated water resources model. (see Supplementary material).

These two contrasting narratives collided during our participatory modelling workshop to compare alternative water supply solutions and the Zapotillo project for Guadalajara and León. The workshop was powered by a water resources model originally used to assess the Zapotillo project using reliability, resilience, and vulnerability (Godinez Madrigal et al., 2020). We compiled the most important alternative solutions and built them into the model to assess and compare all alternatives. Through a user-friendly interface, participants could choose their preferred strategies and analyse their performance. However, this time the indicators were based on both perspectives against and in favour of the Zapotillo project: water supply reliability for León, Guadalajara and water users in the donor basin, groundwater dynamics, and environmental flows.

During the workshop, engineering participants of IMTA, opted to test the communities' position and the alternative solutions they proposed. Their overall criticism of the participatory model was the underlying assumptions of the alternatives and that models are much more complex than what lay people can understand. "To lay people it is very obscure what a model entails; it is not as easy as giving them a computer and off they go […] [Regarding alternatives] you are trying to limit urban growth. I don´t think that is viable, I didn't understand that [measure] of limiting urban growth […] So, how are you going to make it happen [limit urban growth to 1 %/year?] It is unrealistic. If we are growing 2 %/year, how am I going to decrease it to only 1 [%/year], sure not magically." (IMTA engineer, 6 Dec 2018).

Other participants acknowledged the uncertainties of the model as well and considered that citizens should also be part of choosing which data fed the model to increase trust. Moreover, the participant of Jalisco's government saw value in the model as a tool to aid in complex decision-making and celebrated an active role of scientists in controversial situations. And participant engineers appreciated the capacity of the model to generate dialogue as a steppingstone for building concrete alternatives:

"The importance of this methodology [participatory modelling] is that it has been able to generate dialogue without confrontations […] because [we] Mexicans do not know how to dialogue. We impose our vision, we want everybody to agree with us, and, this methodology, this process, generates its own structure to generate dialogue." (Former IMTA engineer, 6 Dec 2018).

Social actors comprised of NGOs and dam-affected communities preferred to test the performance of the Zapotillo project and realized that it would also take years before the dam could be filled and be ready to use for León and Guadalajara, and that it would not be a solution for the groundwater over-exploitation. As a response to the engineering group, they acknowledged that the data in the participatory model may not be optimal and found the need to democratically curate input data, which led them to critically assess how data and expert opinions of water managers and engineers could also easily be manipulated: "The model is not perfect, because there is incomplete information, and needs to have more adjustments to become more useful. But we agree that previous governmental models [that warranted the Zapotillo project] were also running with incomplete information and were biased by their own interests. […] This tool can be useful for communities to criticize technical and political arguments and support alternatives, because the situation can be analysed in a more integrated way, with more social criteria, not like the government´s previous models." (representative of IMDEC).

Although all actors agreed that the model itself was incapable of finding an optimal solution to the conflict because of its inherent uncertainties and numerous configurations, most actors stated that participatory modelling could become a powerful process to engage actors to find negotiated solutions in the long run. They reflected on how essential it is to improve our governance processes to better deal with complex issues and uncertainties, since they cannot be reduced by technical studies nor expert engineers: "The more connections we make [in the model], the less certainty we have, therefore, it is an issue of governance, where all actors must be present to discuss and build agreements, because there will never be a 100% satisfactory technical solution." (representative of Tómala). Other civil society participants acknowledged the uncertainties of the model as well and considered that citizens should also be part of choosing which data to feed the model to increase trust. Especially for communities affected by socio-environmental problems, the modelling tool seemed to also have an additional potential:

"I sincerely see this tool´s potential not so much for helping make decisions, but for understanding what the problem is. I was envisioning... and felt emotional, that in my community we could have the chance to work the model with a lot of people. Because just imagine that the community could make a leap in understanding in a brief period of time a whole problem." (Member of an affected community, 6 Dec 2018).

After the workshop, the head of Conagua and the engineers who participated in the workshop stated their commitment to continue developing alternatives to solve the conflict. This participatory modelling workshop led to follow-up activities. A year later some of the social actors who participated further explored alternative technical solutions by organizing a series of workshops in coordination with the newly elected leftist federal government of Mexico, in which three alternatives were further explored with the assistance of a dozen of international and national experts in different fields: improving groundwater management, rainwater harvesting and reducing physical losses. including rainwater harvesting and reducing physical losses. However, the state governments of Jalisco and Guanajuato criticised and disapproved the participation and support of the federal government in these workshops on alternative solutions. The president of the business association of León mentioned that "We do not know the intention of these workshops, but we are against exploring new alternatives, especially if they are serious […] All this affects our competitiveness." (Aristegui, 2019).

However,In this series of workshops lackedcontext, the capacity to develop scenariospublic attention and compare them with the federal public policies have shifted from the Zapotillo project. Therefore, to increase as the social impact of scientific knowledge, we developed five sets of scenarios with different combinations of infrastructure configurations. Table 1 presents the results and characteristics of the scenarios we explored. (See supplementary material for a more detailed description of these sets.)

Table 1: Overview of the scenarios' performance.

Infrastructure configuration	Dam	✗	**60 m**	**80 m**	**105 m**	**60, 80, 105 m**
	Alternatives	✓	✓	✓	✓	✗
Number of scenarios		15	30	30	30	3
Indicators	> 95 % water supply coverage	0	8	8	24	0
	Sustainable groundwater use	0	0	0	9	0
	Meet Eflows requirements	15	30	30	15	0
	Dam-affected communities are not flooded	15	30	0	0	1
Number of acceptable indicators per group of scenarios		2/4	3/4	2/4	3/4	1/4

The results of the fifth set shows that the Zapotillo project in its three configurations without the conjunctive useonly option, to the potential of alternative strategies perform poorly, since they are not even able to produce a > 95 % coverage for water solutions for Guadalajara and León, which is. Currently (November 2021), the primary objectivefederal government has agreed to decrease the operation scale of the Zapotillo project. However, decommissioning the dam and implementing three alternative solutions simultaneously cannot produce a > 95 % coverage forfrom 105 m to a maximum dam height of 50 m (which implies that the water supply from the dam to Guadalajara and will reduce to 3 m^3/s, and that the water transfer to León either. Therefore, decommissioning the dam might be counterproductive. On the other hand, the hybrid infrastructural configurations (using the Zapotillo project in 60, 80 and 105 m in conjunction with the alternative solutions) present better outputs.

The different pathways represented by these infrastructural configurations show the multiple trade-offs involved with the Zapotillo dam. On the one hand, with the group of infrastructural configurations with a 60 m is cancelled)" (Conagua, 2021) in order to spare the dam, only 8 scenarios have a positive > 95 % coverage for affected communities. Guadalajara and León, but these scenarios cannot reverse the groundwater overexploitation present in both regions. However, environmental flows meet the flows stipulated by the Mexican law (Norma Mexicana, 2012), and the dam-affected communities are spared.

The group of infrastructural configurations with an 80 m dam improves the groundwater indicator by helping reverse groundwater overexploitation in León´s aquifer and curbs the overexploitation in Guadalajara´s aquifers. However, the caveat is that, although they all meet the ecological flows in the Verde River, the communities will be flooded.

Finally, most of the scenarios of the 105 m dam group of infrastructural configurations have positive results in the > 95 % coverage for Guadalajara and León indicator. Of these, a group of nine scenarios can reverse the groundwater over-exploitation in both regions, and within that group, even three meet the ecological flows in the Verde River when the dam management prioritizes ecological flows. However, all the dam-affected communities would be flooded. In conclusion, will either search for new, further and more costly large-scale supply augmentation projects with the risk of triggering more conflicts or be forced to start experimenting and adopting some of the alternative solutions described in this then is the crux of the crossroads: no alternatives exist that can satisfy all competing demands. Thus, trade-offs exist and, inevitably, choices must be made.paper.

45 Discussion

Socio-hydrology and hydrosocial studies are two (usually competing) disciplines that have focused on analysing the many challenges facing urban water systems. There is a To fully understand the pathways of León and Guadalajara, they need to be framed under larger social, economic, and political dynamics and the Zapotillo supply augmentation project. With a sociohydrological perspective, we analysed the interplay of social, and hydrological processes that resulted in the current heated scientific debate whether one discipline offers better explanations or solutions for troubled urban water systems or if they can complement each other to make their knowledge more actionable and relevant (Wisselink et al., 2017; Di Baldassarre et al., 2019). We argue thatpredicament of León and Guadalajara. Moreover, our concept of development pathway crossroads offers a cross-fertilization opportunity for both disciplines.

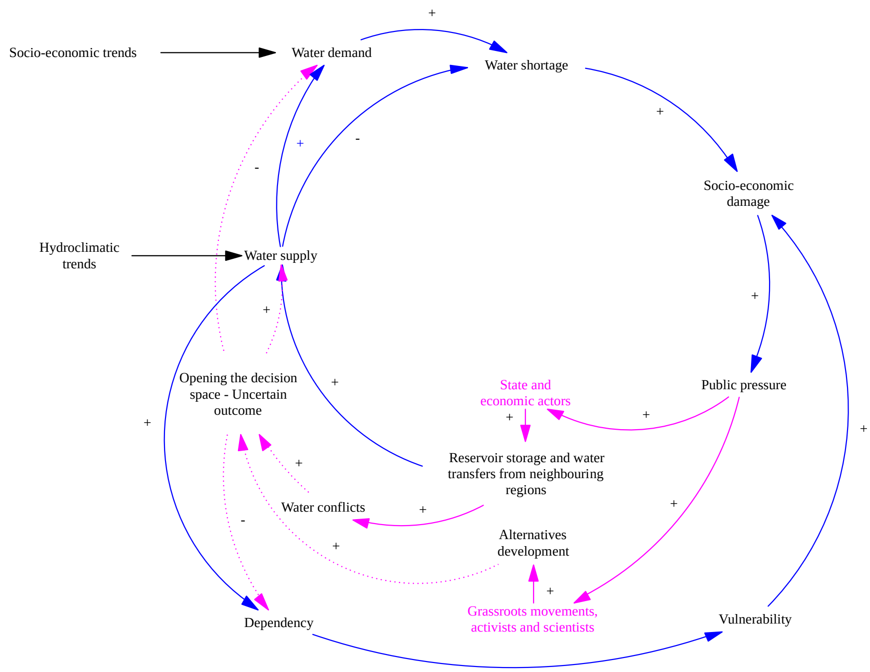
Our retrospectivepolitical ecology analysis based on hydrosocial studies of Kallis (2008) and Molle & Wester (2009) of the co-evolution of Guadalajara´s and León´s human-water systems shows that the trajectories of both cities have been defined by its continuous and unrestrained socio-economic growth. As a result, these cities have sought additional water sources for at least the past thirty years. Although although water managers have warranted thatthe quest for new water supply sources based on the "inevitability" of socio-economic growth, we found that more than inevitable, socio-economic growth has been actively promoted as a development pathway.

To fully understand the Zapotillo case, it needs to be framed under larger social, economic, and political dynamics. Therefore, although the project will certainly endow Guadalajara and León the necessary water resources to keep growing, it may not guarantee its long-term water security as explained below.

Our results show that the Zapotillo project is conceived by the authorities´ own accounts as a provisional strategy (CEA-Guanajuato & Conagua, 2018; CEA-Jalisco & Gobierno del Estado de Jalisco, 2018), since they willwould require additional future large supply augmentation infrastructure once water demand outstrips water supply again in the coming decades. This is so, because there are socio-economic dynamics that are currently bounded by limited water availability, which would then be unleashed and be supported by an increased water supply. This behavioural pattern of cities and water managers is understood as a driver of the supply-demand cycle found in other cases around the world (Kallis ~~2008~~2010, Di Baldassarre et al., 2018).

~~Furthermore, analysing~~Analysing the case of Guadalajara through the lens of ~~the~~ socio-hydrology ~~work on the 'Reservoir effect' by Di Baldassarre et al. (2018),~~ we found that the city´s current water shortage and its concomitant socio-economic damage (as of June 2021) is the result of the ~~higher vulnerability of the city due~~ increased water demand fostered by its ~~dependence to its current~~ intra-basin water transfers (Calderón dam and Lake Chapala~~). In turn, public pressure is being used~~), and its increased dependency on these reservoirs. Moreover, a critical perspective on this urban water system shows that the emphasis given to the large supply-augmentation Zapotillo project will not fix the current situation of non-networked residents and the multiple network deficiencies (high physical losses and aging infrastructure). These deficiencies are partly responsible for the water shortages and an intermittent water supply experienced by mostly poor neighbourhoods. This shows a policy gap between non-networked and intermittent water systems and large infrastructure, as shown in other cases (Allen et al., 2017). Despite this policy gap, politicians ~~to peddle~~peddled the Zapotillo project ~~(another~~as the only solution to bring about water ~~transfer) to shield~~security for Guadalajara~~ from future water shortages.~~, despite that the supply augmentation will most likely attend new water demand. Thus, this ~~decision continues~~project would further continue the supply-demand cycle and ~~an increased dependency and~~thus increase the vulnerability ~~for~~of Guadalajara in the future.

~~Figure 4 shows (in blue arrows) the composition of the feedback loops between the human and water systems that cause the "reservoir effect". However, since some of these feedback mechanisms are still not well understood (Di Baldassarre et al., 2018), we elaborated a more nuanced understanding of the variable 'public pressure' and introduce the concept of crossroads. We argue that once cities experience water shortages due to hydroclimatic trends and socio-economic growth, politicians (and other economic interests) channel this public pressure to further and warrant large supply augmentation schemes, as in the present case of Guadalajara. However, grassroots movements, civil organizations, and scientists also device strategies to channel the public pressure to support alternative strategies and criticize the dominant large supply augmentation development pathway. This creates a rift in the decision space, which we have dubbed 'the development pathways crossroads' (shown in pink arrows in Fig. 4).~~



~~**Figure 4: The water conflict disruption in the reservoir effect (the dashed lines indicate their hypothetical status, while the pink lines indicate new variables not yet considered by the original conceptualization by Di Baldassarre et al. (2018).**~~

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~~This kind of crossroads is characterized by conflict and a highly polarized public discussion packed with controversies of the subject, in this case, how to bring about sustainable water security to Guadalajara and León (Godinez Madrigal et al., 2020). Our results based on the hydrosocial approach show that the political economy of Guadalajara has subordinated urban water management as a function of urban expansion, while its water utility has not had leeway to set tariffs matching production costs to gather the necessary resources to maintain an aging and increasingly faulty infrastructure. The meagre resources have been directed to facilitate the addition of new customers, not increasing physical efficiency. Although León has been able to raise tariffs to maintain and improve its distribution network to a certain extent, its amassed financial resources have been saved to afford the Zapotillo´s water transfer as its only alternative to keep growing its economy.~~

~~Moreover, the development pathway characterized by continued population and economic growth has been naturalized as evidenced by the IMTA engineer ("So, how are you going to make it happen [limit urban growth to 1 %/year?] It is unrealistic.") The urban development of Guadalajara and León have privileged a chaotic urbanization that has disrupted~~

~~hydrological processes like stormwater infiltration, causing at the same time a lower rate of infiltration and recharge of over-exploited aquifers as well as costly urban flash floods. Therefore, analysing the Zapotillo case from the perspective of development pathways shows that events have a longer chain of causalities than is apparent at first sight. Not only is the conflict more than 15 years-old, but the social, political, and economic dynamics that have transformed the territory and made the Zapotillo project seem necessary dates decades back.~~

~~Likewise, the emergence of a competing alternative development pathway needs to be traced back since at least the inception of the conflict. However, transitioning~~In the case of León, although its urban water system characteristics are different than Guadalajara´s, the effect of the supply augmentation Zapotillo project is similar. Our analysis shows that, due to its almost total water supply dependency on groundwater, León´s water utility has improved its efficiency indicators better than Guadalajara´s in terms of lower non-revenue water, higher percentage of networked households and reclaimed water for agricultural purposes. However, its alarming groundwater situation, also affected by large-scale agricultural dynamics, is not likely going to change with a water transfer. To the problem of groundwater over-exploitation in the region, water managers need to consider radically different and equitable institutional arrangements between rural and urban users to curb its unsustainable water use, as suggested by Hoogesteger & Wester (2015) and Molle & Closas (2019) (see also Hoogendam, 2019, for a similar case in Cochabamba).

Therefore, the similarity between the two cases lies in the way politicians overestimate the capacity of the large supply augmentation Zapotillo project to solve the current water problems and future challenges of these urban water systems. Moreover, these politicians also underestimate the potential of alternative solutions as well as the likely unintended negative consequences of such an infrastructure project, such as like the supply-demand cycle (Kallis, 2010; Gohari et al., 2013) or the reservoir effect (Di Baldassarre et al., 2018).

Leach et al. (2010) work on development pathway argues for the need to unearth alternative, often marginalized pathways by using different assessment tools and methods. Therefore, with a transdisciplinary approach, we analysed the emergence and dynamics of the competing alternative development pathway of the conflict. Our analysis on the decision space shows that the engineering mentality prevalent among water managers tended to dismiss any alternative pathway based on the perceived incapacity of the grassroots movement to show results or empirical evidence of the alternatives. Water managers also dismissed alternative solutions based on the lack of time and resources to investigate their merits, since the groundwater overexploitation and water shortages facing Guadalajara and León are so urgent that only the tried-and-tested, ready-made solution of the Zapotillo project is framed as feasible.

Transitioning to an alternative development pathway is usually faced with fierce opposition, since "[t]here is often assumed to be a singular path to progress, any questioning of which is taken to indicate an 'anti-innovation', 'anti-technology' or 'antidevelopment' stance" (Leach et al., 2010), and in the Zapotillo case ~~also known as~~personified by the "*oposi-todos*". ~~And critics~~Critics often pitch a simplistic narrative of pitting the rights of the majority against the rights of the minority and ask the latter to sacrifice for the "common good" (Roy, 1999~~,~~; Leach et al., 2010). This narrative frames the minority as the culprit for not accepting the project, which is left unquestioned. In fact, Scott (1998) and Agrawal (2005) explain that 'high modernist'

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planning actively excludes political processes such as deliberation and negotiation precisely to avoid further questioning and preclude the emergence of alternatives. ~~Nevertheless, any kind of deliberation and negotiation around solutions for water problems in both cities has necessarily been skewed, since the current decision space has been largely determined by the dominant large supply augmentation strategies. The technical actors promoting the Zapotillo project emphasized that there was not enough time and resources to develop any alternative solutions, since the water problems facing Guadalajara and León are so urgent that only the tried-and-tested, ready-made solution of the Zapotillo project is feasible. This professional culture of water engineers and managers acts as a powerful feedback mechanism that fosters the 'reservoir effect', since water managers consider that the water problems facing Guadalajara and León are technical problems, and downplay the importance of deliberative and negotiation processes, which are political in nature.~~

~~Our results of the scenario exploration analysis, a tool often used in socio-hydrology, show that even if an alternative development pathway is implemented, both urban water systems of Guadalajara and León will present difficulties in decreasing groundwater over-exploitation and achieving a higher than 95 % coverage. Therefore, if most optimal scenarios require hybrid solutions (supply augmentation infrastructure plus alternatives), then both social actors and engineering and governmental actors need to acknowledge the necessity to open the decision space and include each other´s inputs, perspectives, and proposed solutions to build a sustainable and socially just urban water system.~~

~~We argue that opening the decision space is an opportunity for socio-hydrology and hydrosocial scientists to contribute and complement each other's work to make it actionable and to increase its relevance. Some socio-hydrology research conclude on the need to implement different strategies to increase sustainability and socially just outcomes in troubled water systems (i.e., Enteshari et al., 2020), but fail to acknowledge the socio-political complex dynamics of the water system, in which such strategies should be implemented. Such important contributions can fall on deaf ears and be ignored without the relationship with local actors.~~

~~Our~~Regarding the dynamics that determine the decision space of urban water systems, our experience from the participatory modelling process showed the importance of open science not only to replicate results (Godinez Madrigal et al., 2020), but also to repurpose the design of a water resources model that was initially used to justify the Zapotillo project by expanding its system boundaries. By adding the Guadalajara and León water systems in the model~~ to test~~, alternative water supply strategies ~~(originally absent from the UNOPS model), the model~~ could ~~answer questions raised by actors opposing the Zapotillo project. However, we were also limited by the many uncertainties inherited by the original UNOPS model related to groundwater in the donor basin (see Godinez Madrigal et al., 2020), and the running time of the model, which limited the number of scenarios ran by the stakeholders in the workshop~~be tested, allowing participants to explore different strategies based on contrasting narratives.

The results of the participatory modelling workshop show that stakeholders critically reflect on the role of data, information and scenarios that are often used to justify policies, decisions and infrastructures ("because the situation can be analysed in a more integrated way, with more social criteria, not like the government´s previous models" as said by the representative of

Tómala). This critical perspective also allowed for a reflection on the purpose of water resources models as decision support systems. When an IMTA participant warned on the risk of giving a complex modelling tool to lay people, a representative of the grassroots movement acknowledged the assumptions and uncertainties of the model and foregrounded the key role of governance processes in relation to these unavoidable technical shortfalls of models. Participants of the grassroots movement were eager to participate in designing the model and deciding on the input information. This interest further contributed later to technical workshops with the federal government to develop alternatives to the Zapotillo project.

Therefore, we argue that in the socio-hydrological conceptualization of the supply-demand cycle and the reservoir effect, scientists need to pay special focus to the almost inevitable water conflicts inherent to endless supply augmentation projects, and to the emergence of grassroots movements presenting alternative narratives. This can evolve into a development pathway crossroads that opens up the decision space as presented in Figure 4. Based on our analysis of the cases of León and Guadalajara in relation to the Zapotillo project, water conflicts driven by grassroots movements have a role in disrupting the supply-demand cycle. First, by blocking and delaying the implementation of the large supply augmentation project, and second, by fostering a more conscientious public debate about the decision space of the urban water systems. The main narrative that framed the Zapotillo dam as a necessity and the only solution and ignored alternative solutions has changed. Water managers no longer ignore alternative solutions, at first, they criticized them, and now they take them seriously. Further research is needed to see if they will be implemented, but judging from the recent downscaling of the Zapotillo project, they may be forced to at least consider them. Without a large supply augmentation project, the cities will need to implement demand management (negative feedback for water demand in Fig.4) and/or decentralized small-scale supply augmentation strategies (positive feedback for water supply in Fig. 4) that could thwart the supply-demand cycle.

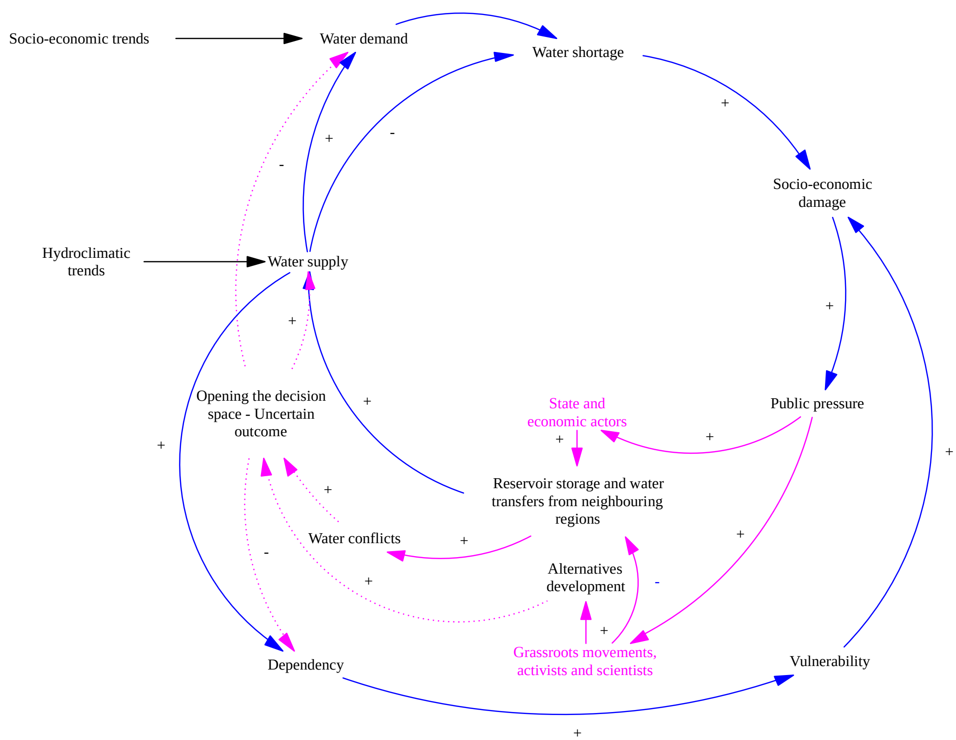

Figure 4: The water conflict disruption in the reservoir effect (the dashed lines indicate their hypothetical status, while the pink lines indicate new variables not yet considered by the original conceptualization by Di Baldassarre et al. (2018).

~~The results of the participatory modelling workshop show that stakeholders are eager to learn and use new tools, but especially to be considered in their design. Other actors even envisioned using the tool not for helping decision-making, but for problem understanding within the affected community. Therefore, scientists can have an active role in promoting deliberation and negotiation between stakeholders, even in contexts of conflict, polarization, and knowledge controversies. Moreover, scientists may need to take on an additional role to repurpose their own tools to elicit the stakeholders' own purposes and goals. As a result, a participatory modelling process can open the decision space by co-developing alternatives proposed by actors~~

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representing a competing pathway to have a more balanced deliberation and negotiation processes even in contexts of power asymmetry (i.e., Basco-Carrera et al., 2017; Van Cauwenbergh et al., 2018).

However, these roles may lie outside the current tasks that are expected from scientists (Lane, 2017), and may require an active support from universities, since these social processes may not have immediate scientific relevance and require investing time and resources (Lane, 2017). Furthermore, in the pursuit of more sustainable approaches, socio-hydrology must not only aim at informing policymaking (Di Baldassarre et al., 2018), but also empowering actors that propose an alternative development pathway through the co-production of knowledge and technical tools. Similarly, in the pursuit of transforming conflicts, hydrosocial studies must not only challenge power asymmetries that seek to preserve the status quo by means of identifying and describing power devices, but also identify and co-develop alternatives that can open the decision space and boost the position and perception of social actors to articulate and enlarge a network of actors (Huitema & Meijerink, 2010).

We are certainly not arguing that we have achieved a conflict transformation in the Zapotillo case nor found an optimal strategy to bring about sustainability and socially just outcomes. Instead, we explored the complexity and difficulty of a potential conflict transformation and the gamut of possible strategies through the lens of a development pathway crossroads, which captures the tension between social and political actors with different visions analysed by hydrosocial studies, as well as the potential future pathways studied by socio-hydrology.

56 Conclusion

This paper researchedconceptualized and investigated the current development pathway crossroads of the Zapotillo conflict in Mexicocities of León and Guadalajara to understand the multiple influences that determine dominant development pathways and the role of conflicts in opening the decision space to embark a new alternative pathway for the urban water systemrole of water conflicts and grassroots movements in interfering with the supply-demand cycle. It did so by analyzing the urban water system trajectories that configured the present water scarcity and over-exploitation problems in León and Guadalajara and León, and exploring the potentialsocio-political dynamics of alternative future pathways proposed by actors in conflict.

The dominant development pathway in León and Guadalajara and León has been characterized by a techno-managerial, control-oriented approach that went unchallenged for almost a century, what Leach et al. (2010) describe not as a pathway, but a 'motorway'. However, in the last three decades this pathway has been heavily scrutinized and thoroughly criticized by social actorsa grassroots movement opposing this kind of development pathway. This social opposition disrupted and caused two large infrastructural projects to fail and put the Zapotillo project in an indefinite hiatus. This hiatus has lasted 15 years, and to date it remains unclear which development pathway León and Guadalajara and León will undertake. embark on.

With a transformative spirit infused by the work of Leach et al. (2010) Di Baldassarre et al. (2019) and), Zeitoun et al. (2019), and Rusca & Di Baldassarre (2019) we aimed at using socio-hydrology and hydrosocial studies to understand better the social, political, cultural, and economic factors and dynamics that have configuredanalysing the development pathways at the crossroads and contribute to stimulate the necessary deliberation and negotiation of urban water systems with a larger decision

~~space to~~ transdisciplinary political ecology and socio-hydrology approach and explore the role of conflicts and grassroots movements in forcibly creating a ~~more sustainable~~ development pathway~~.~~ crossroads. Our research showed that the methodological framework of socio-hydrology related to the 'reservoir effect' (Di Baldassarre et al., 2018), combined with the critical political ecology approach of hydrosocial studies (Kallis, 2008; Molle & Wester, 2009, Savelli et al., 2021), can be used to problematize the still dominant sanctioned discourse of large supply augmentation infrastructure in other contexts. This exercise in conjunction with a participatory ~~approach and~~modelling workshop with key actors based on an empowering design (Stirling et al., 2007; Leach et al., 2010) can broaden what are the issues at stake in the urban water systems and open up the decision space beyond large supply augmentation infrastructure.

We broadened the issues by identifying that the main urban water problems are not only related to a ~~discrepancy~~gap of water supply and water demand over time, but also to an unchecked and even sponsored economic and population growth, ~~low~~uneven water ~~tariffs~~access, aging distribution infrastructure and neglected ~~intractable drivers like climate change. Our research design was also influenced by the actors who aim at finding alternatives~~rural-urban dynamics related to groundwater overexploitation. This is relevant because a large ~~infrastructure.~~water supply augmentation project will not solve these issues. With our ~~water resources model and~~ participatory modelling workshop, we ~~opened~~contributed to opening up the decision space by modelling most of the alternative solutions brought up by the ~~actors opposing the conflict, the 'oposi-todos'~~grassroots movement.

~~We arrived at two main conclusions. One, if Guadalajara and León choose to follow the dominant development pathway, it is likely that they will trigger, and be trapped by, the 'reservoir effect' (Di Baldassarre et al., 2019) and make the urban water systems more vulnerable to intractable drivers of change in the future. And two, that although the dominant development pathway presented large drawbacks, we could not identify any alternative development pathways without trade-offs. Therefore, if scientific disciplines like socio-hydrology and hydrosocial studies want to contribute to transform urban water systems to become more sustainable and just, they have to identify the hard choices that have to be made and to bridge the gap between technical and social disciplines to account for power relationships and the complex nature of water systems; as well as conducting 'slow science' (Lane, 2017) in close proximity with actors to contribute to more sustainable and just societies.~~We arrived at three main conclusions. One, that the supply-demand cycle is fuelled by the perceived inevitability of urban and economic growth, and an unwarranted faith that large-scale augmentation projects will solve complex current and future water problems like water shortages and groundwater overexploitation. Two, that water conflicts driven by grassroots movements have an important role in interfering with the supply-demand cycle by stalling the implementation of large infrastructure projects, creating a development pathway crossroads and fostering public discussion on alternative pathways. And three, that participatory modelling is a promising tool to open the decision space by co-developing alternatives proposed by actors representing a competing pathway to have a more balanced deliberation and negotiation process even in contexts of power asymmetry.

Code Availability

The reader can access the SimVerde software at: https://github.com/jongmadrigal/SimVerde.

Data Availability

The reader can access the data produced in the analysis of the different infrastructure configurations of the SimVerde at: https://github.com/jongmadrigal/SimVerde

Author ~~contribution~~Contribution: Conceptualization, JGM, NVC and PvdZ; Data curation, JGM and PCG; Formal analysis, JGM; Investigation, JGM, JH, PCG and NVC; Methodology, JGM, NVC and PvdZ; Software, JGM and PCG; Supervision, NVC and PvdZ; Writing—original draft, JGM; Writing—review & editing, NVC, JH and PvdZ

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Competing interests: ~~The authors declare that they have no conflict of interest~~THE AUTHORS DECLARE THAT THEY HAVE NO CONFLICT OF INTEREST.

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Financial ~~support~~Support:

This research has been supported by the Consejo Nacional de Ciencia y Tecnología (grant no. 409777).

References

Agrawal, A.: Environmentality: Technologies of Government and the Making of Subjects, Duke University Press, Durham, 2005.

Ahlers, R., Zwarteveen, M., & Bakker, K., (2017). Large dam development: from trojan horse to pandora's box. In Flyvbjerg, B. (ed.) The Oxford Handbook of Megaproject Management. Oxford University Press, 2017.

Allan, T.: 'IWRM/IWRAM: a new sanctioned discourse?', School of Oriental and African Studies, Occasional, pp. 1–27, 2003.

Allen, A., Hofmann, P., Mukherjee, J., & Walnycki, A.: Water trajectories through non-networked infrastructure: insights from peri-urban Dar es Salaam, Cochabamba and Kolkata. Urban Research & Practice, 10(1), 22-42, 2017.

Aristegui: En Guanajuato, IP y gobierno rechazan búsqueda de alternativas a la presa El Zapotillo. Available at: https://aristeguinoticias.com/1411/mexico/en-guanajuato-ip-y-gobierno-rechazan-busqueda-de-alternativas-a-la-presa-el-zapotillo/, November 14, 2019.

Bakker, K.: Archipelagos and Networks: Urbanization and Water Privatization in the South, The Geographical Journal, 169 (4): 328–341, doi:10.1111/j.0016-7398.2003.00097.x, 2003.

Basco-Carrera, L., van Beek, E., Jonoski, A., Benítez-Ávila, C., & Guntoro, F. P.: Collaborative modelling for informed decision making and inclusive water development. Water resources management, 31(9), 2611-2625, 2017.

Basco-Carrera, L., Meijers, E., Sarısoy, H. D., ~~Biswas, A. K., Sachdeva, P., & Tortajada, C.: Phnom Penh water story. Springer, 2018.~~

Şanli, N. O., Coşkun, S., Oliemans, W., ... & Jonoski, A.: An adapted companion modelling approach for enhancing multi-stakeholder cooperation in complex river basins. International Journal of Sustainable Development & World Ecology, 25(8), 747-764, 2018.

Bloomberg: Water Futures to Start Trading Amid Growing Fears of Scarcity. 6 December 2020. ~~Available at: www.bloomberg.com/news/articles/2020-12-06/water-futures-to-start-trading-amid-growing-fears-of-scarcity,~~Available at: www.bloomberg.com/news/articles/2020-12-06/water-futures-to-start-trading-amid-growing-fears-of-scarcity, 2020.

Boehm Schoendube, B.: Agua, Tecnología y sociedad en la Cuenca Lerma-Chapala: Una historia regional global. Nueva antropología, 19(64), 99-130, 2005.

Boelens, R.: Cultural politics and the hydrosocial cycle: Water, power and identity in the Andean highlands. Geoforum, 57, 234-247, 2014.

Boelens, R., Shah, E., & Bruins, B.: Contested knowledges: Large dams and mega-hydraulic development. Water 2019, 11(3), 416; ~~https://doi.org/10.3390/w11030416,~~https://doi.org/10.3390/w11030416, 2019.

Budds, J.: Contested H2O: Science, policy and politics in water resources management in Chile. Geoforum, 40(3), 418-430, 2009.

Cabrales-Barajas, L., Chávez-Hernánez, A., & Zaragoza-Vargas, F.: El Río Verde: Agua para Guadalajara, Carta Economica Regional, año 5, num. 29, 1993.

Caldera-Ortega, A. R.: Gobernanza y sustentabilidad: desarrollo institucional y procesos políticos en torno al agua subterránea en México: los casos del valle de León y del valle de Aguascalientes, 2009.

Caldera-Ortega A. R.: La gestión del agua urbana de León, Guanajuato: Un análisis político de las ideas que dan forma a las políticas públicas y sus resultados. In Tagle-Zamora (ed.) La crisis multidimensional del agua en la ciudad de León, Guanajuato. Universidad de Guanajuato-Porrúa: León, México, 2014.

Caldera-Ortega, A. & Tagle Zamora, D.: Saneamiento del agua en León, Guanajuato: Revisión de los conflictos desde el enfoque de la gobernanza ambiental democrática. In Castro, J. E. et al. El conflicto del agua: Política, gestión, resistencia y demanda social. FLACSO Mexico, 2017.

Caldera-Ortega, A., Tagle Zamora, D., & Mazabel, D. G.: Guanajuato: crónica del cambio en su gestión del agua. In Caldera Ortega, A. & Tagle Zamora, D. (coord.) Agua en el Bajío Guanajuatense. Universidad de Guanajuato: Guanajuato, México, 2020.

Camisa, Z. C.: Efecto de la migración en el crecimiento y la estructura de la población de las ciudades de la América Latina. Centro Latinoamericano de Demografía. Accessed on 21 June 2021. ~~Available at:~~

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

https://repositorio.cepal.org/bitstream/handle/11362/7915/S7200578_es.pdf?sequence=1,Available at: https://repositorio.cepal.org/bitstream/handle/11362/7915/S7200578_es.pdf?sequence=1, 1972.

Castillo-Girón, V., Revelo Hurtado, C., & Villalobos Torres, D.: Asentamientos irregulares en la zona metropolitana de guadalajaraGuadalajara: ¿expansión urbana inducida o crecimiento incontrolable?. Carta Económica Regional, (34), 32-39. https://doi.org/10.32870/cer.v0i34.7517,https://doi.org/10.32870/cer.v0i34.7517, 1994.

Castree, N., Adams, W.M., Barry, J., Brockington, D., Büscher, B., Corbera, E., Demeritt, D., Duffy, R., Felt, U., Neves, K. and Newell, P.: Changing the intellectual climate. Nature climate change, 4(9), 763-768, 2014.

CEA Jalisco: Déficit asociado a la sobreexplotación de acuíferos. Available upon request, 2014.

CEA Jalisco & Gobierno del Estado de Jalisco: Factibilidad económica: Actualización de la evaluación socioeconómica del proyecto de construcción de la presa y sistema de bombeo Purgatorio – Arcediano, para abastecimiento de agua al área Metropolitana de Guadalajara, Jalisco. Accessed on 28 February 2020. Document obtained through transparency procedures, 2018.

CEA Guanajuato & Conagua: Factibilidad económica: Construcción del proyecto de abastecimiento de agua potable El Zapotillo, para la ciudad de León, Gto. Accessed on 28 February 2020. Document obtained through transparency procedures, 2018.

CIESAS: Propuesta de modificación del programa de ordenamiento ecológico local de Zapopan: Sintesis ejecutiva. Available at: https://www.zapopan.gob.mx/wp-content/uploads/2018/06/sintesis-ejecutiva.pdf. Last access: 3 January 2021, 2018.

COMDA, MAPDER, AMCF, TODXS, A. P., DESC, E., RGEMA, MUPCND (2019) Informe sobre violaciones al agua potable y al saneamiento en México, 2017. Available at: http://www.comda.org.mx/informe-editado-sobre-violaciones-a-los-derechos-humanos-al-agua-potable-y-al-saneamiento-en-mexico/ Last access: 21 December 2020.

Conagua: PMPMS para usuarios urbanos de agua potable y saneamiento. Available at: https://www.gob.mx/cms/uploads/attachment/file/99855/PMPMS_ZM_Guadalajara_Jal.pdf Last access 28 February 2020, 2015.

Conagua: Sistema Nacional de Información del Agua, available at: http://sina.conagua.gob.mx/sina/tema.php?tema=cuencas (last access: 19 March 2020), 2018..

Conagua: Presa Zapotillo, Jal. Propuesta Conceptual Para Transitar Avenida de Diseño sin Afectar a Pobladores, Mexico DF, November 2021.

CONAPO: Proyecciones de la Población de los Municipios de México, 2015-2030. Accessed on 28 February 2020. Available at: https://www.gob.mx/conapo/documentos/proyecciones-de-la-poblacion-de-los-municipios-de-mexico-2015-2030,Available at: https://www.gob.mx/conapo/documentos/proyecciones-de-la-poblacion-de-los-municipios-de-mexico-2015-2030, 2015.

Consejo Consultivo del Agua: Gestión del agua en las ciudades de México: Indicadores de Desempeño de los Sistemas de Agua Potable, Alcantarillado y Saneamiento. Available at: http://www.aguas.org.mx/sitio/index.php/de-interes/publicaciones,Available at: http://www.aguas.org.mx/sitio/index.php/de-interes/publicaciones, 2011.

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: Dutch (Netherlands)

Cortés, S. A., Lozano, G. A. and Pérez, J.: 'Study of Water Quality Through Hydro-Chemical Signature in León, Guanajuato, Mexico', in Gutiérrez-López, G. F. et al. (eds) Water Stress in Biological, Chemical, Pharmaceutical and Food Systems. New York: Springer Science+Business Media, pp. 549–556, 2015.

Costa-i-Font, J., Rodriguez-Oreggia, E., & Lunapla, D.: Political competition and pork-barrel politics in the allocation of public investment in Mexico. Public choice, 116(1), 185-204, 2003.

Craven, J.: SimBasin. Available at: http://joannecraven.co.uk/projects/simbasin/,http://joannecraven.co.uk/projects/simbasin/, 2018.

Del Castillo, A.: SIAPA, obeso de políticos y con pocos técnicos. Available at: http://agustindelcastillo.blogspot.com/2011/07/siapa-obeso-de-politicos-y-con-pocos.html, last access 17/12/2020, 2011.

Del Castillo, A.: 'Agua en el AMG, 27 años de omisiones', Milenio, 22 Mar. Available at: https://cronicadesociales.wordpress.com/2018/03/23/agua-en-el-amg-27-anos-de-omisiones/, last access 15/12/2020, 2018.

Del Castillo, A.: 'La demagogia del agua.', El Respetable, 11 Mar. Available at: http://elrespetable.com/2021/03/11/la-demagogia-del-agua/,Available at: http://elrespetable.com/2021/03/11/la-demagogia-del-agua/, 2021.

Delgado-Aguiñaga J.A., Begovich O.: Water Leak Diagnosis in Pressurized Pipelines: A Real Case Study. In: Verde C., Torres L. (eds) Modeling and Monitoring of Pipelines and Networks. Applied Condition Monitoring, vol 7. Springer, Cham. https://doi.org/10.1007/978-3-319-55944-5_12,https://doi.org/10.1007/978-3-319-55944-5_12, 2017.

Di Baldassarre, G., Wanders, N., AghaKouchak, A., Kuil, L., Rangecroft, S., Veldkamp, T.I., Garcia, M., van Oel, P.R., Breinl, K. and Van Loon, A.F.: Water shortages worsened by reservoir effects, Nature Sustainability, 1(11), pp. 617–622. doi: 10.1038/s41893-018-0159-0, 2018.

Di Baldassarre, G., Sivapalan, M., Rusca, M., Cudennec, C., Garcia, M., Kreibich, H., Konar, M., Mondino, E., Mård, J., Pande, S., Sanderson, M.R., Tian, F., Viglione, A., Wei, J., Wei, Y., Yu, D., Srinivasan, V., Blöschl, G.: Sociohydrology: Scientific challenges in addressing the sustainable development goals. Water Resources Research, 55(8), 6327-6355, 2019.

Duran Juárez, J. M. & Torres Rodríguez, A.: Crisis ambiental en el lago de Chapala y abastecimiento de agua para Guadalajara. Carta Económica Regional. 14 (78). Available at: http://www.revistascientificas.udg.mx/index.php/CER/article/view/6155/5545,Available at: http://www.revistascientificas.udg.mx/index.php/CER/article/view/6155/5545, 2001.

Enteshari, S., Safavi, H. R., & van der Zaag, P.: Simulating the interactions between the water and the socio-economic system in a stressed endorheic basin. Hydrological Sciences Journal, 65(13), 2159-2174, 2020.

EJOLT: Mapping environmental unjustice. Available at: http://www.ejolt.org/maps/, Last access: 18 November 2021, 2021.

Esri: Ocean Basemap (2019), available at: https://www.arcgis.com/home/item.html?id=6348e67824504fc9a62976434bf0d8d5 (last access: 12 February 2020), 2019. .

Flores-Berrones, R.: 'Acueducto Chapala-Guadalajara', Ingeniería Hidráulica en México, Enero-Abril, p. 12, 1987.

Flores-Elizondo, R.: Building Urban Water Resilience: New Perspectives for the Guadalajara Drought-readiness Program. Journal of Management for Global Sustainability: 1–27. DOI: 10.13185/JM2016.04105, 2016.

Formatted: Spanish (Mexico)

Formatted: Spanish (Mexico)

Formatted: English (United Kingdom)

Flörke, M., Schneider, C. and McDonald, R. I.: 'Water competition between cities and agriculture driven by climate change and urban growth', Nature Sustainability. Springer US, 1(1), pp. 51–58. doi: 10.1038/s41893-017-0006-8, 2018.

Flyvbjerg, B. Survival of the unfittest: why the worst infrastructure gets built—and what we can do about it. Oxford review of economic policy, 25(3), 344-367, 2009.

Flyvbjerg, B.: What You Should Know about Megaprojects and Why: An Overview, Project Management Journal, vol. 45, no. 2, April-May, pp. 6-19, DOI:10.1002/pmj.21409, 2014.

Flyvbjerg, B., Bruzelius, N., & Rothengatter, W.: Megaprojects and risk: An anatomy of ambition. Cambridge university press, 2003.

García-Garnica, A.: Inicio y auge de las zonas industriales en México; el caso de la industria automotriz en Guanajuato. In Martinez, A. & Carrillo, J. (eds.) Innovación, Redes de Colaboración y Sostenibilidad. UNAM-Unidad León, 2017.

García Garnica, A., & Martínez-Martínez, A.: Trends of automotive industry FDI in Guanajuato, Mexico. Análisis económico, 33(84), 99-122. http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2448-66552018000300099&lng=es&tlng=en,http://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S2448-66552018000300099&lng=es&tlng=en, 2018.

Gleason, J. A., & Casiano, C.: Challenges of Water Sensitive Cities in Mexico: The Case of the Metropolitan Area of Guadalajara. Water, 13(5), 601, 2021.

Global Water Partnership: Water demand management: A Mediterranean experience. Technical Focus Paper, available at: https://www.gwp.org/globalassets/global/toolbox/publications/technical-focus-papers/01-water-demand-management—the-mediterranean-experience-2012-english.pdf., 2012.

Gobierno de Jalisco: Respuesta a la comunidad académica del ITESO sobre pronunciamiento de desabasto de agua. Available at: www.jalisco.gob.mx/es/prensa/noticias/122789, 2021.

Godinez Madrigal, J., van der Zaag, P., & Van Cauwenbergh, N.: A half-baked solution: drivers of water crises in Mexico. Proceedings of the International Association of Hydrological Sciences, 376, 57-62, 20182018a.

Godinez Madrigal, J., Claure, P., Craven, J., Van Cauwenbergh, N., van der Zaag, P.: SimVerde: Participatory decision support system for the Verde River Basin in Mexico in the context of the Zapotillo conflict. Available at: https://github.com/jongmadrigal/SimVerde, 2018Available at: https://github.com/jongmadrigal/SimVerde, 2018b.

Godinez-Madrigal, J., Van Cauwenbergh, N. and van der Zaag, P.: 'Production of water knowledge in the face of water crises: Revisiting the IWRM Success Story of the Lerma-Chapala Basin, Mexico', Geoforum, 103, pp. 3–15. doi: 10.1016/j.geoforum.2019.02.002, 2019.

Godinez-Madrigal, J., Van Cauwenbergh, N. and van der Zaag, P.: 'Unravelling intractable water conflicts: the entanglement of science and politics in decision-making on large hydraulic infrastructure, Hydrology and Earth System Sciences, 2020.

Gohari, A., Eslamian, S., Mirchi, A., Abedi-Koupaei, J., Bavani, A. M., & Madani, K.: Water transfer as a solution to water shortage: a fix that can backfire. Journal of Hydrology, 491, 23-39, 2013.

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Gómez-Jauregui-Abdo, J. P.: Sustainable development of domestic water supply in emerging megacities: the case of the city of Guadalajara, Mexico. Available at: https://opus4.kobv.de/opus4-btu/files/3607/Gomez_Jauregui_Abdo.pdf, 2015.

González-Valencia, M: Los acaparadores del agua. Análisis plural, pp. 201-218, available at:https://rei.iteso.mx/bitstream/handle/11117/6419/S4-Los%20acaparadores%20del%20agua.pdf?sequence=1&isAllowed=y, 2020.

Greene, J.: Bottled water in Mexico: The rise of a new access to water paradigm. Wiley Interdisciplinary Reviews: Water, 5(4), e1286, 2018.

Greene, J.: What happens when water is commodified? Case study Mexico: dominant movements and alternative discourses in the access to water landscape (Doctoral dissertation, University of Geneva), 2021.

Gupta, J., & van der Zaag, P: Interbasin water transfers and integrated water resources management: Where engineering, science and politics interlock. Physics and Chemistry of the Earth, Parts A/B/C, 33(1-2), 28-40, 2008.

Hernández-González, J.: Efectos de la urbanización metropolitana en la gestión del agua en las comunidades periurbanas. El caso de la zona metropolitana de León. In Caldera Ortega, A. & Tagle Zamora, D. (coord.) Agua en el Bajío Guanajuatense. Universidad de Guanajuato: Guanajuato, México, 2020.

Herrera, V.: Water and politics: Clientelism and reform in urban Mexico. University of Michigan Press, 2017.

Hoogesteger, J.: Democratizing water governance from the grassroots: The development of Interjuntas-Chimborazo in the Ecuadorian Andes. Human Organization, 71(1), 76-86, 2012.

Hoogendam, P.: Hydrosocial territories in the context of diverse and changing ruralities: The case of Cochabamba's drinking water provision over time. Water International, 44(2), 129–147. doi:10.1080/02508060.2019.1551711, 2019.

Hoogesteger, J.: The ostrich politics of groundwater development and neoliberal regulation in Mexico. Water Alternatives, 11(3), 552-571, 2018.

Hoogesteger, J., & Wester, P: Intensive groundwater use and (in) equity: Processes and governance challenges. Environmental science & policy, 51, 117-124, 2015.

Hoogesteger, J., & Wester, P.: Regulating groundwater use: The challenges of policy implementation in Guanajuato, Central Mexico. Environmental Science & Policy, 77, 107-113, 2017.

Hommes, L., Boelens, R., & Maat, H.: Contested hydrosocial territories and disputed water governance: Struggles and competing claims over the Ilisu Dam development in southeastern Turkey. Geoforum, 71, 9-20, 2016.

Huitema, Hommes, L. and Boelens, R.: Urbanizing rural waters: Rural-urban water transfers and the reconfiguration of hydrosocial territories in Lima, Political Geography, 57, pp. 71–80. doi: 10.1016/j.polgeo.2016.12.002, 2017.

Hommes, L., Boelens, R., Harris, L. M., & Veldwisch, G. J.: Rural–urban water struggles: urbanizing hydrosocial territories and evolving connections, discourses and identities, 2019.

D., & Meijerink, S.: Realizing water transitions: the role of policy entrepreneurs in water policy change. Ecology and Society, 15(2), 2010.

Formatted: English (United Kingdom)

INEGI: Censo General de la República Mexicana 1900. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1900/,~~https://www.inegi.org.mx/programas/ccpv/1900/, 1900.

INEGI: Tercer Censo de Población de los Estados Unidos Mexicanos 1910. Accessed on 28 February 2020. ~~Available at: https://www.inegi.org.mx/programas/ccpv/1910/,~~Available at: https://www.inegi.org.mx/programas/ccpv/1910/, 1910.

INEGI: Censo General de Habitantes 1921. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1921/,~~https://www.inegi.org.mx/programas/ccpv/1921/, 1921.

INEGI: Quinto Censo de Población 1930. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1930/,~~https://www.inegi.org.mx/programas/ccpv/1930/, 1930.

INEGI: Sexto Censo de Población 1940. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1940/,~~https://www.inegi.org.mx/programas/ccpv/1940/, 1940.

INEGI: Séptimo Censo General de Población 1950. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1950/,~~https://www.inegi.org.mx/programas/ccpv/1950/, 1950.

INEGI: VIII Censo General de Población 1960. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1960/,~~https://www.inegi.org.mx/programas/ccpv/1960/, 1960.

INEGI: IX Censo General de Población 1970. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1970/,~~https://www.inegi.org.mx/programas/ccpv/1970/, 1970.

INEGI: X Censo General de Población y Vivienda 1980. Accessed on 28 February 2020. ~~Available at: https://www.inegi.org.mx/programas/ccpv/1980/,~~Available at: https://www.inegi.org.mx/programas/ccpv/1980/, 1980.

INEGI: XI Censo General de Población y Vivienda 1990. Accessed on 28 February 2020. ~~Available at: https://www.inegi.org.mx/programas/ccpv/1990/,~~Available at: https://www.inegi.org.mx/programas/ccpv/1990/, 1990.

INEGI: Conteo de Población y Vivienda 1995. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/ccpv/1995/,~~https://www.inegi.org.mx/programas/ccpv/1995/, 1995.

INEGI: XII Censo general de población y vivienda 2000. Accessed on 28 February 2020. ~~Available at: https://www.inegi.org.mx/programas/ccpv/2000/,~~Available at: https://www.inegi.org.mx/programas/ccpv/2000/, 2000.

INEGI: II Conteo de Población y Vivienda 2005. Accessed on 28 February 2020. Available at: ~~http://www.beta.inegi.org.mx/proyectos/ccpv/2005/default.html,~~http://www.beta.inegi.org.mx/proyectos/ccpv/2005/default.html, 2005.

INEGI: Censo de población y vivienda 2010. Accessed on 28 February 2020. Available at: ~~http://www.beta.inegi.org.mx/proyectos/ccpv/2010/,~~http://www.beta.inegi.org.mx/proyectos/ccpv/2010/, 2010.

INEGI: Encuesta intercensal 2015. Accessed on 28 February 2020. Available at: ~~https://www.inegi.org.mx/programas/intercensal/2015/,~~https://www.inegi.org.mx/programas/intercensal/2015/, 2015.

Jalomo Aguirre, F.: Gobernar el territorio entre descentralización y metropolización: el patronato y el SIAPA como formas de gestión (1952-2006) y escenarios prospectivos. Universidad de Guadalajara: Guadalajara. ~~Available at:~~

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

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Formatted: English (United Kingdom)

~~https://issuu.com/publicaciones_cucsh/docs/francisco_jalomo1,~~Available at: https://issuu.com/publicaciones_cucsh/docs/francisco_jalomo1, 2011.

Kallis, G.: Coevolution in water resource development. The vicious cycle of water supply and demand in Athens, Greece, Ecological Economics. Elsevier B.V., 69(4), pp. 796–809. doi: 10.1016/j.ecolecon.2008.07.025, 2010.

Konijnenberg, V. (2019). ~~Leon's~~León's water system. MSc Thesis. Wageningen University.

~~Krueger, T., Maynard, C~~Kuil, L., Carr, G., ~~Bruns~~Viglione, A., ~~Mueller, E. N., & Lane, S.:~~Prskawetz, A~~ transdisciplinary account.~~, & Blöschl, G.: Conceptualizing socio-hydrological drought processes: The case of ~~water~~the Maya collapse. Water resources research, ~~Wiley Interdisciplinary Reviews: Water, 3(3), pp. 369–389. doi: 10.1002/wat2.1132~~52(8), 6222-6242, 2016.

Lach, D., Rayner, S., & Ingram, H.: Taming the waters: strategies to domesticate the wicked problems of water resource management. International Journal of Water, 3(1), 1, 2005.

~~Lane, S. N.: Slow science, the geographical expedition, and Critical Physical Geography. The Canadian Geographer/Le Géographe Canadien, 61(1), 84-101, 2017.~~

Larsen, T. A., Hoffmann, S., Lüthi, C., Truffer, B., & Maurer, M.: Emerging solutions to the water challenges of an urbanizing world. Science, 352(6288), 928-933, 2016.

Lave, R., Wilson, M.W., Barron, E.S., Biermann, C., Carey, M.A., Duvall, C.S., Johnson, L., Lane, K.M., McClintock, N., Munroe, D. and Pain, R.: Intervention: Critical physical geography. The Canadian Geographer 58 (1): 1—10, 2014.

Leach, M., Scoones, I., Stirling, A.: Dynamic Sustainabilities: Technology, Environment, Social Justice. Earthscan, London, 2010.

Li, B., Sivapalan, M., & Xu, X.: An urban sociohydrologic model for exploration of Beijing's water sustainability challenges and solution spaces. Water Resources Research, 55(7), 5918-5940, 2019.

Linton, J., & Budds, J.: The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. Geoforum, 57, 170-180, 2014.

López-Ramírez, M. E.: Conflicto y agentes en el caso de La presa Arcediano: la gestión pública del agua en la zona metropolitana de Guadalajara. In Ochoa-Garcia & Burkner (eds) Gobernanza y gestion del agua en el Occidente de Mexico: La metrópoli de Guadalajara. ITESO: Tlaquepaque, 2012.

López-Ramírez, M. E., & Ochoa-Garcia, H.: Geopolitica del agua en la zona metropolitana de Guadalajara: historia y situación actual del espacio vital. In Ochoa-Garcia & Burkner (eds) Gobernanza y gestion del agua en el Occidente de Mexico: La metrópoli de Guadalajara. ITESO: Tlaquepaque, 2012.

Lozano, G.: La crisis del agua en León: Claves para su comprensión. In Tagle-Zamora (ed.) La crisis multidimensional del agua en la ciudad de León, Guanajuato. Universidad de Guanajuato-Porrúa: León, México, 2014.

Maxmen, A.: As Cape Town water crisis deepens, scientists prepare for 'Day Zero'. Nature, 554(7690), 2018

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

McCulligh, C.: Alcantarilla del progreso: Industria y Estado en la contaminación del río Santiago en Jalisco. CIESAS: Guadalajara,., & Tetreault, D.: Water Management in Mexico. From Concrete-Heavy Persistence to Community-Based Resistance. Water Alternatives, 10(2), 2017.

Formatted: English (United Kingdom)

McCulligh, C., Arellano-García, L. & Casas-Beltrán, D.: Unsafe waters: the hydrosocial cycle of drinking water in Western Mexico, Local Environment, DOI: 10.1080/13549839.2020.1805598, 2020.

Mekonnen, M. M., & Hoekstra, A. Y.: Four billion people facing severe water scarcity. Science advances, 2(2), e1500323, 2016.

Formatted: English (United Kingdom)

Miller, T. R., Baird, T. D., Littlefield, C. M., Kofinas, G., Chapin III, F. S., & Redman, C. L.: Epistemological pluralism: reorganizing interdisciplinary research. Ecology and Society, 13(2), 2008.

Melsen, L. A., Vos, J., & Boelens, R.: What is the role of the model in socio-hydrology? Discussion of "Prediction in a socio-hydrological world". Hydrological Sciences Journal, 63(9), 1435-1443, 2018.

Molle, F.: Why enough is never enough: The societal determinants of river basin closure. International Journal of Water Resources Development, 24(2), 217-226, 2008.

Molle, F., Mollinga, P. P., & Wester, P.: Hydraulic bureaucracies and the hydraulic mission: Flows of water, flows of power. Water alternatives, 2(3), 328-349., 2009.

Molle, F., & Wester, P. (Eds.). (2009). River basin trajectories: societies, environments and development (Vol. 8). IWMI.

Formatted: English (United Kingdom)

Norma Mexicana: NMX-AA-159-SCFI-2012. Que establece el procedimiento para la determinación del caudal ecológico en cuencas hidrológicas. Available at: https://www.gob.mx/cms/uploads/attachment/file/166834/NMX-AA-159-SCFI-2012.pdf. Last accesss: 12 December 2020. 2012.

Ochoa-García, H.: ¿Alternativas para la gestión del agua y el desarrollo regional? Conflicto por la presa El Zapotillo, Revista Observatorio del Desarrollo, Núm. 7, Zacatecas: Universidad Autónoma de Zacatecas, págs. 16-21, 2013.

Molle, F., & Closas, A.: Comanagement of groundwater: A review. WIREs Water, 7(1). doi:10.1002/wat2.1394, 2019.

Ochoa-García, H., Arrojo-Agudo, P., Godínez-Madrigal, J., López-Villegas, P., López-Aguayo, A., & Quiroz-Hernández, M. L.: Agua para el desarrollo regional en los Altos de Jalisco. Gestión del agua e impacto social del proyecto El Zapotillo, 2014.

Ochoa-García, H. (Ed.): Imposición, resistencia y alternativas ante una crisis interregional del agua en México: proyecto El Zapotillo. WATERLAT-GOBACIT Network Working Papers, 2015. ., & Rist, S.: Water justice and integrated water resources management: constitutionality processes favoring sustainable water governance in Mexico. Human ecology, 46(1), 51-64, 2018.

Formatted: English (United Kingdom)

Formatted: Spanish (Mexico)

Pastrana, D., Ramirez, J., & Ramos C.: Guanajuato. El costo del agua que no llega al nuevo Bajío industrial. El Universal: 11 August. Available at: https://www.eluniversal.com.mx/articulo/periodismo-de-investigacion/2017/08/11/guanajuato-el-costo-del-agua-que-no-llega-al-nuevo. https://ladobe.com.mx/2017/08/empresas-espanolas-costo-del-nuevo-bajio-industrial/,https://ladobe.com.mx/2017/08/empresas-espanolas-costo-del-nuevo-bajio-industrial/, 2017.

Pérez-Peña, O., & Torres-González, G.: La insaciable sed de agua de la zona metropolitana de Guadalajara. 2001.

Pérez-Peña, O., Torres-González, G., Romo-Reyes, M.: Agua y mas agua para la zona conurbada de Guadalajara: La gestión no sustentable del recurso hídrico. In Vargas, Soares, Pérez-Peña & Ramírez (eds.) “La gestión del recurso hídrico: Realidades y perspectivas.” pp. 154-174, Instituto Mexicano de Tecnología del Agua~~, pp. 154-174~~, 2009.

Pfannenstein, B., Anacleto Herrera, E. E., & Sevilla Villalobos, S.: La ciudad cerrada y su diversificación como reto del Área Metropolitana de Guadalajara, México. Revista de Geografía Norte Grande, (68), 163-184, 2017.

Platt, R.H.: The 2020 Water Supply Study for Metropolitan Boston. Journal of the American Planning Association 61 (2), 185–199, 1995.

Purvis, L., & Dinar, A.: Are intra-and inter-basin water transfers a sustainable policy intervention for addressing water scarcity?. Water Security, 9, 100058, 2020.

~~Rauschmayer, F., Bauler, T., & Schäpke, N.: Towards a thick understanding of sustainability transitions — Linking transition management, capabilities and social practices. Ecological economics, 109, 211-221, 2015.~~

Reis, N.: Finance capital and the water crisis: Insights from Mexico. Globalizations, 14(6), 976-990, 2017.

Rinaudo, J.D., Barraque, B.: Inter-basin transfers as a supply option: the end of an era? in: Q. Grafton, K.A. Daniell, C. Nauges, J.-D. Rinaudo, N.W.W. Chan (Eds.), Understanding and Managing Urban Water in Transition, Springer, Berlin, pp. 175-200, 2015.

Rodríguez, M. D.: Sobrexplotación de mantos acuíferos genera conflictos a habitantes de León. La Jornada: 19 May. Available at: https://www.jornada.com.mx/2004/05/20/047n1soc.php?printver=1&fly=. Last access 7 January 2021, ~~2016~~2004.

Rodríguez, M. D.: Sin agua, León, Guanajuato; sólo tiene reservas para 10 años. La Jornada: 2 February. Available at: https://www.jornada.com.mx/2008/02/02/index.php?section=estados&article=027n1est. Last access 15 December 2020, 2008.

Rodríguez-Labajos, B., & Martínez-Alier, J.: Political ecology of water conflicts. Wiley Interdisciplinary Reviews: Water, 2(5), 537-558, 2015.

Roy, A~~. (1999)~~.: ‘The greater common good’, Frontline, vol 16, no 11, ~~2008~~1999.

Rubino, F., Corona, Y., Jiménez Pérez, J. G., & Smith, C.: Bacterial contamination of drinking water in Guadalajara, Mexico. International journal of environmental research and public health, 16(1), 67, 2019.

Rusca, M., & Di Baldassarre, G. Interdisciplinary critical geographies of water: Capturing the mutual shaping of society and hydrological flows. Water, 11(10), 1973, 2019.

SAPAL.: El agua en León. Un encuentro con el futuro. Available at: ~~http://www.sapal.gob.mx/images/phocagallery/sapal_21072011.pdf,~~http://www.sapal.gob.mx/images/phocagallery/sapal_21072011.pdf, 2009.

SAPAL.: Trayectoria y futuro. Available at: ~~http://www.sapal.gob.mx/media/files/1553888365-SAPAL_Trayectoria_y_Futuro_2012.pdf,~~http://www.sapal.gob.mx/media/files/1553888365-SAPAL_Trayectoria_y_Futuro_2012.pdf, 2012.

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

SAPAL.: El agua subterránea en Guanajuato. Profundidad del nivel estático 2015. Available at agua.guanajuato.gob.mx. last access 13 January 2021, 2015.

SAPAL.: Agua Siempre y Para Todos: Informe de Resultados 2013-2016. León. Available at: http://www.sapal.gob.mx/media/files/1456268400-Informe Consejo 2013-2016.pdf, 2016.

SAPAL.: Data on León's water supply since 1988. Data obtained through transparency procedures, 2020.

Savelli, E., Rusca, M., Cloke, H., & Di Baldassarre, G.: Don't blame the rain: Social power and the 2015–2017 drought in Cape Town. Journal of Hydrology, 594, 125953, 2021.

Schlosser, C.A., Strzepek, K., Gao, X., Fant, C., Blanc, É., Paltsev, S., Jacoby, H., Reilly, J. and Gueneau, A.: The future of global water stress: an integrated assessment, Water Resources Research, 2 (8), 341–361, 2014.

Schmidt, J. J.: Historicising the hydrosocial cycle. Water Alternatives, 7(1), 2014.

Scott, J.: Seeing Like a State. How Certain Schemes to Improve the Human Condition Have Failed, Yale University Press, New Haven, 1998.

SIAPA.: Plan Institucional 2014-2018 del SIAPA. Available at: https://www.siapa.gob.mx/sites/default/files/doctrans/plan_institucional_siapa_2014-2018.pdf, Last access: 21 December 2020, 2014a.

SIAPA.: Cronología de las fuentes de abastecimiento para Guadalajara. Proceedings from the congress "Abastecimiento de agua a las metrópolis del país". Guadalajara, 2014b.

SIAPA.: Abastecimiento de agua para Guadalajara: El río del tiempo. Available upon request, 2016.

SIAPA.: Data on Guadalajara's water supply since 1988. Data obtained through transparency procedures, 2020.

Sivapalan,~~Srinivasan, V., Lambin, E. F., Gorelick, S.~~ M., ~~Thompson, B. H., & Rozelle, S.: The nature~~& Blöschl, G.: Time scale interactions and ~~causes~~the coevolution of ~~the global~~humans and water~~ crisis: Syndromes from a meta-analysis of coupled human-water studies.~~. Water Resources Research, ~~48(10), 2012~~51(9), 6988-7022, 2015.

Srinivasan, V., Sanderson, M., Garcia, M., Konar, M., Blöschl, G., Sivapalan, M.: Moving socio-hydrologic modelling forward: unpacking hidden assumptions, values and model structure by engaging with stakeholders: reply to "What is the role of the model in socio-hydrology?". Hydrological Sciences Journal, 63(9):1444-6, 2018.

Stirling, A., Leach, M., Mehta, L., Scoones, I., Smith, A., Stagl, S., & Thompson, J.: Empowering Designs: towards more progressive social appraisal of sustainability, 2007.

Swyngedouw, E.: Power, nature, and the city. The conquest of water and the political ecology of urbanization in Guayaquil, Ecuador: 1880–1990. Environment and planning A, 29(2), 311-332, 1997.

Swyngedouw, E. Social power and the urbanization of water: flows of power (Vol. 226). Oxford: Oxford University Press, 2004.

Swyngedouw, E. The political economy and political ecology of the hydro-social cycle. Journal of contemporary water research & education, 142(1), 56-60, 2009.

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Tagle~~-~~-Zamora, D., & Caldera~~-~~-Ortega, A. R~~., & Villalpando Vázquez, V.: Negociaciones fallidas en la cuenca del río Turbio 1987-2014: el caso de la industria curtidora y el deterioro del bien común. Argumentos (México, D.F.), 28(77), 59-77, 2015.~~
~~Tagle-Zamora, D., & Caldera-Ortega, A. R. (2021).~~.: Corporatización de tipo neoliberal en la gestión del agua en México. Lecciones de León, Guanajuato. Tecnología y ciencias del agua, 12(2), 207-271~~.~~, 2021.

Torres Rodríguez, A.: 'Infraestructura hidráulica en Guadalajara para el abastecimiento de agua potable: el caso de sustentabilidad en las galerías filtrantes de Guadalajara', (inegi 2000), pp. 317–357, 2013.

UNESCO, UN-Water.: United Nations World Water Development Report 2020: Water and Climate Change, Paris, UNESCO, 2020.

Universidad Autónoma de San Luis Potosí & CEA Jalisco.: Propuesta metodológica para la implantación de una batería de indicadores de salud que favorezcan el establecimiento de programas de diagnóstico, intervención y vigilancia epidemiológica en las poblaciones ubicadas en la zona de influencia de la Presa Arcediano en el Estado de Jalisco. Last access: 22 June 2021. ~~Available at: https://transparencia.info.jalisco.gob.mx/sites/default/files/u531/INFORME%20FINAL%20ARCEDIANO_CEA_UEAS_JALISCO_2011_1%20-%20copia_opt.pdf,~~Available at: https://transparencia.info.jalisco.gob.mx/sites/default/files/u531/INFORME%20FINAL%20ARCEDIANO_CEA_UEAS_JALISCO_2011_1%20-%20copia_opt.pdf, 2010.

Van Cauwenbergh, N., Ciuró, A. B., & Ahlers, R.: Participatory processes and support tools for planning in complex dynamic environments. Ecology and Society, 23(2), 2018.

Villalobos-Aragón, A., Ellis, A. S., Armienta, M. A., Morton-Bermea, O., & Johnson, T. M.: 'Geochemistry and Cr stable isotopes of Cr-contaminated groundwater in León valley, Guanajuato, México', Applied Geochemistry, 27(9), pp. 1783–1794. doi: 10.1016/j.apgeochem.2012.02.013, 2012.

Vörösmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R. and Davies, P.M.: Global threats to human water security and river biodiversity. Nature, 467 (7315), 555-561, doi.org/10.1038/nature09549, 2010.

~~Von Bertrab, E.: Guadalajara's water crisis and the fate of Lake Chapala: A reflection of poor water management in Mexico. Environment and Urbanization, 15(2), 127-140, 2003.~~

~~Von Bertrab, E., & Wester, P.: Gobernabilidad del agua en México. La crisis de agua de Guadalajara y el destino del Lago de Chapala. Medio Ambiente Y Urbanización, 62 (1–2), pp. 143-160, 2005.~~

Wesselink, A., Kooy, M., & Warner, J.: Socio-hydrology and hydrosocial analysis: toward dialogues across disciplines. Wiley Interdisciplinary Reviews: Water, 4(2), e1196, 2017.

Wester, P., Scott, C. A., & Burton, M.: River basin closure and institutional change in Mexico's Lerma-Chapala Basin. Irrigation and River Basin Management: Options for Governance and Institutions, 125-144, 2005.

WWAP (UNESCO World Water Assessment Programme).: The United Nations World Water Development Report 2019: Leaving No One Behind. Paris, UNESCO, 2019.

Formatted: English (United Kingdom)

Formatted: English (United Kingdom)

Zeitoun, M., Mirumachi, N., Warner, J., Kirkegaard, M., & Cascão, A.: 'Analysis for water conflict transformation', Water International. Routledge, 00(00), pp. 1–20. doi: 10.1080/02508060.2019.1607479, 2019.

Zwarteveen, M., Kemerink-Seyoum, J.S., Kooy, M., Evers, J., Guerrero, T.A., Batubara, B., Biza, A., Boakye-Ansah, A., Faber, S., Cabrera Flamini, A., Cuadrado-Quesada, G., Fantini, E., Gupta, J., Hasan, S., ter Horst, R., Jamali, H., Jaspers, F., Obani, P., Schwartz, K., Shubber, Z., Smit, H., Torio, P., Tutusaus, M. and Wesselink, A.: Engaging with the politics of water governance. WIREs Water, 4: e1245. https://doi.org/10.1002/wat2.1245, 2017.