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Publication date
2022

Document Version
Final published version

Citation (APA)
Godinez Madrigal, J. (2022). *Paradigm Lost: On the Value of Lost Causes in Transforming Cities and Water Systems' Development Pathways*. [Dissertation (TU Delft), Delft University of Technology].

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DISSERTATION

Submitted in fulfillment of the requirements of
the Board for Doctorates of Delft University of Technology
and
of the Academic Board of the IHE Delft
Institute for Water Education
for
the Degree of DOCTOR
to be defended in public on
Tuesday, 26 April 2022, at 15:00 hours
in Delft, the Netherlands

by

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This research was conducted under the auspices of the Graduate School for Socio-Economic and Natural Sciences of the Environment (SENSE)

Cover design: Julio César Godínez Suárez

Published by IHE Delft Institute for Water Education
www.un-ihe.org
ISBN 978-90-73445-39-0

To my beautiful daughter and my late mother.

ACKNOWLEDGMENTS

There are two conceptions of the trajectory of one's life. One, is the myth of the self-made person. Its extreme form may be depicted in the film *The Fountainhead*, where Howard Roark, out of pure will, manages to overcome all challenges imposed by society and fate. To characterize freedom, Roark defined it as: "To ask nothing. To expect nothing. To depend on nothing."

The second conception is that of the poet John Donne, exemplarily portrayed by his poem *For whom the bell tolls?* In the poem, Donne invites us to think of humankind as a living and interdependent network of individuals:

"No man is an island,
Entire of itself.
Each is a piece of the continent,
A part of the main.
If a clod be washed away by the sea,
Europe is the less.
[…]
Each man's death diminishes me,
For I am involved in mankind.
Therefore, send not to know
For whom the bell tolls,
It tolls for thee."

I think life is necessarily a combination of both conceptions. If we all are but a grain in the vastness of sand in the sea, we may find our individuality and freedom but a sad joke. The first conception of life possesses a vitality that overflows the limits of our body and mind. A will of life that transcends and can achieve whatever our hearts beat for. But the second conception is more realistic. Without the others we are less.

So, in that spirit I would like not only to acknowledge, but also to celebrate all of those who have been with me in this PhD journey. With them, I became so much more than I was. First, I want to celebrate my promotor and mentor, Pieter. Without knowing me, you took a leap of faith in accepting me as your PhD student. I came to you with just a vague notion of a scientific project. And you moulded that will and enthusiasm of mine to create something of scientific and social value. I cannot deny how hard it was for me in the first two-three years of my PhD journey. I think I have never been tried and tested to the limits of my abilities to produce something of excellence. Looking back, Pieter, you not only guided my research, but you also mentored the scientist in me. "You are doing a PhD, you are a scientist, you're not an activist" you would repeat after reading my first manuscripts. And in the cracks and crevasses between science and activism I found a niche that has made this PhD journey worthwhile, enriching and fulfilling. Pieter, you are a brilliant man and a critical thinker, sometimes appearing as too tough; but after knowing you better, anyone can see how powerful and warm your heart is. Pieter, you have played a crucial role in forming generations of scientists stretching all corners of the continents, and I am proud to be one of them.

As I said, the PhD journey was a long and winding path, but I wouldn’t be able to walk half of it without Nora. Since the start of her mentoring, Nora proved to be an incisive mind, taking my research to another level of clarity and relevance. But that’s not all, besides your incisive and sharp mind, Nora, I also cherish you because of your humanity, compassion, and wholehearted commitment to improve the world. You supported me not only by guiding my research, but also as a human being. Besides being my daily supervisor, I have the privilege to call you my friend. You are literally one of the small group of people that, without hesitation, I can say you make the world a better place. Perhaps even without realizing it, you are like a lighthouse in the lives of many people. You certainly were a guiding lighthouse in many murky moments during my PhD. Looking far beyond mere appearances, you provide a steady, honest, and selfless hand that guides with a warm heart, but with the serenity, sensibility and far-reaching sight of a true woman of wisdom.

I also want to thank other mentors that have had a great role and influence in my early professional and personal life. After studying international relations, a journey that took me all the way to water may seem extravagant. But I owe it to Mario, who first introduced me to the world of water with a geopolitical perspective. You were the first one who believed in me and gave me an opportunity. I learned from you to dare employing great and long-term perspectives to understand the past, present, and future, and above all to have a strong moral compass and spiritual confidence. Then Guicho, working with you I understood what it meant to work in real inter-disciplinary research on water conflicts, and what it meant to be a critical and committed scientist and the necessary high standards we need to produce useful science, especially for marginalized people. Your work ethics have been an example to me, and your friendship a fortune. Finally, I thank Gabriel, who also gave me the opportunity to work alongside many hands-on projects to protect the environment and marginalized people; you especially taught me the practical value of hard work and believing with an infinite hope that a better world is possible and that things will improve over time despite all odds.

With a both heavy but happy heart, I am turning the page of a journey of more than 6 years. This has been the longest professional commitment of my career, and longest period of my life living anywhere outside Mexico. So, it was inevitable to find new friends that slowly became like family. Even before setting foot on the Netherlands, I received an email from an unknown person at the time: “Dear Jonatan, Heartiest welcome to IWSG and to IHE. Wish you a safe and pleasant journey to the Netherlands. Kindly feel free to ask for any information and/or support." And like that it started to feel like home in no time, Shahnoor. It can become difficult at times when one spends so much time with international people that eventually leave to their home countries. Carlos S., you were an amazing friend, funny and smart as hell. And for the people that have remained, I am happy to feel like home with you guys: Berend, Bianchita, Mohaned, Shahnoor, and Carlos. I thank you to be in my life, and I am especially proud of who you are, and calling you my dear friends.

I also want to thank all the amazing people at IHE and the Netherlands that I have met along this road: Akosua, Roos, Jaime, Tesfay, Nadine, Yvonne, Irene, Oscar, Hermen, Stefan, Luis Miguel, Maria Laura, Victor, Peter, Gabriela, Andrés, Alex, Miroslav, Hans, Sara, Afua, Mohan, Rens, Erwin, Musaed, Mohammed, Carlos Mauricio, Mary, Fernanda, Bosman, Uwe, Adriano, Mario, Vitali, Febe, Maria Luisa, Adele, Sara, Thaine, Clara, Neiler, Pamela, Lucia, Adey, Nazanin, Aftab, Ilyas, Jolanda, Zaki, Schalk, Ferdi, Lyzette, Angeles, Eddy, Gerald, Jaap, Margreet, Emanuele, Vero, Wout, Gerda, Jos, Peter, Conny, León, Monique, Andreja, Jeltsje, Anique, Michelle, Fred, Janez, Michael, Alyssa, Bota, Selvi, Arlex, Elga, Klaas, Seema, Dmitri, Nemanja, Wout, and Jochen.

I also want to recognize my PhD sponsor CONACyT for providing the funds to embark this journey.

My dear friends and family, you all supported me in this trip by helping me during my numerous fieldtrips, providing advice and lots of love. To my family, Aysha, Max, Abraham, Perla, Dad, Lucero, César, Cesarín, Lorenzo, Tío Daniel, Leo; and my dear friends, Joshua, Amira, Ana Sofía, and Tlacaelel, thanks for everything.

Finally, I would like to thank the people closest to me. You are generally the ones that suffer the most with the ups and downs of a PhD life. Long working hours, and a sometimes (often, perhaps) difficult and disquiet mood. Thanks, Sandra, for your patient and persistent love, you trusted in me even when I doubted myself. And last but not least, an immense thanks to my mom, who did so much for me, I know you would be incredibly proud of me. I can only repay you by being the best father I can be to my beautiful daughter, your granddaughter.

SUMMARY

In the last decades, thousands of socio-environmental conflicts have spawned, especially at the sub-national scale. Among these, water conflicts are especially complex and multi-faceted, since most are driven by a combination of socio-economic dynamics that increase pressure on natural resources, more extreme hydro-climatic trends, outdated or biased legal frameworks, large power asymmetries between actors, and the dominance of socio-technical paradigms that reduce the decision space of water policies. Although water conflicts often receive a lot of attention, public scrutiny, and media exposure, this has not necessarily transcended into improving our understanding of their relation to the coupled human-water systems in which they are embedded, and even less of their transformative potential to open the decision space on the development pathways of cities and water systems.

Furthermore, if a conflict drags on, it creates the notion of conflict impasse, of a static nature and confined to a narrowed space. This can further obstruct our understanding of what the conflict is really about, what are its root causes, what are the motivations of key actors, how do actors mobilize different capitals to achieve their goals and coalesce in networks, and what are the best ways to move forward and find transformative alternatives. This PhD thesis aims to reveal that water conflicts are highly dynamic and the result of a complex web of events influenced by social and natural long-term dynamics, knowledge controversies, and actors and network dynamics that widen the perception of the boundaries of water conflicts. To map out and navigate these turbulent waters of water conflicts, new transdisciplinary methods and action research are necessary.

The realization that conflicts are complex and dynamic, and that transdisciplinary and action methods are needed to transform them has many implications. First, given the long-term dynamics that determine a conflict, it is necessary to analyze its history beyond the "official" start of the conflict, even before the involvement of the main actors in the conflict. Therefore, a water conflict involves much more than only just a dispute between parties, but also wider and more transcendent discussions of sustainability of cities and water systems and fairness of socio-political systems. Second, these long-term dynamics are both social and natural, thus, water conflicts need to be analyzed in an interdisciplinary manner to better deal with controversies composed of different kinds of uncertainties and ambiguity in the coupled human-water systems. The development of new hybrid disciplines like socio-hydrology and hydrosocial studies are a step forward, but they keep being dominated by either a natural sciences or social sciences epistemology. Third, further analyzing the conflict in a transdisciplinary and longitudinal manner, by involving actors in knowledge co-production, can improve our understanding of knowledge controversies, which in turn increases the reflectivity of the role of science and scientists in these conflicts.

To investigate the depth and complexity of these implications, I chose the emblematic case of the Zapotillo conflict in Mexico. This is a 16-year-old conflict that started when the Zapotillo project, a large water transfer infrastructure to aid two urban heartlands, was announced. Guadalajara and León, two important cities in Mexico, have been unsustainably depleting their local water sources and are currently suffering severe water shortages. Their relentless urban growth indicates that the gap between water demand and available water supply will keep deepening in the long term if nothing is implemented. However, in the donor basin, the Zapotillo dam would displace hundreds of people, and local farmers are afraid of losing their water to these cities. Supported by national and international engineering organizations, the water authorities have developed water resources models and assessments that show that the Verde River in the donor basin has enough water to export some of it to these cities. While politicians have repeatedly argued in relation to the displacement of people, that the benefit of a majority should prevail over the rights of a minority, actors against the project have argued for the potential of demand management and other low-scale water supply strategies in Guadalajara and León to provide for their water demand that are more sustainable and equitable compared to the Zapotillo project. Although these alternatives have not been thoroughly tested, they would mark a transition to a very different urban development pathway should they be implemented. Currently, after almost two decades of conflict, the Zapotillo dam remains unfinished, its construction stalled, and it is uncertain if it will ever be completed.

This case begs a variety of different questions. Can the Zapotillo conflict be understood solely by the opposition to the Zapotillo project, or by tendencies, dynamics, and a development pathway (with its concomitant paradigm) that started way before the Zapotillo project was even conceived? What is the role of scientific knowledge and its artefacts, such as water resources models, in conflicts? To which extent can they resolve different kind of uncertainties and ambiguity in the water systems, and how can they positively influence the science-policy processes influencing water conflicts? How come a grassroots movement that started with a few dozen people from the dam-affected communities has managed to challenge the federal and state governments and stop one of the largest infrastructure projects in Mexico, and is even proposing a water system transition based on a different paradigm? What are the social, political, cultural, and technical determinants of the current trajectory of the water systems of Guadalajara and León and what are the implications of new potential development pathways for these cities?

To answer these questions, this thesis is structured in four parts. 1) Understanding the past: no conflict can be understood without a thorough background of actors and trends.

2) Analyzing the current knowledge controversies, which are the heart and soul of every water conflict. 3) Acknowledging that conflicts can be understood as social-political and technical processes that, when reaching critical mass, are capable of ripping apart the fabric of the decision space of water management, thus creating a crossroads of development pathways of the cities' water systems. 4) Understanding and analyzing water conflicts not as events, but as co-evolving processes related to the decision space on public agendas, infrastructure, and institutions.

Chapter 2, Production of competing water knowledge in the face of water crises: revisiting the IWRM success story of the Lerma-Chapala basin, Mexico, aims to understand the historic socio-political context, narratives, and territorial projects that, although started in the Lerma-Chapala sub-basin many decades ago, have determined the chain of events leading to the Zapotillo conflict in the Santiago River sub-basin. Chapter 3, Unravelling intractable water conflicts: the entanglement of science and politics in decision-making on large hydraulic infrastructure, analyses knowledge controversies and the role of science, specifically the role of water resources models in the conflict. Since controversies are the heart and soul of conflicts, scientists' assessments can easily be perceived as biased and escalate the conflict. Chapter 4, The limits to large scale supply augmentation: exploring the disruptive role of water conflicts in the crossroads of urban water system development pathways, explores in detail the water systems' trajectories of Guadalajara and León and how the conflict has forced a development pathway crossroads that may have large consequences for the future of these cities and their water systems. A participatory water resources model was used to make a quantitative analysis and compare the performance of competing development pathways and associated infrastructural alternatives. And finally, Chapter 5, Water conflicts as drivers of socio-technical transitions in water management systems, analyses water conflicts as a multi-dimensional, multi-actor, lengthy, and evolving process largely influenced by grassroots movements with the aim of forcing the water system to a transition that is more sustainable and equitable.

This research contributes to five fields of scientific work: water conflicts, transition management, science-policy processes, socio-hydrology and transdisciplinary action research. To the field of water-related conflicts, this research has shown that there is great opportunity in researching water conflicts through a longitudinal and transdisciplinary approach of transition management, which that dares at proposing new solutions both technically sound and aware of power dynamics. To the field of science-policy processes in contexts of conflict, the findings of this research point out that scientific knowledge cannot positively influence the water conflict when it fails to involve key actors in the conflict and manage epistemic uncertainties and ambiguity. Failing to do so might raise concerns of biased knowledge and encourage other actors to claim unsubstantiated knowledge, or, at least, knowledge with critical uncertainties and ambiguity to further their positions and interests. This cannot transform the conflict, only escalate it. This research also contributed to socio-hydrology by unpacking the many dynamics and factors affecting the supply-demand cycle and finding how grassroots movements and water conflicts can open the decision space and offer a development pathways crossroads. The last contribution comprises the previous ones. If water conflicts require to be studied with a different approach, and knowledge, albeit crucial, suffers from manipulation of both powerful actors and non-hegemonic actors, then it is necessary to design and conduct not only transdisciplinary but also transformative action research. Participatory modelling was used as a key example of a transdisciplinary approach with the purpose of opening the decision space to gauge the transformative potential of the alternative solutions proposed by the grassroots movement in Mexico and support deliberation and negotiation between key actors in the conflict. Thus, this thesis proposes that the management of water conflicts would greatly benefit from longitudinal, transdisciplinary and action research methods that are aware of power dynamics as well as facilitate co-production of knowledge between scientists, grassroots movements, and stakeholders to transform the trajectories of cities and water systems into more sustainable and equitable development pathways.

SAMENVATTING

In de afgelopen decennia zijn duizenden sociaal-milieuconflicten ontstaan, vooral op subnationale schaal. Hiervan zijn waterconflicten bijzonder complex en veelzijdig, aangezien de meeste worden veroorzaakt door een combinatie van sociaaleconomische dynamiek die de druk op natuurlijke hulpbronnen verhoogt, extremere hydroklimatologische trends, verouderde of vooringenomen juridische kaders, grote machtsasymmetrieën tussen actoren, en de dominantie van sociaal-technische paradigma's die de beslissingsruimte van waterbeleid verkleinen. Hoewel waterconflicten vaak veel aandacht, publieke controle en media-aandacht krijgen, heeft dit niet noodzakelijk geleid tot een beter begrip van hun relatie tot de gekoppelde mens-watersystemen waarin ze zijn ingebed, en nog minder van hun transformatieve potentieel om de beslisruimte openen over de ontwikkeltrajecten van steden en watersystemen.

Bovendien, als een conflict voortduurt, creëert het de notie van conflictimpasse, van statische aard en beperkt tot een vernauwde ruimte. Dit kan ons begrip van waar het conflict werkelijk over gaat verder belemmeren, wat de onderliggende oorzaken zijn, wat de motivaties zijn van de belangrijkste actoren, hoe actoren verschillende kapitalen mobiliseren om hun doelen te bereiken en samen te smelten in netwerken, en wat de beste manieren zijn om vooruit te gaan en transformatieve alternatieven te vinden. Dit proefschrift heeft als doel te laten zien dat waterconflicten zeer dynamisch zijn en het resultaat zijn van een complex web van gebeurtenissen die worden beïnvloed door sociale en natuurlijke langetermijndynamieken, kenniscontroverses, en actoren en netwerkdynamieken die de perceptie van de grenzen van waterconflicten verruimen. Om deze turbulente wateren van waterconflicten in kaart te brengen en te navigeren, zijn nieuwe transdisciplinaire methoden en actieonderzoek nodig.

Het besef dat conflicten complex en dynamisch zijn en dat transdisciplinaire en actiemethoden nodig zijn om ze te transformeren, heeft veel implicaties. Ten eerste is het, gezien de lange termijn dynamiek die bepalend is voor een conflict, noodzakelijk om de geschiedenis ervan te analyseren voorbij de "officiële" start van het conflict, zelfs vóór de betrokkenheid van de belangrijkste actoren in het conflict. Een waterconflict omvat daarom veel meer dan alleen een geschil tussen partijen, maar ook bredere en meer transcendente discussies over duurzaamheid van steden en watersystemen en eerlijkheid van sociaal-politieke systemen. Ten tweede is deze langetermijndynamiek zowel sociaal als natuurlijk, dus waterconflicten moeten op een interdisciplinaire manier worden geanalyseerd om beter om te gaan met controverses die bestaan uit verschillende soorten onzekerheden en ambiguïteit in de gekoppelde mens-watersystemen. De ontwikkeling van nieuwe hybride disciplines zoals socio-hydrologie en hydrosociale studies zijn een stap voorwaarts, maar ze blijven gedomineerd door ofwel een natuurwetenschappelijke of sociale wetenschappen epistemologie. Ten derde kan het verder analyseren van het conflict op een transdisciplinaire en longitudinale manier, door actoren te betrekken bij kenniscoproductie, ons begrip van kenniscontroverses verbeteren, wat op zijn beurt de reflectie van de rol van wetenschap en wetenschappers in deze conflicten vergroot.

Om de diepte en complexiteit van deze implicaties te onderzoeken, koos ik het emblematische geval van het Zapotillo-conflict in Mexico. Dit is een 16 jaar oud conflict dat begon toen het Zapotillo-project, een grote infrastructuur voor wateroverdracht om twee stedelijke kerngebieden te helpen, werd aangekondigd. Guadalajara en León, twee belangrijke steden in Mexico, hebben hun lokale waterbronnen op onhoudbare wijze uitgeput en kampen momenteel met ernstige watertekorten. Hun niet-aflatende stedelijke groei geeft aan dat de kloof tussen de vraag naar water en het beschikbare wateraanbod op de lange termijn alleen maar groter zal worden als er niets wordt ingevoerd. In het donorbekken zou de Zapotillo-dam echter honderden mensen verdrijven, en lokale boeren zijn bang hun water aan deze steden te verliezen. Met de steun van nationale en internationale technische organisaties hebben de waterschappen modellen en beoordelingen voor watervoorraden ontwikkeld die aantonen dat de rivier de Verde in het donorbekken voldoende water heeft om een deel ervan naar deze steden te exporteren. Terwijl politici herhaaldelijk hebben betoogd met betrekking tot de ontheemding van mensen, dat het voordeel van een meerderheid moet prevaleren boven de rechten van een minderheid, hebben actoren tegen het project gepleit voor het potentieel van vraagbeheer en andere kleinschalige strategieën voor watervoorziening in Guadalajara en León om in hun watervraag te voorzien die duurzamer en rechtvaardiger is in vergelijking met het Zapotillo-project. Hoewel deze alternatieven niet grondig zijn getest, zouden ze een overgang naar een heel ander stadsontwikkelingstraject markeren als ze worden geïmplementeerd. Op dit moment, na bijna twee decennia van conflict, is de Zapotillo-dam nog steeds niet voltooid, de bouw ervan stagneert en het is onzeker of deze ooit zal worden voltooid.

Deze casus roept verschillende vragen op. Kan het Zapotillo-conflict alleen worden begrepen door de oppositie tegen het Zapotillo-project, of door tendensen, dynamiek en een ontwikkelingstraject (met het bijbehorende paradigma) dat begon lang voordat het Zapotillo-project zelfs maar werd bedacht? Wat is de rol van wetenschappelijke kennis en haar artefacten, zoals modellen voor watervoorraden, in conflicten? In hoeverre kunnen ze verschillende soorten onzekerheden en ambiguïteit in de watersystemen oplossen, en hoe kunnen ze de wetenschap-beleidsprocessen die waterconflicten beïnvloeden positief beïnvloeden? Hoe komt het dat een basisbeweging die begon met enkele tientallen mensen uit de door dammen getroffen gemeenschappen, erin geslaagd is de federale en deelstaatregeringen uit te dagen en een van de grootste infrastructuurprojecten in Mexico te stoppen, en zelfs een watersysteemtransitie voorstelt op basis van een ander paradigma? Wat zijn de sociale, politieke, culturele en technische determinanten van het huidige traject van de watersystemen van Guadalajara en León en wat zijn de implicaties van nieuwe potentiële ontwikkelingstrajecten voor deze steden?

Om deze vragen te beantwoorden is dit proefschrift in vier delen gestructureerd. 1) Het verleden begrijpen: geen enkel conflict is te begrijpen zonder een lange achtergrond van actoren en trends. 2) Analyseren van de huidige kenniscontroverses, die het hart en de ziel vormen van elk waterconflict. 3) Conflicten die ook worden opgevat als sociaal-politieke en technische processen die een kritische massa bereiken die in staat is om het weefsel van de beslissingsruimte van waterbeheer uit elkaar te scheuren, en zo een kruispunt van ontwikkelingspaden van de watersystemen van de steden te creëren. 4) Begrijpen en analyseren van waterconflicten niet als gebeurtenissen, maar als co-evoluerende processen gerelateerd aan de beslissingsruimte op publieke agenda's, infrastructuur en instellingen.

Hoofdstuk 2, Productie van concurrerende waterkennis in het licht van watercrises: een nieuw bezoek aan het IWRM-succesverhaal van het Lerma-Chapala-bekken, Mexico, heeft tot doel de historische sociaal-politieke context, verhalen en territoriale projecten te begrijpen die, hoewel begonnen in de het naburige Lerma-Chapala-bekken, vele decennia geleden, hebben de reeks gebeurtenissen bepaald die leidden tot het Zapotillo-conflict in het stroomgebied van de Santiago-rivier. Hoofdstuk 3, Het ontrafelen van hardnekkige waterconflicten: de verstrengeling van wetenschap en politiek in de besluitvorming over grote hydraulische infrastructuur, analyseert kenniscontroverses en de rol van de wetenschap, in het bijzonder de rol van waterbronnenmodellen in het conflict. Aangezien controverses het hart en de ziel van conflicten zijn, kunnen de beoordelingen van wetenschappers gemakkelijk als bevooroordeeld worden beschouwd en het conflict escaleren. Hoofdstuk 4, De grenzen aan grootschalige aanbodvergroting: onderzoek naar de ontwrichtende rol van waterconflicten op het kruispunt van ontwikkelingstrajecten van stedelijke watersystemen, onderzoekt in detail de trajecten van de watersystemen van Guadalajara en León en hoe het conflict een kruispunt van ontwikkelingstrajecten heeft gedwongen die grote gevolgen kunnen hebben voor de toekomst van deze steden en hun watersystemen. Een participatief waterbronnenmodel werd gebruikt om een kwantitatieve analyse te maken en de prestaties van concurrerende ontwikkelingstrajecten en bijbehorende infrastructurele alternatieven te vergelijken. En tot slot, Hoofdstuk 5, Waterconflicten als aanjagers van socio-technische transities in waterbeheersystemen, analyseert waterconflicten als een multidimensionaal, multi-actor, langdurig en evoluerend proces dat grotendeels wordt beïnvloed door basisbewegingen met als doel het water te dwingen systeem naar een transitie die duurzamer en rechtvaardiger is.

Dit onderzoek draagt bij aan drie gebieden van wetenschappelijk werk: waterconflicten, wetenschap-beleidsprocessen en transdisciplinair actieonderzoek. Op het gebied van watergerelateerde conflicten heeft dit onderzoek aangetoond dat er grote mogelijkheden zijn om waterconflicten te onderzoeken door middel van een longitudinale en transdisciplinaire benadering die het aandurft om nieuwe oplossingen voor te stellen, zowel technisch verantwoord als bewust van machtsdynamiek. Op het gebied van wetenschap-beleidsprocessen in conflictcontexten wijzen de bevindingen van dit onderzoek erop dat wetenschappelijke kennis het waterconflict niet positief kan beïnvloeden wanneer het er niet in slaagt de belangrijkste actoren bij het conflict te betrekken en epistemische onzekerheden en ambiguïteit te beheersen. Als u dit niet doet, kan dit aanleiding geven tot bezorgdheid over vooringenomen kennis en kunnen andere actoren worden aangemoedigd om ongefundeerde kennis te claimen, of op zijn minst kennis met kritische onzekerheden en ambiguïteiten om hun standpunten en belangen te bevorderen. Dit kan het conflict niet transformeren, alleen escaleren. De laatste bijdrage omvat de eerste twee. Als waterconflicten met een andere benadering moeten worden bestudeerd en kennis, hoewel cruciaal, lijdt onder manipulatie van zowel machtige als niet-hegemonische actoren, dan is het noodzakelijk om niet alleen transdisciplinair maar ook transformatief actieonderzoek te ontwerpen en uit te voeren. Participatieve modellering werd gebruikt als een belangrijk voorbeeld van een transdisciplinaire benadering met als doel de beslissingsruimte te openen om het transformatieve potentieel van de alternatieve oplossingen die door de basisbeweging in Mexico worden voorgesteld te peilen en de beraadslaging en onderhandeling tussen de belangrijkste actoren in het conflict te ondersteunen. Dit proefschrift stelt dus voor dat het beheer van waterconflicten veel baat zou hebben bij longitudinale, transdisciplinaire en actieonderzoeksmethoden die zich bewust zijn van machtsdynamiek en die de coproductie van kennis tussen wetenschappers, basisbewegingen en belanghebbenden vergemakkelijken om de trajecten van steden te transformeren en watersystemen in duurzamere en rechtvaardigere ontwikkelingstrajecten.

FOREWORD

> [O]nce […] a bibulous, semi-literate, ageing country squire two hundred years ago or more, sitting by his fireside listening to Paradise Lost being read aloud. He's never read it himself; he doesn't know the story at all; but as he sits there, perhaps with a pint of port at his side and with a gouty foot propped up on a stool, he finds himself transfixed.
>
> Suddenly he bangs the arm of his chair, and exclaims 'By God! I know not what the outcome may be, but this Lucifer is a damned fine fellow, and I hope he may win!'
>
> —Philip Pullman, *Preface to Paradise Lost*

What is it about a small town of less than 500 people to dedicate more than six years studying its whereabouts, perspectives, actions, conflicts, rifts, friends, foes, relations, alliances, weaknesses, strengths, and positions? What is it of interest for science to know the outcome of the breach they have accomplished to produce in the fabric of ideas, perceptions, and especially decisions on water management in Mexico? After all, they might as well be the footnote of a train that started course years prior, only but an insignificant smudge in the large picture of water, large infrastructure and the stability of a water system.

That is precisely the question that Pieter used to ask me every time we met for a couple of years at the start of my PhD. "What does this mean to science? You are not an activist or cheerleader; you are a scientist. Why is this case significant to science?"

I cannot deny that that question haunted me and worried me. I could only but feel and know in my innermost being that this case was worthy to investigate; it was worthy to dedicate a lustrum-long effort to study it. I had the certainty that any effort would be handsomely compensated if I just follow my instinct.

Heidegger said that one can recognize a paradigm because it shines. And the Zapotillo conflict seems to be a paradigmatic case that is shedding light blindingly. And it is precisely that blinding light that I knew my focus ought to study. This research aims at putting on glasses to be able to look at it, even if only partially.

To understand the Zapotillo conflict, one needs to familiarize with the human condition of yearning for one's roots, and the psychological toll it takes to uproot one's past for the sake of an uncertain future. Being flexible is often regarded as a vital skill to be able to adapt and thrive in a changing, globalized world. Children can adapt to many contexts because they have a plastic brain. Sometimes, however, adapting oneself to an unfair world is a bad option. Perseverance or stubbornness to not let one be changed and adapted to the world is, in my perspective, of essence. We are not simply expendable pawns in the world. “You are not machines, you are not cattle… you are men!” said Chaplin at the end of the movie The Great Dictator, and indeed, we are humans, and sometimes even pawns can become queens that checkmate kings. Powerful transformations offer hope, not flexibility.

Indeed, the tireless efforts of the people from Temacapulín may be futile, and that blinding light be put off, giving room for the same old glaring obscurity. We all may be forced to adapt one day. But it is also true that some events transcend space and time to become eternal. They become shining beacons as a guide for others. Just like stars in the dead of night, some of them may already be extinguished, but they keep on lighting.

Camus argued that a rebel is someone “who says no, but whose refusal does not imply a renunciation. He is also a man who says yes, from the moment he makes his first gesture of rebellion.” Most acts of rebellion fail, but paradoxically, they live on to inspire future successful rebellions. It is just hard to say if a rebel would rebel at all knowing that his or her act will fail. However, for most rebels, winning is not the primary motivation to mobilize, but to shatter the chains of inhuman conditions. To make a claim that will rumble far longer than the shackles that forced them.

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1
INTRODUCTION

"If I were to wish for anything, I should not wish for wealth and power, but for the passionate sense of the potential, for the eye which, ever young and ardent, sees the possible. Pleasure disappoints, possibility never. And what wine is so sparkling, what so fragrant, what so intoxicating, as possibility."

—Søren Kierkegaard, *A fragment of life*

1.1 BACKGROUND

The Zapotillo conflict started in 2005 when the water authorities decided to implement the Zapotillo project, a supply augmentation scheme to transfer water to two major cities in western Mexico. However, this conflict cannot be fully understood without exploring varied social and natural dynamics such as the increasing weakness of the nation-state, the relevance and more active role of economic interests in public affairs, increased water use with more stochastic patterns of precipitation due to climate change, the urban/rural dynamics characterized by a high migration rate of people leaving the country side to look for a better life in the big cities, the formation of an actor-network against dams, the emergence of social media as a tool for social movements, large hydraulic projects as the only solutions against the water problems of the country and the more common incredulity in science and technical knowledge in society.

During most of the twentieth century, the nation-state had been the most powerful actor in all societies. Whatever the plans of the nation-state may be, those plans would eventually find a course to be implemented, regardless of its success or eventual failure. The strength of the State was unparalleled, especially in Mexico where it was autocratic, that it would be able to implement sweeping reforms affecting society at large. Just as in the 1910s, after a revolution, the State redistributed agrarian land to millions of impoverished farmers against the interest of large landowners, and afterwards it even tried to outlaw religious celebrations in order to impose a secularist state, which faced a violent backlash in what is known as the “Guerra Cristera” in the most conservative region of the country: Los Altos de Jalisco.

During most of the twentieth century, Mexican authorities practiced a kind of water management that sought to develop water resources with the clear aim of promoting economic development regardless of negative social and ecological considerations (Van der Zaag, 1992; Wester, 2009; Chapter 2 of this thesis). This kind of water management was based on a broader water paradigm of industrial modernity, characterized by “the ideas of the Enlightenment, engineering capacity, science and investment initiatives of the state and the private sector” (Allan, 2003). This paradigm was instrumentalized through the ´Hydraulic mission´, which is briefly defined as the mission to make every drop of water productive before it is wasted in the sea (Wester, 2009). Because of this, the heyday of dam development in Mexico happened during 1930s-1980s (Wester et al., 2009c; McCulligh & Tetreault, 2017). This fever for water resources development was accompanied with social institutions according to the interests and power of the main stakeholder, the State. The irrigation infrastructure was developed and fully operated by the Ministry of Water Resources and Irrigation; and water utilities were also developed and operated by a central government agency. Although this status quo was useful for promoting development during the hydraulic mission, soon it became cumbersome for the government itself. Corruption and inefficiency plagued the operation and management of the infrastructure in irrigation (Sijbrandij & van der Zaag, 1993) and water utilities, whose service was considered poor by the population and its non-revenue water skyrocketed to more than 50% (Herrera, 2017).

In 1988, the country embraced a new political and economic ideology with the election of a Harvard-educated presidential candidate. Salinas de Gortari eloquently elaborated a modernist discourse that argued that Mexico would inevitably follow the path to wealth and eventually become a first-world country if the economy would be liberalized. During this period, most of the state companies were privatized under the logic that the state was corrupt and would deliver inefficient services, because it would always politicize the operation and management of water services. Moreover, the national water authority projected the emergence of multiple urban water conflicts across the country due to an increase of demand and limited water resources (Castro, 2007). The market was presented as an effective alternative, whereby the quality of public services would improve for a cheaper price due to market forces. This approach was originated and financed by the World Bank, which was key in sponsoring such changes in Mexico (Wilder, 2010).

Under the same logic, the government implemented four main changes in the water sector legitimized by the concept of Integrated Water Resources Management, whose tenets were booming at the time as a sanctioned discourse in international organizations like the World Bank and the Global Water Partnership (Molle, 2008). One, irrigation districts were transferred to Water User Associations, a move that is considered as having been the largest and fastest in the world (Rap, 2006). Second, although water utilities were previously decentralized in 1983 to increase the responsibility of the local and state governments (Barkin, 2011), few years later privatization of water utilities was also allowed (Herrera & Post, 2014). Three, in 1992 user participation was promoted through the creation of basin councils to promote the coordination of water users with the objective to achieve an optimal sustainable and efficient use of water throughout the basin (Caire Martínez, 2004). And finally, these socio-technical changes were accompanied by a new water law, which allowed, not the commodification, but the *de facto* privatization of water rights, by allowing long-term water rights (25 years), and the possibility to renew them (Rosegrant and Schleyer, 1996). This water right system would later evolve into the creation of water markets and tradable water rights.

The future could not look more promising. The former President even took Mexico as a member of the wealthier nations in the world club, to the OECD. That certainly was a symbolic reward for an apt pupil. Internationally, this time was even regarded as the "End of History" (Fukuyama, 1989), signalling a moment whereby humanity had finally devised the optimal political and economic systems after the fall of the Berlin wall. What for heaven's sake could go wrong?

International praise followed this alleged exemplary water management transition regarding irrigation, water utilities and public participation in basin councils (Rap, 2006; Lenton & Muller, 2009). However, empirical evidence showed that, except for some cases, Irrigation Management Transfer did not improve the maintenance of infrastructure, cost recovery, agricultural and economic productivity, nor efficient water distribution (Kloezen, 2002; Rap, 2004, 2006). Water utilities experienced a similar story, whereas with some exemplary exceptions, most utilities are still lagging behind in terms of cost recovery, reduced non-revenue water, and access to safe drinking water to the general population (COMDA et al., 2019; Herrera, 2018). And finally, user participation, although formally encouraged, was deterred by absence of clear actionable mechanisms to incorporate the users' contributions in decision-making, as well as intergovernmental operation (Caire Martínez, 2004; Hoogesteger & Wester, 2017). Thus, the *de facto* decision-making still depended almost entirely on the water authorities, a situation that was described as a simulation (Muñíz-San Martin & Torres-González, 2012; Chapter 2 of this thesis), a situation that has also been seen in many other countries (Ribot et al., 2006).

The legal water framework has been unable to effectively address serious water problems in Mexico such as the general pollution of the surface water bodies, water scarcity and over-exploited aquifers and poor water access for poor people in large growing cities (Godinez Madrigal et al., 2018a). Water quality has deteriorated over time because what has been described as institutional corruption, including an appalling incapacity to inspect industrial and domestic effluents and outdated norms and regulations set by the polluters themselves (McCulligh, 2017). Water scarcity is exacerbated by a relentless urban growth promoted by the housing industry (Reis, 2017), facilitated by the water authorities who grant water rights regardless of availability (Reis, 2014), and worsened by negligence of water utilities to invest in infrastructure and demand management strategies (Ochoa-García, 2015). Over-exploited aquifers are also related to the water authorities' incapacity to monitor and inspect groundwater users, while actively frustrating bottom-up initiatives (Hoogesteger & Wester, 2017). All of the above has resulted in an overall decline in trust in official institutions and their knowledge and projects (Reis, 2014).

Acknowledging the many water problems Mexico faces, political actors on the one hand, and a collective of organized social actors (*Agua para todos*) comprised of civil society organizations, academics, and NGOs on the other, have presented two competing water bills in the past recent years (Wilder et al., 2020). These competing bills address the water problems in divergent and even opposite ways. The political actors wage for increasing the role and weight of Conagua (the highest water authority in Mexico) and decreasing the influence of non-state actors in water issues (e.g., it would make it illegal for a university to produce hydrological data), while aiming to strengthen the legal framework to facilitate the development of large infrastructure and water transfers across the country.

The social actors´ bill would increase democratic decision-making by incorporating communities, academics, peasants and other often neglected actors to the decision-making arena.

By the end of 2021, neither bill has been approved and emerging socio-ecological dynamics are creating new water challenges. First, the general pollution of surface water and poor water quality supplied to domestic users have generated a general aversion to tap water and the emergence of one of the world's most lucrative bottled water market (Greene, 2018). Second, the incapacity to accurately monitor groundwater extraction, together with the growing economic importance of clean water in water scarce but economically vibrant regions of the country and a generalized surface water pollution, have generated a black market of groundwater rights (Reis, 2014). Third, the critical groundwater over-exploitation has revamped supply augmentation projects drawing from surface water to protect the aquifers in important cities (Chapter 3 of this thesis).

The Zapotillo conflict is embedded in these broader social, political, and economic dynamics in Mexico. But also, the future of the currently bogged down Zapotillo project could support either group of actors. For hydraulic engineers in Conagua it could be a prime example of the necessity to revamp the legal basis to implement further large infrastructural water projects they see necessary in Mexico, while the collective of social actors see it as an example of how society might triumph against all odds and implement a social agenda in the Mexican water sector.

1.2 PREVENTING OR TRANSFORMING WATER CONFLICTS?

Considering this background, it becomes evident that the conflict over the Zapotillo project is much more than just the dam and a water transfer; it is also about deeper issues involving sustainability, fairness, and the legal frameworks and institutions that operationalize them. Therefore, we may pose the question whether water conflicts are events we want to avoid, if possible, or necessary events that catalyse the symptoms of serious maladies in the existing water management system. Of course, there are no black and white answers. Although it is certainly preferable to prevent violent conflicts where human lives are at risk, should we try to prevent conflicts because of their potential violence? Or are they an inevitable characteristic of the human condition, and the best we can do is to manage them and work for a good outcome?

Although it is extremely difficult to answer these questions in general, they have configured two different approaches for understanding water-related conflicts. As described in detail in Chapter 5, one is a data-driven socio-hydrological approach, trying to understand the conditions that enable the emergence of conflicts, while the other, a political ecologist approach, aims at understanding the social processes that enable an acceptable result for all parties, especially interested in environmentally sustainable and socially just outcomes.

In the first approach, water conflicts are perceived as having the potential to escalate and to tear the social fabric with social unrest and violence (Homer-Dixon, 1994; 1999). Gleick (2014) pinpointed the emergence of the Syrian civil war on a prolonged drought; and concluded on the need to implement demand management strategies such as modernization of agriculture to prevent future conflicts. This type of analysis brings about interesting questions, like should we attempt to predict the occurrences of conflicts around the world by mapping the conditions that enable them? Is there a one-size-fits-all mix of conditions that increase the proclivity of (armed) conflicts around water?

To answer the first question, data-driven models of conflicts would argue that it is indeed possible to find that a mix of conditions or variables can predict the occurrence of conflicts. However, if conflicts can be predicted, what to do with this information? A straight, linear answer would be to prevent the occurrence of conflicts as much as possible: "Climate–conflict linkages could be reduced by addressing environmental challenges in building cooperation and peace or by preventing relapse into conflict in societies with especially high vulnerability and exposure to climatic hazards." (Mach et al., 2019).

However, as pointed out by Zeitoun et al. (2019), there are many destructive forms of cooperation that deflect much-need transformation towards more sustainable and just socio-technical systems. Thus, outright conflicts prevention may mire the possibility to transform unsustainable and unequitable water systems.

Depending on the scale and intensity of conflicts, they can produce socio-political crises. However, crises are also capable of reinterpreting how collectively the functioning of the system is understood and, thus, broadening what the real issues are, and re-opening the decision space, as Chapter 2 suggests in the Lerma-Chapala case. This relation is not far-fetched when one considers that the etymology of the word crisis comes from the Greek word 'krisis', which means 'decision'. Thus, this already changes the perception of conflicts as inherently bad.

Therefore, it is useful to think of conflicts and crises as crossroads, as explained in Chapter 5. Emerging actors, especially those who have built a considerable network, and accumulated different kinds of social capitals (e.g., legal, political, scientific, and technical), can take advantage of windows of opportunity to exert system transformations, even paradigmatic, as discussed in Chapter 4. Alternatively, dominant actors can exert their power to narrow what the issues are and close the decision space to stabilize the paradigm in which they are nested. Nevertheless, when societies opt for a non-transformative solution to conflicts, they are rarely solved, but rather displaced in space and time, as Chapter 2 will describe.

Eventually, if societies opt for transformative solutions and processes, these usually imply a thorough transformation not only in infrastructure, but also institutions, legal frameworks, culture, and socio-economic dynamics. When societies reach that point, the problem is not to identify what is not wanted, but to decide which pathway to undertake to move forward. For that, knowledge development is essential, but not devoid of difficulties, contradictions, gaps, complexities, and antagonisms as the next section describes.

1.3 KNOWLEDGE DEVELOPMENT IN TRANSFORMATIVE PROCESSES

The inherent complexity of water has generated many ways to study it. Science and the generation of knowledge about water have taken two different paths, although with some similar aspects and components. On the one hand, the social sciences have adopted a conceptual framework of political ecology where water is analyzed through theories that study power as an exercise of hegemonic domination extended to all social dimensions related to water by certain social groups towards the rest of society (Zeitoun & Werner, 2006). In this way, the social studies of water have become socio-centric and tend to be suspicious of technical approaches employed by natural scientists (cfr. Boelens et al., 2019). For their part, the natural sciences have been dominated by groups of scientists who conceive water systems and their biophysical characteristics in isolation from society (Sivapalan et al., 2012).

However, new approaches are beginning to dispute these views of the social and natural sciences. New critical disciplines are germinating from the social sciences that consider the explanatory power of science as important as the study of power relations (Forsyth, 2011, Lave et al., 2014). While a new discipline has emerged from the peripheries of the natural sciences that tries to formally incorporate a dialectical relationship between natural systems and society, which is mathematically measurable (Sivapalan, 2015). The first type of disciplines are known as hydrosocial studies and critical human geography (Wesselink et al., 2016), and the latter belong to the field of socio-hydrology (Sivapalan, 2015). The two paths coincide in the incidence that societies have on water systems and vice versa, but they differ in the assumptions with which they define the scope of their research (which constitutes different ontologies) and that determines their methodologies (which constitutes different epistemologies) (Wesselink et al., 2016).

These epistemological and ontological differences have led to a series of harsh criticisms between both fields of knowledge. Scientists in the natural sciences criticize that political ecology does not incorporate ecology, leaving incomplete an analysis that is supposed to be holistic (Walker 2005; Forsyth, 2011; Turner 2016); and that it is weary and reluctant of proposing solutions (Wesselink et al., 2017). While social scientists criticize that socio-hydrological studies only incorporate society in an oversimplified way, running the risk of promoting a post-political society led by experts and technocrats (Melsen el al., 2018; Wesselink et al., 2017, Savelli et al., 2020).

Mired in this debate, science-policy processes are in crisis due to the growing perception that scientific knowledge is not as unbiased as it purported to be. This growing perception comes at a time when societies around the globe face grand socio-environmental challenges needing urgent action (Di Baldassarre et al., 2019).

Therefore, if social scientists produce unactionable knowledge, and technicians and engineers produce powerful but naive or even counterproductive knowledge; is it possible to produce powerful, and especially actionable knowledge that considers the influence of power and is valid for both groups of scientists?

1.4 BEYOND POWER: TOWARDS THE EMERGENCE OF A POTENT TRANSDISCIPLINARY SCIENCE

Foucault has been perhaps the most relevant philosopher of the 20th century to study the architecture of power and analyze the devices with which it is exercised. Especially in political ecology studies, academics have used the term of governmentality to account for the influence that power exerts on how the socio-natural reality is conceived and the main strategies to control socio-natural spaces (Boelens et al., 2019). As such, Foucault's corpus has focused on the constant evolution of the mechanisms by which power is exercised: from the tyrannical, to the disciplinary, and to the microcellular (Baudrillard, 1977). Foucault's analysis shows that everything is political and has to do with power and control devices. However, if everything is political, and power and control permeates everything and everybody, then all people and institutions are subject of suspicion.

Against this apparent paradox, Spinoza, the cursed and exiled Dutch philosopher of the 17th century, introduced, (three centuries before Foucault) the divergence of the meaning of power in Latin: *Potentia* and *Potestas*. Romance languages conserve this differentiation (i.e., potencia & poder in Spanish and Portuguese, puissance & pouvoir in French, potenza & potere in Italian, etc.), but the English language does not. So, let me further explain the differences.

These types of power can only be understood under the logical framework of the Spinozian work in the Tractatus Theologicus-Politicus and its Ethics (Spinoza, 1986; 1989). For Spinoza the difference between *Potentia* and *Potestas* parallels the difference between ethics and morals. There is no Good and Evil, there is only good and bad. Spinoza uses the example of food and poison to differentiate between what is good and what is bad for a person's intake (Deleuze, 1981). Morality indicates to the subjects what is Good and what is Evil and orders them to act accordingly, and such order requires blind obedience: God orders Adam not to eat the apple from the garden, but Adam does not know what the origin of that order is. Deleuze (1981) said: “Perhaps this obedience is indispensable, perhaps the commandments are well founded. This is not the question. The law, moral or social, does not give us any knowledge, it does not make us know anything." Therefore, ethics is the path by which the individual reaches the good through the understanding of causes.

In this way, *Potestas* is related to morality, to disciplining, in the Foucaultian sense; it is not necessary for the masses to understand how good comes, as long as they follow it. While the *Potentia*, related to ethics, implies the freedom of people in understanding, and eventual encounter, with what is good. Therefore, power (*potentia*) and ethics are inseparable from knowledge conducive to that which is good. A good thing is anything that increases the *potentia* of the rest. With which it is concluded that a greater good implies the scope of the individual *potentia* of the members of a community; that is, *potentia* does not restrict other *potentias*, on the contrary… it increases their power (in Spanish this is described with Potentia as a verb: “las potencia”).

However, academic studies based on Foucault's philosophy, by concentrating on *Potestas*, have been suspicious of most tools developed by natural scientists without making the distinction between *Potestas* and *Potentia*. According to these scholars, any kind of technical solution or quantitative description is insufficient, since the answer lays in addressing all power imbalances in society (Harvey, 1972). An idea that persists until today in critical geography (Zwarteveen et al., 2017; Rusca & Di Baldassarre, 2019). But what if some technical solutions and quantitative descriptions may have the potential of addressing some kind of power imbalances? Recent progressive interdisciplinary research has used the power of models, statistics, maps and spatial analysis with the goal of addressing social justice (Schwanen et al., 2009; Barnes, 2009; Madden & Ross, 2009; Pullan et al., 2014, Boakye-Ansah et al., 2016). Instead of using technical tools to their advantage, an over-critical political ecology approach may have the unintended consequence of thwarting potential solutions to wicked water problems and efforts to better understand nature and its relationship with society.

Nevertheless, differentiating between *Potestas* and *Potentia* is not easy, since an effort starting as *Potentia* can easily derive in *Potentas*: Revolutions that are institutionalized or knowledge that is dogmatized. And in this context, Baudrillard's (1977) critique becomes pertinent: “Foucault's discourse (which is also a discourse of power) ... is the mirror of the powers it describes.” This raises the question of how to avoid the dogmatization of understanding power only as *Potestas*?

Despite the best efforts to understand coupled natural and social systems, epistemic uncertainties are always present, and some are irreducible, regardless of the computational prowess or system knowledge we acquire (Di Baldassarre, et al., 2016). There are things we know we do not know, and even things we do not know we do not know. For example, although we know how climate change will affect the planet at large, it is not precisely known how it will affect specific regions. Furthermore, nature may respond with varied feedbacks simultaneously, which makes highly uncertain how a region like Los Altos might be affected in the future.

Added to these irreducible uncertainties, ambiguity, on the other hand, reflects the mental frameworks that people use to make sense of reality. As described in Chapters 3, 4 and 5, the solution to water scarcity for a certain group of actors can only be supply-augmentation infrastructure despite of its externalities, while for another group of actors, the only solution can be those without negative social nor environmental externalities. There are many solutions to the same problem and the complexity of the coupled natural-human system makes it difficult to reduce ambiguity regarding the correct pathway to choose.

Given these characteristics of complex socio-environmental problems and conflicts, Chapter 3 describes how technical knowledge dogmatizes itself as uncontroversial in a complex socio-environmental conflict full of uncertainties, ethical complexities, and political conundrums regarding social values. Conversely, it is community knowledge that unveils technical knowledge generated in the Zapotillo case as *Potestas*; a black box model in which modellers developed arbitrary scenarios that contributed little to the understanding of the system and the root causes of the conflict. However, as Chapter 4 shows, this same model, originally built with a *Potestas* perspective, could be repurposed and refurbished to better represent the ambiguity of the conflict by incorporating alternative views, which aimed at better understanding the system and propose long-term solutions, a *Potentia* perspective.

Therefore, inter- and transdisciplinary scientific research based on an ethic that leads to a greater understanding of nature and society could chart alternative pathways that provide more sustainable and socially just outcomes, as inferred in Chapter 4. This type of research should make use of all the tools at its disposal, and therefore incorporate natural and social epistemologies in search of a transformation of the water-human systems.

1.5 PROBLEM STATEMENT

The Zapotillo conflict represents a crossroads of water management for the three regions mired in the conflict in Western Mexico, but also for Mexican society at large and involves important scientific debates on water conflicts, knowledge development, science-policy processes, and transdisciplinary science. A first crossroads/debate refers to the way conflicts are managed in Mexico specifically, and worldwide in general. Water conflicts are not only disputes about divergent interests between a configuration of actors, but they are also disputes on long-term paradigms, sanctioned discourses that naturalize certain strategies over others; a dispute over how and who gets to make decisions and which strategy to follow, which will leave an enduring legacy for society and future generations; and a dispute over whose knowledge is valid to take into account when making decisions. Therefore, scientific inquiry on water conflicts should expand its interests beyond issues of conflict and cooperation, intensities of conflict and the root causes of the conflict, to also ponder about which long-term strategies do non-hegemonic actors follow to bridge the asymmetries of power? Which legacy will any pathway to conflict resolution imprint on society and future generations? And more importantly, which pathway may lead to a more sustainable and socially just outcome? Because if these questions are not addressed, conflict prevention and/or resolution will eventually reproduce the conditions that generated the conflict in the first place, as observed in the Lerma-Chapala case described in Chapter 2.

A second crossroads/debate refers to knowledge development and its role in public policies. Scientists and knowledge developers have a crucial role in informing society, but this role gets ticklish, but also even more relevant, when society faces a crossroads derived from a crisis and/or a conflict. Scientific data can strive to be objective, but scientific knowledge is necessarily the product of subjective choices in the methodology design and the kind of questions driving the scientific research. These subjective choices can be consciously influenced by powerful actors, or even unconsciously influenced by knowledge frames based on sanctioned discourses. Therefore, although scientific knowledge plays a primordial role in designing effective public policies, its role needs to be critically analysed by stakeholders who stand to be affected by decisions based on such knowledge. Who gets to decide which methodology to use? Which research questions to ask? How to manage intrinsic uncertainties and ambiguities? To which extent should stakeholders be part of the scientific research, especially in contexts of conflict?

This thesis does not aim at comprehensively answering all of the questions posed in this section. That would be a gargantuan task. However, I believe that the following research questions I have selected may shed light on the rest:

- How are water paradigms affecting, and affected by water conflicts? And if so, how and to which extent?
- Which kind of influence/challenge do scientists face in their practice when requested to play a significant role in water conflicts? How does that influence further translate into the artifacts and research design choices that scientists employ in their practice? Can some of these scientific tools and artifacts be repurposed to give voice to the interests, positions, and propositions of previously unheard/less vocal/more vulnerable actors in conflict?

- Can water conflicts have the potential to exert development pathway transitions to large and complex urban water systems? If so, what is the motivation of the actors in the conflict? Which challenges do they face? Which strategies do they follow? Which are dead ends and which have the potential to flourish?

1.6 STRUCTURE OF THE THESIS

This thesis is organized in six chapters. This first chapter has served as an introduction and background to the Zapotillo conflict, as well as its theoretical justification and research questions.

Chapter 2 analyses the prolegomenon to the Zapotillo conflict happening in the Lerma-Chapala basin between 1910s until the early 2000s. Specifically, the chapter describes in detail the knowledge claims around the Lake Chapala crisis, and embeds those knowledge claims in wider water paradigms, and how these paradigms influence and are influenced by the actors in conflict. The chapter concludes that actors use water crises to redefine societies' relationship with water systems, and that water resources modelling is the continuation of politics by other means.

Chapter 3 analyses the science-policy processes during the Zapotillo conflict. Specifically, the chapter describes the system uncertainties in the three regions involved in the conflict, and the ambiguity resulting from the possible alternatives put forward by the actors in the conflict. The chapter concludes that while the use of models is a proven method to construct future scenarios and test different strategies, the parameterization of scenarios and their results depend on the knowledge and/or interests of actors who own the model. This may have a negative impact on conflict resolution processes.

Chapter 4 analyses the development pathways of the recipient regions of the Zapotillo project, and the potential future development pathways proposed by the actors. Specifically, the chapter first historically describes the supply-demand cycle that has configured the present conundrum of Guadalajara and León, the recipient regions of the Zapotillo project, and the donor region of Los Altos. Second, it explores participatory modelling as a useful tool to understand the role of water conflicts in disrupting the demand-supply cycle and elicit the exploration of the decision space of urban water systems. The chapter concludes that water conflicts play a role in widening the decision space of urban water systems by disrupting the feedback mechanisms of the supply-demand cycle.

Chapter 5 describes and analyses the evolution of the conflict by following in rich detail the journey of the network of actors of the grassroots movement until today. Specifically, it explores how their perception has evolved from the start of the conflict until now, and which strategies and capitals they have employed and mobilized to keep their case valid, current and with a chance to flourish. Through the lens of transition management approach, the chapter concludes that when a water conflict persists, the grassroots movement’s perspective, interests, motivations, objectives, capitals and strategies are upscaled from the particular project causing the conflict to the water paradigm sustaining the current socio-technical water system as a whole. Therefore, water conflicts need to be further researched not only as events in need of prevention, but also as socio-technical processes with potential to change the status quo.

Chapter 6 describes important socio-technical and political events that happened after the completion of this thesis.

Chapter 7 presents the conclusions of the research, the contribution to the scientific community and recommends further research.

2

PRODUCTION OF COMPETING WATER KNOWLEDGE IN THE FACE OF WATER CRISES: REVISITING THE IWRM SUCCESS STORY OF THE LERMA-CHAPALA BASIN, MEXICO[1]

"We are our memory, we are that chimerical museum of shifting shapes, that pile of broken mirrors."

—Jorge Luis Borges

[1] Based on: 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.

Summary of the chapter.

Integrated Water Resources Management (IWRM) is an approach that aims to change conventional water management. International agencies and organizations have promoted IWRM across the globe. The Lerma-Chapala Basin in Mexico is an archetypal case study on basin closure, where IWRM principles were said to have been applied in the early 2000s to help solve a serious water crisis. This chapter analyses the controversies around socio-hydrological uncertainties that were raised during this and an earlier crisis of Lake Chapala, whose resolution defined the water management policies of the basin. We interviewed key stakeholders, analysed different hydrological models, and reviewed the most important literature assessing the case. Then, we analysed how stakeholders understood the functioning of the socio-hydrological system, and how that determined their perception of what the root causes of the crisis were, and ways to resolve it. We found that the modelling efforts by two stakeholders to understand the root causes of the crisis could not clarify important socio-hydrological uncertainties, which limited the scope of their conclusions. From the proposed responses, only those based on the existing institutional and regulatory framework were implemented. Our results question the assertion that IWRM principles of public participation, sound knowledge, and river basin institutions, actually changed the traditional water management paradigm. We conclude that economic and political interests, more than IWRM principles, influenced the decision-making process to solve the water crisis in the Lerma-Chapala basin.

2.1 INTRODUCTION

Water crises are generally characterized by uncertainties, which makes it difficult to find their root causes and propose policy solutions (Srinivasan et al., 2012). Controversies abound on whether water crises are caused by mismanagement, a crisis of governance or a lack of investment in water infrastructure (UNESCO, 2006; Castro, 2007; Grey & Sadoff, 2007; Sivakumar, 2011; Muller et al., 2015). Resolving controversies plays an important part in the decision-making of water resources management, since they determine policy responses. Molle (2003) argues that the set of responses to water crises vary from increasing supply, managing demand and reallocating water. Proponents of Integrated Water Resources Management (IWRM) argue that to improve water access and solve water crises, water managers should manage water at the river basin scale, include public participation and consider water as an economic good, rather than the creation of new infrastructure (Young et al., 1994). The Global Water Partnership (2000) later included these principles in its definition of IWRM: "a process which promotes the coordinated development and management of water, land and related resources to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment." International water agencies and organizations like the Global Water Partnership and the World Bank promote IWRM principles and disseminate successful case studies of IWRM implementation (Molle, 2008a). Between the years 1989 and 2004, IWRM principles were reported to have been applied to solve the water crisis in the Lerma-Chapala basin, characterized by basin closure. This case has been portrayed as a success story, where the Mexican water authority, Conagua, solved a water crisis by building compromises and cooperation between all actors through public participation (Hidalgo & Peña, 2011).

Despite this assertion, other researchers have claimed that the resolution of the Lerma-Chapala's crisis has not addressed the root causes, and that the policies implemented were not appropriate (von Bertrab, 2003; Torres-González & Pérez-Peña, 2005; von Bertrab & Wester, 2005; Torres-González & Pérez Peña, 2009; Wester et al. 2009b). This is a controversy formed also by several uncertainties in the socio-hydrological system: volume of surface and groundwater used, efficiency by agriculture upstream Lake Chapala, volume of water supplied to the main urban settlements and industries within and outside the basin, growth of water demand by different uses, effects of different water allocations, water availability and average renewable water in the basin, as well as the relationship between surface and groundwater.

The Lerma-Chapala basin underwent two major water crises manifested by the dramatic decrease of the water level of Lake Chapala, the first starting in the 1950s, and the second in the 1990s. Detailed descriptions of both crises allowed us to analyze and compare the two events and the uncertainties of each crisis and the controversies on the implemented responses that followed. We describe how water authorities framed the uncertainties around water management in the Lerma-Chapala basin in narratives that transited from the 'hydraulic mission', inspired by the Tennessee Valley Authority (Wester et al. 2009c), to that of IWRM. That transition implied a change in perception of agriculture as a driver of economic development, poverty alleviation and food security in Mexico, to a sector viewed as inefficient.

A major change in both crises is the use of river basin modelling as the main tool by water managers and stakeholders to identify the crisis' main root cause, and hence, propose adequate responses to solve the water crisis. This article poses the question whether the use of IWRM principles in general, and public participation, transparency and sound technical knowledge in particular, changed the perception and positions of the actors to cooperate and compromise to a new allocation agreement. Conagua (2011), Hidalgo & Peña (2011) and Güitrón (2005) have suggested that the participatory modelling process shaped the decisions that resulted in the policy responses implemented to solve the water crisis. We aim to investigate whether and how this happened and whether it generated policies based on IWRM that solved the crisis.

Despite the vast literature that has studied this case (Mestre, 1997; Huerta, 2004; Pérez-Peña, 2004; DOF, 2006; Wester, 2008; Wester et al., 2008; Hidalgo & Peña, 2009; Torres-González & Pérez-Peña, 2009; Wester et al., 2009b; Conagua, 2011), the modelling process, central to the decision-making mechanisms of the case, has not received sufficient attention. In this chapter, we aim to fill that gap, and to link uncertainty with knowledge claims, policy responses and their impact on the socio-hydrological system. We argue that water knowledge based on hydrological modelling, which helped reach conclusions and recommendations for decision-making in the basin, was influenced by politics, culture and economics.

2.2 UNCERTAINTIES AND CONTROVERSIES IN THE HYDROSOCIAL CYCLE

A crucial endeavour for sociology is to study and understand historic changes in society. Latour (1986: 273) argued that uncertainties and controversies are decisive in societal changes, because they are "part and parcel of the very definition of the social bond". In the field of water management, the scientific attempts at solving controversies redefines the relationship between society and the hydrological cycle (Bouleau, 2014). In the context of a water crisis, uncertainties and controversies become even more relevant because any stakeholder's definition of the root causes of the crisis will be linked with a specific response. These attempts at defining the appropriate responses to a water crisis are an exercise of power, understood as the "intense activity of enrolling, convincing and enlisting [other actors]" (Latour, ibid.) into one's own perspective.

Political ecologists have pointed out the difficulty of presenting scientific proof for a single root cause (Brown, 2004; Budds, 2009; Porto et al., 2016; Jansen, 1998). Funtowicz & Ravetz (1990: 24) argued that this is similar to forensic science, where uncertainty is managed by skilled judgements in piecing together and sifting evidence to understand and explain the behaviour of a system, rather than mathematical techniques (Srinivasan et al. (2015) used this approach to confront the many hypotheses for the causes of a drying river in India.) However, the uncertain nature of complex environmental problems opens the possibility for actors to exploit every bit of uncertainty in water knowledge to impose their interests (Karl et al., 2007). This makes it important to be aware of the uncertainties and limitations of decision-making processes and resulting policies by assessing the mutual influence between water knowledge, politics, culture and economics (Krueger et al., 2016).

An alternative way to address these controversies is through public participation, which has been considered an important tool to improve decision-making in conflict management (Savenije & van der Zaag, 2000; Delli Priscoli, 2004). However, Cabello et al. (2018) argued that participatory processes also introduce epistemic uncertainty, which question not only policy responses to a problem, but also what the problem really is about.

Public participation in uncertain complex environmental problems can catalyse increased reflexivity and new creative policy responses, instead of perceiving uncertainties as problems to solve (ibid.). However, reordering social institutions may be too unstable for some actors, who seek instead “associations that last longer than the interactions that formed them […] to be able to stabilize a particular state of power relations” (Callon & Latour, 1981: 283). These associations are constituted by actors, claims of knowledge, discourses and practices. Such associations create a tension between macro-actors and micro-actors. Callon & Latour (1981) defined the first as the main actors that have aligned more actors to their own interests and values, like policy makers, think tanks and water authorities. While the second are those aiming to challenge macro-actors’ influential associations by enrolling additional actors into their own particular interests and values. This tension increases with public participation in water management, because its aim is to include micro-actors, which present alternative arrangements of associations that compete with those of macro-actors.

Molle (2008a) analysed the process of association in epistemic communities, consolidated groups of actors who share “causal beliefs and cause-and-effect understandings” and strengthen a concept or an approach in water management to a point where it can be considered a truth. These communities articulate their approach in discourses, which Allan (2003) described as water management paradigms or sanctioned discourses.

Despite the best efforts of these epistemic communities to stabilize associations in society, the interaction of the hydrological cycle and actors with diverging interests constitute powerful forces that can open the ontological question of what water is in relation to society (Bouleau, 2014). These forces can include: water crises and/or new actors challenging the sanctioned discourses. We hypothesize that these forces, especially water crises, represent opportunities for micro-actors to redefine and challenge how the hydrosocial cycle must be.

This ongoing interaction of water and society shapes and defines each other in a dialectical way (Linton & Budds, 2014). To understand the continuous change in society with the material world, such as the hydrological cycle, Callon and Latour (1981) suggested directing our attention to two kinds of processes: 1) actors creating lasting social asymmetries, like creating laws, institutions or reaching agreements based on a sanctioned discourse, and 2) actors defining methodologies to solve controversies and uncertainties, like the use of supposedly neutral science. Molle (2008b) argued that beliefs, viewpoints and ideology can influence scientific assessments. Jacobs et al. (2018) illustrate how these assessments represent different values and interests in function of the methods and tools used. Therefore, models can be used by actors as tools for enlisting, convincing and enrolling actors with diverging interests. In order to understand the outcomes of a water crisis' negotiation, the analysis might thus focus on the tools used by the actors to convince others.

2.3 CASE STUDY AND METHODOLOGY

2.3.1 Lerma-Chapala basin

Lake Chapala is at the receiving end of the Lerma-Chapala basin in central Mexico, and the beginning of the Santiago-Pacífico Basin that discharges in the Pacific Ocean. Covering an area of 110,000 ha and with approximately 7900 hm^3 of storage capacity, Lake Chapala is the largest and most important lake in Mexico. Due to its magnitude, the first Spanish colonizers called it the Mar Chapálico (the Chapalean Sea). Its cultural heritage is also important, because Mezcala, one of Chapala's islands, was the scenery of the last indigenous stand against the invaders; the lake is also considered a sacred place by the Wixárikas, an indigenous community.

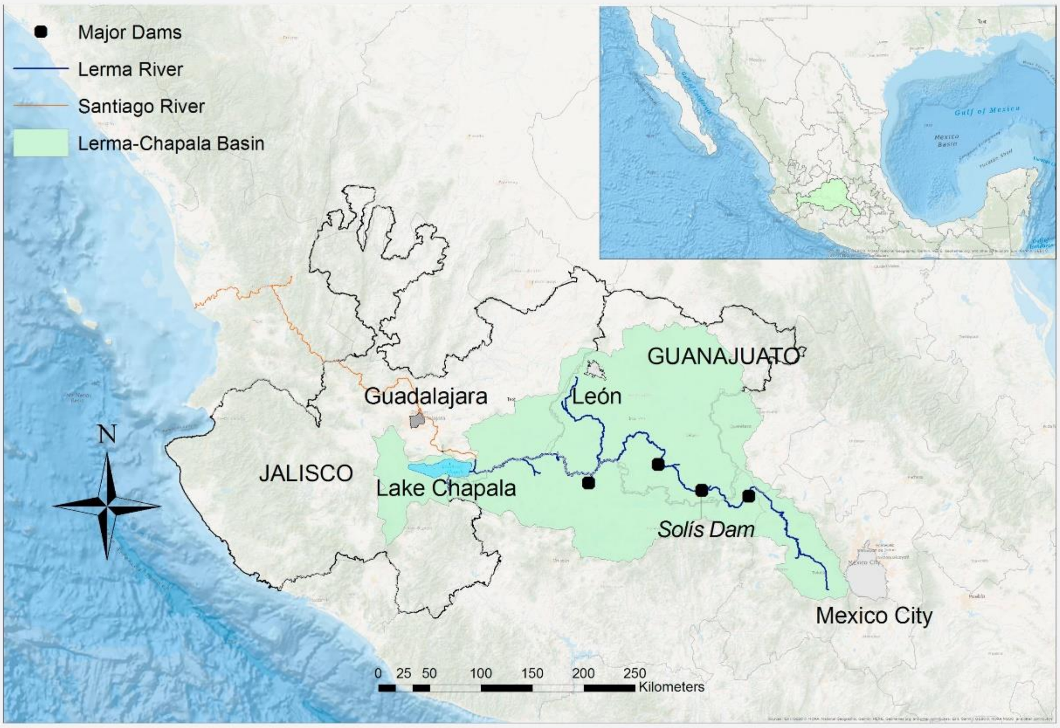

Figure 2.1 Map of the study area.

The shallowness of the lake is its defining feature as an ecosystem, with a mean depth of only 3 m (Lind and Dávalos-Lind, 2001). The lake's inputs are the Lerma River and direct rainfall. Since the 1980s the Lake has not naturally discharged water into the Santiago River, due to a water gate at the beginning of that river that controls the level of the Lake (Lind and Dávalos-Lind, 2001, Hidalgo and Peña, 2009).

The headwaters of the Lerma-Chapala basin are located near Mexico City, which currently draws part of its water supply from the basin. The Lerma River passes through 5 States in Mexico: Mexico State, Querétaro, Michoacán, Guanajuato, and Jalisco (see Fig. 2.1). Precipitation varies from 300 to more than 1000 mm/year, the median precipitation being 730 mm/year (Aparicio, 2001). The basin has a well-defined rainy season from June to October. Therefore, the hydrological year for water allocation starts at the beginning of the dry season on the first of November.

The Lerma-Chapala basin is second in socio-economic importance to Mexico after the Valley of Mexico basin. More than 10 million people live in the basin, roughly a tenth of Mexico's population. Although the size of the basin is 54,421 km2, a mere 2.8% of the total Mexican territory, the basin produces 53% of the country's manufacturing exports, and its industrial output represents 11% of Mexico's GNP (Conagua, 2011). Agriculture has also played a big role in developing the basin. Irrigation area grew 500% in the last 50 years, extending the agricultural frontier to 830,000 ha, approximately 15% of all irrigation area in Mexico (DOF, 2006).

2.3.2 Methodology

We performed a meta-analysis of the different perspectives on the root causes of two water crises of the Lerma-Chapala basin through an extensive literature review and in-depth interviews with two key stakeholders in the modelling process during the second crisis of Lake Chapala. We reviewed the most important articles published in the scientific literature, grey literature and governmental reports depicting the uncertainties and controversies during both crises. The meta-analysis reconstructs the way actors´ narratives interpret cause-impact-response relationships through their own knowledge and economic and socio-political contexts to understand water crises. Our approach combines methods from political ecology of environmental crisis (e.g., Porto, 2012) with the sociology of science of (Callon & Latour, 1981). These methods assess how actors propose rival hypotheses to define uncertain system boundaries (contextual uncertainty) (Dunn, 2001; Walker et al., 2003), and how actors with different positions and interests tend to overlook uncertainties and influence policymaking. By mapping competing narratives, sanctioned discourses, and responses, we then analyse how co-existing narratives influence the hydrosocial outcomes.

To describe the 1950s crisis of Lake Chapala, we relied on excerpts of speeches and documents by relevant stakeholders. In this way, we reconstructed the narratives that addressed uncertainties to promote or block hydraulic projects. In the 1990s crisis, we focused on eight papers and reports analysing the crisis from different viewpoints. The first five divulged at international fora the apparent success of the Mexican water authority, Conagua, in managing the Lake Chapala's crisis: Huerta (2004), Güitrón (2005), DOF (2006), Conagua (2011), Hidalgo & Peña (2011). The other three papers critically analysed the management and negotiation processes that took place during the crisis: Torres-González & Pérez-Peña (2005), Huerta et al. (2001), and Wester et al. (2009b). These sources were chosen because they analysed some of the same elements of the crisis: (1) the creation of a river basin council, (2) the negotiations that took place in the Lerma-Chapala basin council, (3) the modelling process and/or data regarding precipitation, run-off and Lake Chapala water levels, and (4) possible responses to the crisis. We analysed all these different sources to identify the spectrum of the root causes identified for the water crisis in the Lerma-Chapala basin. As different accounts elaborated different narratives on the crisis, together they demonstrate the perceived uncertainties on the dynamics of the basin's hydrosocial cycle.

The second crisis culminated in a modelling process of the Lerma-Chapala basin, led by the Mexican water authorities (Conagua & IMTA) and Guanajuato's water commission (hereafter CEA-Guanajuato), which aimed at settling the crisis' uncertainties. We analysed to what extent this was achieved. Although all authors referred to the modelling process as having been central to the decision-making for solving the Lake Chapala's crisis, only Güitrón (2005) and Huerta (2004) analysed the model in depth. However, Güitrón´s analysis presents inconsistencies, as it assumes that the model gained legitimacy despite not fully convincing CEA-Guanajuato; while Huerta described how the model worked to resolve a water conflict but did not describe the conflict within the modelling process. To fill this gap, we interviewed the main modellers that represented IMTA-Conagua and CEA-Guanajuato in the Lerma-Chapala conflict and the modelling process. Between April and August 2017, we interviewed these modellers following the semi-structured type of interviews on the technical aspects of the modelling process during the second Lerma-Chapala crisis. Thereafter, we received additional information through personal communications until May 2018.

Finally, we analysed other proposed policy responses, which were not based on hydrological models, but addressed other uncertainties left out in the modelling process.

2.4 Meta-analysis of the two Lake Chapala crises

2.4.1 First crisis, 1945-1956

Immediately after the Mexican Revolution ended in 1921, the government implemented new reforms to develop the economy, end poverty and alleviate hunger. The agrarian reform changed the land ownership from *hacendados* (large landowners) to the peasants working the land. Wester (2009) described two major phases in the historical evolution of water institutions of modern Mexico. The first, from 1926 to 1946, is characterized by "the rise of the hydraulic mission", whose aim was to increase irrigation land to deliver the benefits promised by the revolution to impoverished farmers through the *Comisión Nacional de Irrigación* (CNI: National Irrigation Commission). The second, from 1946 to 1976, was "the zenith of the hydraulic mission", whose goal was to develop river basins based on the Tennessee Valley Authority model through the *Secretaría de Recursos Hidráulicos* (SRH: Ministry of Hydraulic Resources). In 1989, after the federal government adopted a neoliberal agenda (Wester, 2008), a third phase began, that of IWRM, when the *Comisión Nacional del Agua* was created (Conagua: National Water Commission). These three phases conditioned policies that would affect water management and water bodies in Mexico in different ways.

In 1950, SRH created the Lerma-Chapala basin commission consisting of only SRH engineers to discuss the basin's problems and reach agreements with the stakeholders.

Hydraulic engineers argued that based on below-average rainfall between 1942 and 1955 (Figure 2.2) and high evaporation rates, allocating water to lakes would be a waste. Andrés García Quintero, at the time a respected hydraulic engineer, argued in 1947 that "[*El lago de Chapala] es un lujo dispensioso, que México no puede permitirse*" ("Lake Chapala is a lavish luxury that Mexico cannot afford") (cited in Helbig, 2003), referring to the large evaporation rate of Lake Chapala. The basin commission recommended the desiccation of Lake Cuitzeo, Lake Yuriria, and 25,000 ha of Lake Chapala, "to allocate the largest possible volume of water to irrigation" (SRH 1953, cited in Wester, 2009). Because of these recommendations, a presidential decree in 1953 allowed the reclamation of 18,000 ha of Lake Chapala.

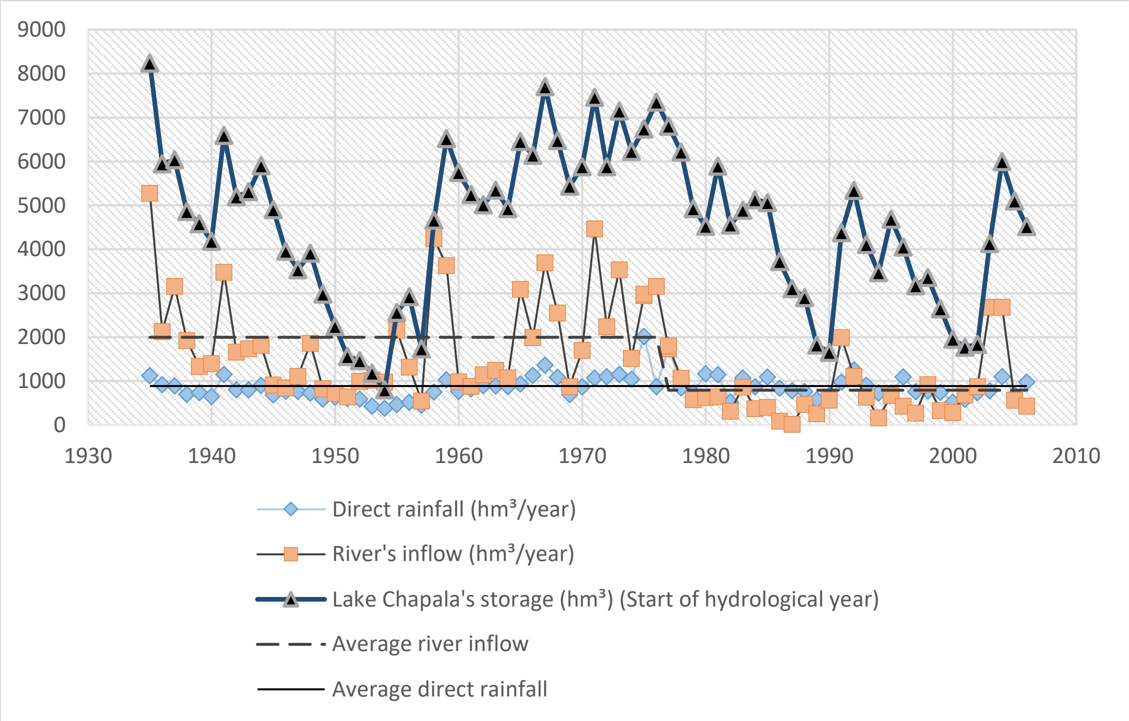

Figure 2.2 Historical water dynamics of Lake Chapala (Data provided by Conagua)

The defence for Lake Chapala came from two groups. The first came from the economic interests of Guadalajara. A hydropower plant for the city of Guadalajara depended on 520 hm^3/year of Lake Chapala's water to operate. In 1947, when the level of the lake dropped to a point that it did not feed the Santiago River anymore, the hydropower plant could not operate at full capacity. This caused several blackouts and increased production cost for industries in the city. The second group, composed of Guadalajara's intelligentsia and environmentalists, created the *Comité Pro-Defensa del Lago de Chapala* (Committee for the Defence of Lake Chapala) (Pérez-Peña, 2004). This group had two arguments: first, that evaporation was a natural process inherent to the water cycle, which was worth preserving; and second, that to reclaim 18,000 ha from the lake, additional to the 50,000-ha reclaimed in 1910 (Figure 2.3), would have permanent negative effects for the lake.

By 1955, the volume of water in Lake Chapala decreased to 980 hm³, a mere 10% of its storage capacity. This downward trend had started in 1945, when the lake still had 6,354 hm³. This generated an important controversy over the future of the lake. Proponents for the land reclamation argued that a lack of sufficient rain since 1941 contributed to the low levels of the lake (González-Chávez, 1956: 103, cited in Helbig, 2003); while environmentalists and other stakeholders from Guadalajara maintained that rain had been sufficient, if not abundant, between 1934 and 1954, and that the lake's crisis should be attributed to the basin development policies of the National Water Commission (Palencia, 1956: 41-52, cited in Helbig, 2003), who built the Tepuxtepec Dam in 1930 with a storage capacity of 370 hm³ to irrigate 55,000 ha, and the Solís Dam in 1949 with a storage capacity of 800 hm³ to irrigate 116,000 ha.

The environmentalist groups regarded the politicians and hydraulic engineers as "*magos de los cálculos*" (magicians of calculations) (Helbig, 2003), because of the way they juggled with numbers to justify hydraulic interventions.

Figure 2.3 Reclaimed land from Lake Chapala (Burton, 2010).

Due to the avid opposition campaign from Guadalajara, the plan to desiccate 18,000 ha from Lake Chapala did not happen. Although stakeholders ardently discussed how overdevelopment upstream was causing the ecological destruction of Chapala and not the evaporation, as stated by the hydraulic engineers, the development trend continued unabated:

"Today, the tragedy weighs in with the frigid breath of fatality over the sad fate of the once mighty Chapala […] new dams and irrigation canals being built upstream, divert and slurp more than half of its volume, to the extent of ignominiously exhausting the estuary of La Barca, where the lake used to enter. This, the scarce rainfall originated from deforestation of all the forests of the region, and the pumping stations to irrigate crops that sprouted like pockmarks in all of its shores, seemed to have combined to result in the tragic end of the consistent drama of the gentle Chapalean Sea." (Rubín, 1993, cited in Pérez-Peña & Torres-González, 2001a, our translation).

At this point, a clear shift emerged from policies seeking to expand cultivable land to policies seeking to develop as much as possible the basin's water resources. Luis Ballesteros, the engineer in charge of the basin's waterworks, considered that the 1,500 hm^3/year leaving Lake Chapala to flow into the Santiago River was a waste, except for the 520 hm^3/year used for hydropower. He proposed to capture the remaining 1,000 hm^3 upstream before reaching the lake to develop irrigation. The government built 26 dams upstream Lake Chapala between the years 1926-1955, adding a total of 1,462 hm^3. In addition, two inter-basin water transfers were undertaken. In the first, 126 hm^3/year were transferred to Mexico City from the Lerma River headwaters in the early 1950s, increasing to 315 hm^3/year by the 1970s (Wester 2009), and 788 hm^3/year in the 1990s (Escobar, 2006). The second transferred 31 hm^3/year to Guadalajara, which started building the waterworks in 1953, at the peak of the lake's crisis, and started operating in 1956. By the end of the 1950s, abundant rainfall increased the water levels of the lake, which allowed the basin commission to conclude that the basin could still be further developed and requested a loan of $150 million from the Inter-American Development Bank to build more irrigation systems (Wester et al., 2001).

2.4.2 Second crisis, 1989-2004

Basin development continued for agriculture and urban uses. Following the construction of 118 dams in the basin from 1960 to 1969, and 80 from 1970 to 1989 (Cotler & Gutierrez, 2005), the dam storage capacity of the basin increased 2,682 hm^3 since the first crisis (Figure 2.4). The Green Revolution increased groundwater development at a rate of 7% per year (Vargas-Velázquez & Mollard, 2005). In Guanajuato alone, almost 18,000 additional boreholes were constructed (Acevedo-Torres, 2004), leading to serious groundwater over-exploitation (Sandoval, 2004). Guadalajara also increased its dependency on the lake's water by building an aqueduct to deliver 283 hm^3/year in 1992.

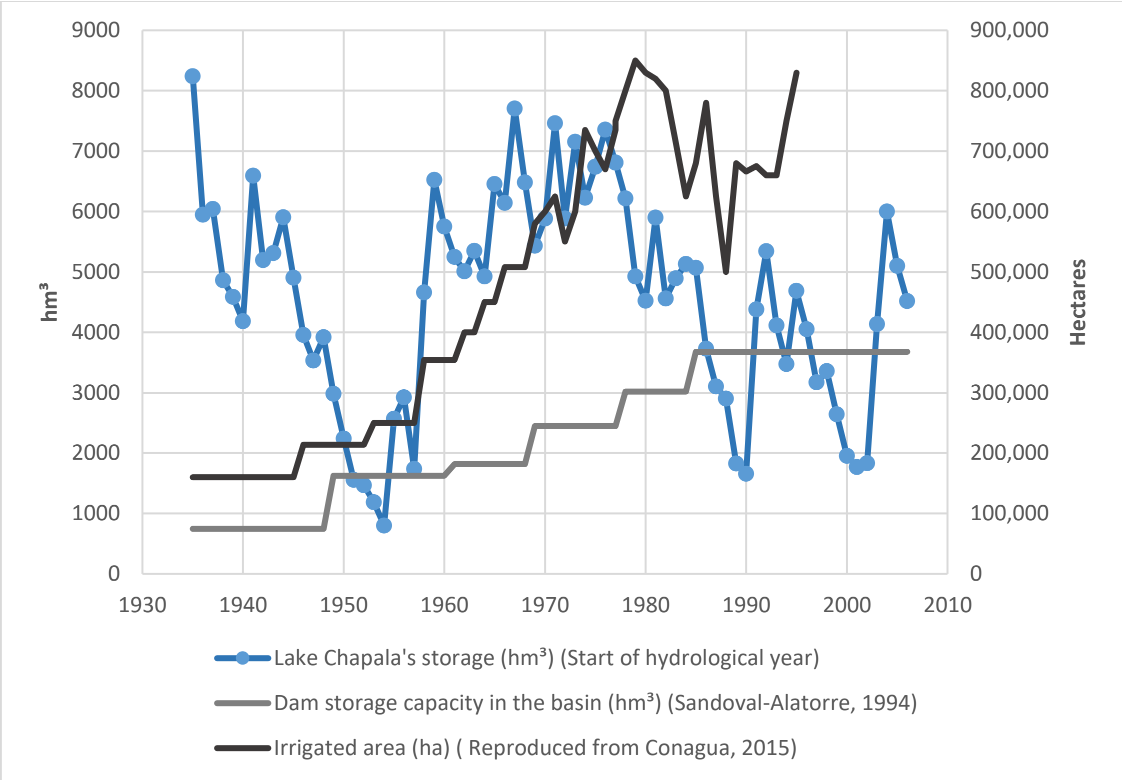

Figure 2.4 Water infrastructure and irrigated land in the Lerma-Chapala basin.

In 1989, the central government undertook a complete overhaul of the water institutions based on neoliberal policies and IWRM principles, including 3 actions: a) introduction of a new water bill that expanded the reach of the previous water rights system to tradeable water rights (Rosegrant & Schleyer, 1996), b) implementation of the subsidiarity principle, which led to the creation of local and regional water management institutions, and transfer of irrigation districts to users (Rap & Wester, 2013), and c) the creation of a new overarching water authority, Conagua. During the same time, Lake Chapala's levels started to drop again. Vargas-Velázquez & Mollard (2005) stated that this environmental problem was an opportunity for the State to gain legitimacy for their new set of policies. Therefore, in 1989 a new Lerma-Chapala commission, composed of the governors of all States within the basin, addressed the falling lake's levels. The commission implemented a top-down program that included a new allocation agreement to save the lake, as promised by the President of Mexico in his election campaign. The allocation agreement distributed water among users based on the level of the lake and the annual surface run-off generated in the basin every start of the hydrological year.

As part of the water reforms, a Lerma-Chapala River Basin Council (RBC) was established in 1993, the first of its kind in Mexico (Wester et al., 2001). Because the lake's levels continued to drop, the members of the RBC deemed additional actions necessary.

The root causes of the lake´s crisis became a topic of heated debates between stakeholders. The problem became so complex that it was difficult to identify a single culprit (Table 1).

Guitrón (2005) and Wester et al. (2009b) argued that the reasons for the failure of the water agreement were an underestimation of the lake's evaporation with at least 16% (Aparicio et al., 2006), an overestimation of runoff (based on hydrological data of the relatively wet period of 1950-1979) and irrigation efficiency, and an underestimation of the irrigated area, illegal water abstractions, over-concessions, and finally, reduced river base flow due to groundwater overexploitation. This failure led Lake Chapala to a crisis comparable to the one in the 1950s.

Despite uncertainty regarding the degree of responsibility of agriculture in Guanajuato and urban demand of Guadalajara for the crisis, Conagua (2011) stated that "In all cases, irrigation has been positioned as the main reason of all basin calamities regarding water deficiencies." Conagua commissioned a socio-economic study on inter-sectoral water productivity, and agriculture was evaluated as the most inefficient (Goicoechea, 2005). Table 1 shows how agriculture was generally perceived as the main sector responsible of the water crisis in the basin, mainly because agriculture is the largest user. Low efficiency and the expansion of irrigation infrastructure, and over-concession of water rights were mainly considered the human-made root causes of the lake's crisis.

Table 2.1 Dimensions of the water crisis and root causes according to several sources.[1]

Dimension	*Root causes (proposed by source reference)*
Water quantity	Low rainfall (**1, 2, 3, 4**)
	Expansion of irrigation infrastructure **(3, 4, 5, 6)**
	Over-concession of water rights **(1, 3, 5, 6)**
	Low water efficiency in agriculture **(1, 2, 4, 5)**
	Low water efficiency in Guadalajara and other urban centers **(1, 2, 7)**
	Groundwater overexploitation by all sectors **(1, 2)**
	Climate change **(4)**
	Illegal water abstractions **(5)**
Ecology	Forest depletion due to agriculture **(1, 2, 4, 5)**
	Economic and population growth **(1, 2, 4, 5)**
	Soil damage due to agroindustrial pollution **(1, 2, 5)**
	Biodiversity loss **(1, 2)**
	Low water quality **(2)**

[1] (1) IMTA (Güitrón, 2005), (2) Conagua (DOF 2006), (3) Hidalgo, J., & Peña, H. (2009), (4) Conagua (2011), (5) Torres-González & Pérez-Peña (2005), (6) Wester et al. (2001), (7) Huerta et al. (2001).

With this mind-set and the continued dropping of water levels, Conagua ordered in October 1999 a release of 200 hm^3 of water from irrigation dams in Guanajuato to Lake Chapala. This resulted in Alto Rio Lerma irrigation district to fallow 20,000 ha out of 77,000 ha (Wester et al. 2005). Because of the historic low rainfall in 1999, the water allocation for the year 2000 was also the lowest since the beginning of the agreement. That year, the Water User Associations of all irrigation districts in Lerma-Chapala basin decided to fallow 200,000 ha of irrigation lands (ibid.). In 2001, Conagua enforced a new 270 hm^3 water release.

Because farmers were not compensated, they resisted the water release and threatened Conagua with civil disobedience (Wester et al., 2009b). In 2001, Guanajuato´s farmers created the *Grupo de Trabajo Especializado en Planeación Agrícola Integral* (GTEPAI: Specialized Working Group on Comprehensive Agricultural Planning), which aimed at proving how the agricultural sector could be more water efficient by changing cropping patterns and be a relevant member of the RBC. This resulted in a 60 hm^3 saving (Paters, 2004, cited in Wester et al., 2009b).

CEA-Guanajuato wanted to assess the impact of water releases from dams upstream to both the lake and farmers and hired Juan Huerta[2] in 2001, a system dynamics modeller, who had previously built the ProEstado-MAUA model for Guanajuato in the mid-1990s. This was a system dynamics model that described how water resources interacted with human activity to facilitate policy decision-making for all of Guanajuato's basins. The model consisted of 2,500 differential equations and 800 variables that integrated rainfall, surface and groundwater along with socio-economic variables. For the Lerma-Chapala basin, Huerta's team built a new model of the whole basin dubbed "Cuenca Lerma", which was based on the same foundations of ProEstado-MAUA. With the model, alternative scenarios were run, which made the modellers conclude that water transfers from agriculture to Lake Chapala would cause a 17% increase in agricultural unemployment, a 39% of reduction in crop value, a 19% increase in unemployment in other sectors, and a 6% overall economic loss; only to improve Lake Chapala's storage by 9% (Huerta et al., 2001). They also concluded that "a more obvious cause for the lake's drying up is the near explosive growth of Guadalajara, […] The national water authorities adamantly refuse to accept this fact as the main source of trouble for the lake."

The mounting pressure came from two sides, the social and political pressure in Jalisco because of the drying Lake Chapala, and the agricultural lobby in Guanajuato because of the economic losses caused by the water releases. Therefore, in March 2002, Jalisco's representatives proposed a new allocation agreement to be worked out in the *Grupo de*

[2] Huerta studied electrical engineering in Mexico and did his PhD on systems and control engineering in the University of Cleveland in USA, with a thesis related to the Stanford Watershed Model.

Ordenamiento y Distribución of the RBC (GOD: Planning and Distribution Group) (Güitrón, 2005).

In 2002, Conagua engaged IMTA, the technical branch of Conagua, to build a rival model of the Lerma-Chapala basin. Previously, during the early 1990s, Conagua had hired Huerta to introduce system dynamics modelling in water management to IMTA's engineers. However, most of the engineers trained by Huerta were absent during the 2000s conflict. Huerta evaluated IMTA's staff as being composed of 'managerial engineers' with little understanding of dynamic models, as opposed to 'analytical engineers´ as himself, who are trained in systems thinking (Huerta, 2004). Also, CEA-Guanajuato perceived this absence of technical capabilities as a handicap for the negotiation process. Therefore, technical training was offered to Conagua´s, Jalisco´s and Guanajuato´s representatives, but not to other civil society's stakeholders (Güitrón, 2005).

Because Lake Chapala was still in crisis while the models were being developed, by the end of 2002 Conagua was pressured to undertake a new water release of 280 hm^3 from the Solis Dam in the summer of 2003. Farmers deeply resented this action and disbanded the GTEPAI group. By the end of 2003, Conagua again ordered to release 205 hm^3 from the Solís Dam, out of which only 173 hm^3 reached Lake Chapala because a court order signalled the illegality of this action, precluding the remaining 32 hm^3 to be released (Wester et al., 2009b).

According to Güitrón (2005), all engineers involved in the conflict criticized each other´s "simple models" and pointlessly made their own model more complex. IMTA´s engineers rejected the hybrid nature of the "Cuenca Lerma" model, regarding the integration of its socio-economic and hydrological variables. Still, IMTA intended to use CEA-Guanajuato's rainfall-runoff algorithms, but Huerta blocked this move based on copyright violations, compelling IMTA to develop its own. IMTA's model, referred as IMTA's Lerma model, consisted of hydrological variables to calculate run-off in all 17 sub-basins of the Lerma-Chapala: precipitation, evapotranspiration and soil humidity based on the USDA´s Soil Conservation Service (López-Pérez et al., 2014); it also included the interaction with 7 main reservoirs, Lakes Yuriria and Chapala; and the water demand of 8 irrigation districts, 7 small irrigation units, and industrial and urban uses. With 52 years of historic rainfall data as input, the model was used to test different allocation policies proposed by Jalisco and Guanajuato, such as the water requirements to have a full lake at 8,000 hm^3, and the possibility to stabilize the lake with only the upstream surplus from agriculture (Güitrón, 2005).

CEA-Guanajuato's representatives suggested improvements to IMTA's rainfall-runoff model, but they were dismissed arguing that each improvement could take from 6 to 12 months to be included in the model (Güitrón, 2005), a situation that IMTA's group interpreted as an attempt to gain time for Guanajuato's farmers. This interpretation prevailed despite evidence that some results from IMTA's model were not able to replicate the behaviour of the Solís Dam (Personal communication with the modeller, May 9, 2018).

After calibrating the model, IMTA's Lerma model showed that sporadic water releases from agricultural dams to Lake Chapala were not a definitive solution to stabilize its levels (Huerta, 2004). This, and the legal instrument undertaken by farmers, proved to be a successful strategy against future discretionary water releases to Lake Chapala. However, IMTA justified past water releases, arguing that without them the levels of the lake would have dropped to 746 hm^3, lower than during the first crisis (Dau-Flores & Aparicio, 2006, cited in Wester et al., 2009b).

When IMTA decided that its model was consistent, they developed a linear optimisation model using genetic algorithms, dubbed SIMOP (Güitrón, 2005). SIMOP's objective function maximized the water volume extracted from the nine largest reservoirs in Guanajuato, while penalizing extraction deficits (Consejo de Cuenca Lerma-Chapala, 2005). IMTA's motivation for introducing a penalty function was that if there were no deficits, the stakeholders would not contest the optimization results (Huerta, 2007).

CEA-Guanajuato criticized IMTA's model for not considering seven major inconsistencies and uncertainties: (1) the high variability of agricultural water demand; (2) monthly time-steps; (3) surface and groundwater interaction; (4) not considering Lake Chapala as a water user; (5) Conagua assumed that current water demand equalled the volume of water rights, hence disregarding illegal overdraft; (6) information on agricultural land, especially in Irrigation Units was dispersed, incomplete (Silva-Ochoa & Vargas, 2005), and contradictory (Winckell & Le Page, 2004); and finally, 7) the model was not tested with an urban water demand management policy; IMTA only tested how demand management of Irrigation Districts could stabilize Lake Chapala (Huerta, 2004).

CEA-Guanajuato considered the first uncertainty very important because water demand for irrigation cannot be calculated *a priori*. Water demand for crops is determined by soil humidity, which varies according to rainfall. With favourable rainfall, farmers could use less water than what was allocated, but Conagua would refuse to count that unused water for next year's water allocation. The farmer would then proceed to sell water or overuse it, instead of saving it or letting it flow to Lake Chapala. Despite this deficiency, IMTA's *a priori* water allocation was preserved until the end, when the agreement became federal law (DOF, 2014).

The second issue, the monthly timestep, introduced new uncertainties as the optimization model could overlook periods of extreme rainfall and dry spells, which influence actual irrigation demands. Next, the groundwater model was never fully developed due to lack of data and knowledge (source: IMTA's interviewee). However, this third issue introduces a very important uncertainty in the model, since aquifers are known to be over-exploited in the basin, while their contribution to Lake Chapala is not precisely known.

The fourth and fifth uncertainties are related. Since Lake Chapala was never considered a user, but only the end recipient of the basin, there could not be any accountability on the water used by Guadalajara. Guzmán (2003), the director of the department of Limnology of the University of Guadalajara, claimed that Guadalajara was drawing 450 hm^3/year, instead of the 240 hm^3 for which it had a right. Durán-Juárez & Torres-Rodríguez (2001) also suggested that Guadalajara may have taken extra water from the Atequiza canal. Moreover, some farmers were also known for illegally over-extracting surface and groundwater.

The sixth uncertainty was central for agriculture and the calibration of the model. A new agreement based on reducing agricultural water use would also have different effects for the distinct economic strata of farmers (Torres-González & Pérez-Peña, 2005; Flores-Elizondo, 2013). The model had serious gaps of input information regarding small irrigation, which accounted for approximately 30% of water demand (Conagua, 2015), which were not addressed (Güitrón, 2005). Tables 2.2 and 2.3 show this disparity in the figures as well as in the water balance, which remained sparse and contradictory.

The last uncertainty is the role of urban water demand management to stabilize Lake Chapala. SIMOP used agricultural control variables from Guanajuato to stabilize the lake. But, because urban water supply is set as a priority in the Mexican water law, the model never simulated urban control variables, such as improved efficiency, reduction of water use per capita or demand management in Guadalajara.

CEA-Guanajuato proposed to redo the model with a different philosophy, based on tracking irrigation areas to control water demand, and balance demand with available water. This required a dynamic algorithm based on real-time agricultural water demand (based on the phenological water requirements of crop growth and size of irrigation areas) in daily time-steps, and to consider Lake Chapala as a user. This implied a daily water allocation to agriculture and a closer look to groundwater use. However, this was again dismissed by Conagua, arguing lack of time and resources. An expert from IMTA commented that “the goal of CEA-Guanajuato’s proposal was to delay the negotiation as much as possible; without them the agreement would have been reached two years before.” At this point, Conagua threatened that if no consensus was reached, they would impose new water allocation rules (Flores Elizondo, 2013).

Table 2.2 Water use (hm³/year), according to the literature

Source	*Agriculture*	*Urban*	*Out-of-basin transfer*	*Industry*	*Net lake evaporation*	*Other*	*Total water use*
1) Wester et al. (2001)	6,584	791	560	278	2,270	154	10,637
2) Hidalgo & Peña (2009)	9,859	1,138	-	382	-	277	11,656
3) Official (DOF, 2006)	7,484	1,598	518	295	1,497	342	11,734
4) Güitrón (2005)	7,882		237	273	1,700	0	10,092

Table 2.3 Water balance (hm³/year), according to the literature

Source	*Renewable water*	*Total water use*	*Water balance*	*Water use as % of renewable water*
1) Wester et al. (2001)	9,737	10,637	-900	109%
2) Hidalgo & Peña (2009)	9,529	11,656	-2,127	122%
3) Official (DOF, 2006)	8,893	11,734	-2,841	132%
4) Güitrón (2005)	8,750	10,092	-1,342	115%

A new allocation agreement was signed based on the Política Óptima Conjunta (POC: Optimal Allocation Policy), which reduced agricultural allocation as a function of Lake Chapala´s water levels (critical, intermediate, and abundant) and the previous year's accumulated basin run-off. This would affect all major agricultural dams in the basin. CEA-Guanajuato accepted the new allocation regime only after high level negotiations between Vicente Fox, the then President of Mexico, and the governors of Jalisco and Guanajuato. They agreed to include the building of two dams in the Verde River Basin in Jalisco for urban supply augmentation for Guadalajara, Jalisco, and León, Guanajuato (Wester et al., 2009b). This *quid pro quo* was so important that the IMTA expert concluded that "CEA-Guanajuato would have never signed the agreement without the water transfer from the Verde River."

Currently, the supply augmentation dam for Guadalajara has been put on hold indefinitely due to financial and structural constraints, while the construction of the supply-augmentation dam for León has been halted for the past 12 years, due to social and legal conflicts (Ochoa-García, 2015; Ochoa-García et al., 2015).

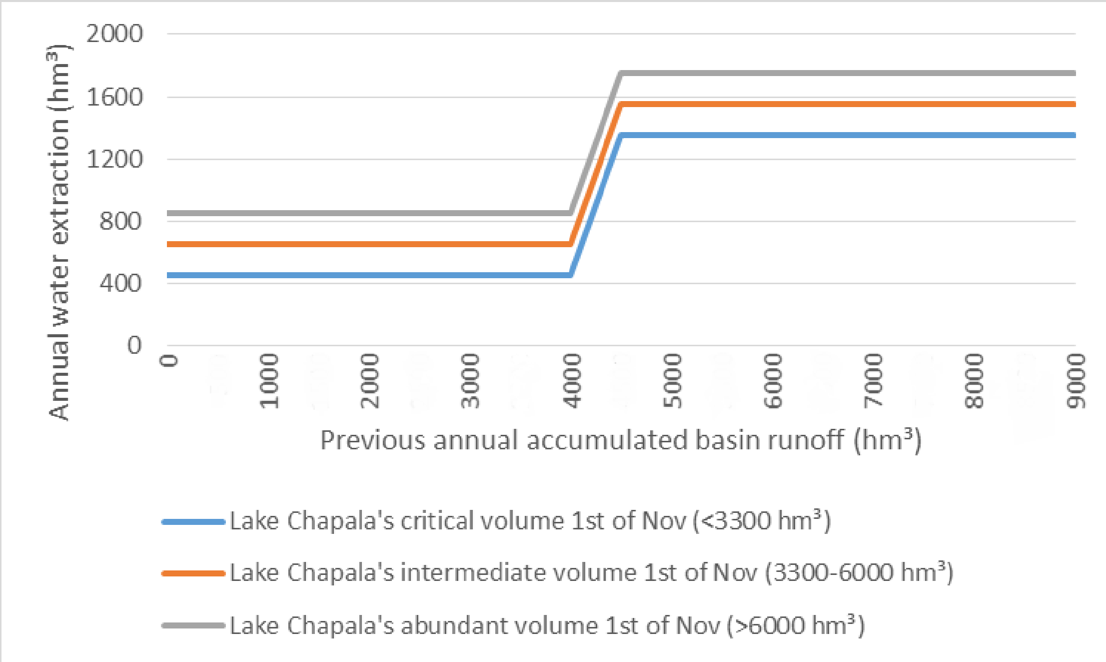

Figure 2.5 The new allocation rules for agricultural dams in Guanajuato (Conagua, 2015).

2.4.3 Alternative responses

This section analyses alternative responses that were presented by various stakeholders but dismissed by Conagua. A first set of proposals focused on the agricultural sector, the largest consumer of water in the basin. A second set addressed urban centers.

In the first group, Scott et al. (2001) proposed compensation mechanisms for affected farmers due to water releases to Lake Chapala. This proposal was later supported by information provided by Vargas-Velázquez, (2008), who surveyed urban homes in the basin, 60% of whom were willing to pay for the lake´s recovery. Farmers were also surveyed, and 39.9% of farmers supported the idea of saving the Lerma River, and 26.8% to save Lake Chapala. But, in the absence of compensations, farmers considered their livelihood more important; as a farmer from Guanajuato described: “As a Mexican I care [about Lake Chapala], it is part of a landscape that affects me. International opinion also affects me, many will say: ‘they let it desiccate!´ It will affect us. But as a farmer […] my crops and family come before Jalisco´s” (excerpt from an interview in Muñíz-San Martin & Torres-González, 2012). Instead, Conagua (2011) argued that the industrialization of the basin was an alternative to agriculture, because industry in the basin generates 11% of Mexico’s GNP, four times the output from agriculture, while using only 3.9% of water, instead of the 82% used by agriculture.

Conagua also proposed to financially support modernization of irrigation to enhance water savings, a promise that remains to be realized (Conagua, 2015). Huerta et al. (2001) suggested that if irrigation districts improved their water use efficiency from an estimated 36% to at least 55%, then the problems of surface water deficit and the Lake Chapala's decreasing levels would be solved. However, Scott & Garces-Restrepo (2000) argued that an increment in water use efficiency could lead to lower aquifer recharge, therefore worsening the existing aquifer crisis. Besides, it is likely that a large portion of the estimated 500 hm^3 annual gains in efficiency calculated by Huerta et al. (2001), would be used by downstream users, if not by the now more efficient users themselves, as Mollard et al. (2005) argued in the case of the Lerma-Chapala basin, as well as other authors have suggested around the world (van Halsema & Vincent, 2012; Berbel et al., 2014; Grafton et al., 2018). Mollard et al. (2005) suggested that more water savings can be made by better organizing those irrigation districts where internal norms of water allocation are not abided. They argued: "the primary goal [of the water users] is to have security in their annual water supply, and for that, they are insatiable. Every water saving should serve their interests first." This means that modernizing irrigation cannot guarantee water savings without new institutional arrangements to restructure the water rights system in accordance with the necessities of the sector, as Torres-González & Pérez-Peña (2009) proposed.

The need for new institutional arrangements between users and water authorities is more evident in groundwater management. Sandoval (2004) and Wester et al. (2011) proposed that all groundwater should be managed by users´ associations, with autonomy and legal and enforcement competencies to grant or withdraw water rights to balance the aquifers.

CEA-Guanajuato has been working since 1997 on a bottom-up approach to raise awareness and organize more than 100,000 groundwater users (Silva-Ochoa & Vargas, 2005; Wester et al., 2011). The institution of the *Consejo Técnico de Aguas Subterraneas* (COTAS: Technical Committee of Groundwater) was promoted by CEA-Guanajuato and consisted of a group of groundwater users, with the goal of self-regulating water use to stabilize the water table of their aquifer. This marked a paradigm shift according to Sandoval (2004: 12), the director of CEA-Guanajuato at the time: "[Conagua´s is a] centralized, rational approach, according to which water problems are relatively stable, isolatable and manageable from a purely scientific and technical approach". Instead, the COTAS approach was based on "models, which work upon the basis of best science and technology available, thus making progress through achievement of social agreements by means of maintaining ongoing communication with the subjects of the initiatives." Although COTAS has organised many users in curbing groundwater over-exploitation, it has not been able to decrease groundwater over-exploitation due to lack of participation of all groundwater users and legal support from Conagua (Wester et al., 2009a).

Conagua, with a top-down approach, has also been unable to balance the aquifers through law enforcement, while economic measures like higher energy prices have been ineffective (Hoogesteger & Wester, 2017). Users' self-regulation through COTAS could be an appropriate solution since buying back water rights from farmers is financially unfeasible (Wester et al., 2011).

Market-based alternatives were proposed by Bravo-Pérez et al. (2005, 2006, 2013) and Guzmán-Soria et al. (2009), who conceived the Lake Chapala water crisis in terms of market failure. They proposed an agricultural water tax to increase the levels of Lake Chapala, and water banks to promote efficiency[3].

Other authors have argued that a more comprehensive and coherent set of actions is needed to address the ecological dimension of the water crisis. The actions range from reforestation to groundwater demand management, and a river basin approach, to be implemented simultaneously (SEMARNAT, 2001; Cotler & Priego, 2004; Cotler et al., 2004; Priego et al., 2004). Although water authorities have implemented some of these actions, their budgets were limited, and actions were implemented in a haphazard manner.

Urban centers have also been targeted by proposals requesting demand management (von Bertrab, 2003; von Bertrab & Wester, 2005), with non-revenue water reaching 35% in Guadalajara and 49% in León (DOF, 2006). Although there could be significant gains in reducing non-revenue water and excessive water use per capita, the only response so far to urban water scarcity in Jalisco has historically been supply augmentation (Berrones, 1987). Jalisco's Water Commission defended supply augmentation solutions to avoid the social-economic costs of fixing the leaks of the city's distribution network, a process that has not been done in some cases for over 80 years (Gómez-Jauregui-Abdo, 2015). However, there seems to be a gap of perception between Jalisco's water authorities and urban water users regarding urban demand management, because 90% of surveyed households were open to decrease their consumption for the benefit of the water systems in the basin (Vargas-Velázquez 2008).

[3] Since 2009, water banks can reallocate water from users who are not fully using all the water entitled in their rights to users who need water. That would avoid the need to grant more water rights and still make water more productive, but Reis (2014) claimed that in practice institutional corruption has increased overall water use in the aquifer by doubling water rights.

2.5 Discussion

After we examined how competing actors in different contexts interpret the root causes of water crises to provide policy responses, we analyse two processes in detail: (1) the use of water crises and uncertainties to define sanctioned discourses that outline what the relationship with water and society should be; and (2) IWRM and the role of politics in science and decision-making.

2.5.1 Uncertainties and discourses

We have analysed that when society is confronted by a water-related crisis, micro-actors propose new values and solutions that challenge macro-actors' policies. This insight supports Bouleau (2014), who argued that challenging circumstances open the debate in water management of what the waterscape should be. Figure 2.6 presents how the two Lake Chapala's water crises allowed micro-actors to challenge the policies of the water authorities.

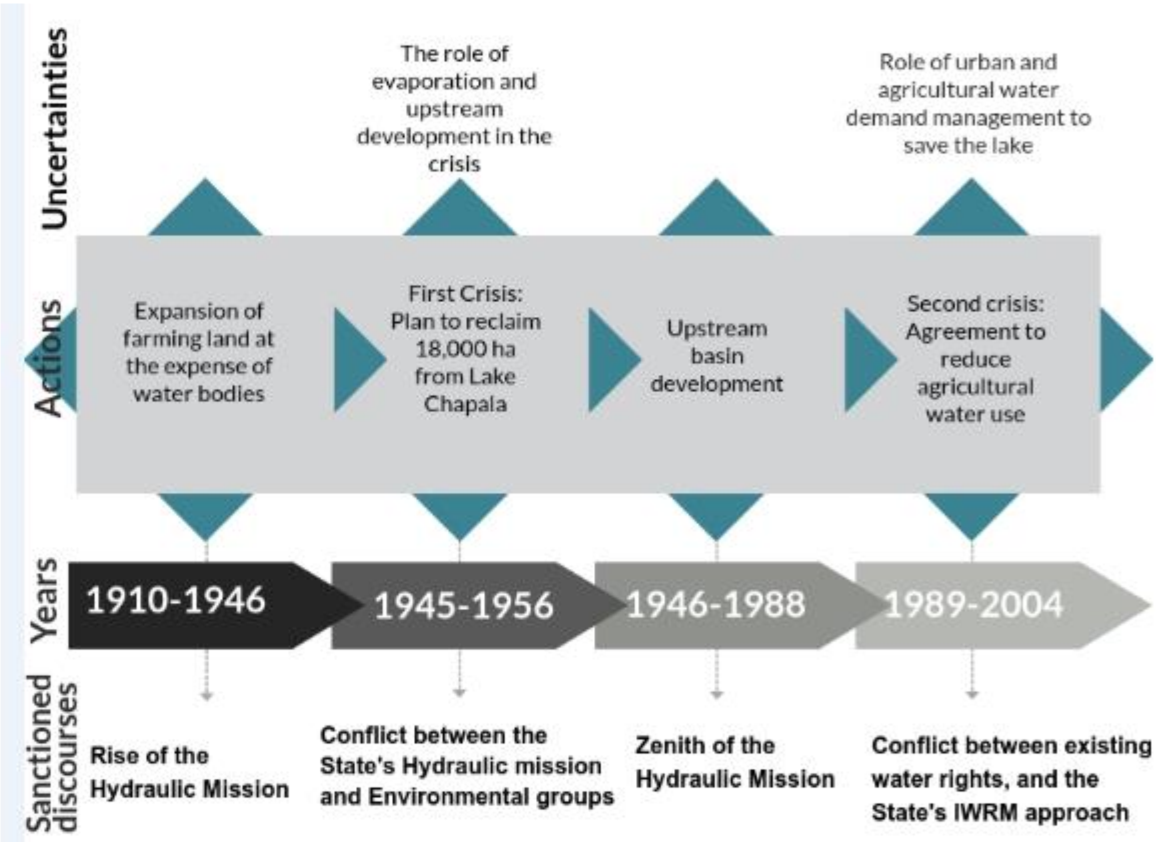

Figure 2.6 Timeline of the dynamic relationship between uncertainties, events and sanctioned discourses in the Lerma-Chapala basin.

During Lake Chapala's first recorded crisis the water authorities defined the system and the problem in hydraulic terms: moving water from one point to the users, while avoiding losses in the system. Lake Chapala's evaporation was seen as a wasteful outflow, one that the nation could not afford. The environmentalist group, however, defined the system as hydrological, claiming that evaporation was a natural physical process, and that the real culprit of the lake's crisis was the intense use of water upstream in Guanajuato. These two water knowledges collided in the public arena to support or reject a project for reclaiming part of the lake's area. The environmentalists were micro-actors who mobilized several concerned public figures from the cultural field to reject the reclamation project. The State, a macro-actor by definition, did not manage to convince Jalisco's public that this was the most appropriate decision, and the project was cancelled. The lake's crisis allowed environmentalists to contend with the 'hydraulic mission' sanctioned discourse, and successfully introduced an ecosystemic interpretation of a physical process.

The second crisis of Lake Chapala would increase in complexity, as the problem transited from the dual confrontation of society-government to multiple actors (Escobar, 2006). Conagua, as the new water authority, replaced the 'hydraulic mission' discourse to IWRM. This discourse was aligned with that of the World Bank (Molle, 2008a), which perceived agriculture as inefficient and wasteful. Jalisco kept its environmental discourse, while Guanajuato was still profiting from the 'hydraulic mission' infrastructural legacy by referring to itself as 'Mexico's breadbasket'.

The two main actors in the conflict, CEA-Guanajuato and IMTA-Conagua, used different approaches of hydrological modelling to resolve contextual uncertainty, each defining system boundaries to find out what the root causes of the problem were. CEA-Guanajuato modelled the social and natural systems as a coupled system to assess the interrelationship between water and the economy. IMTA modelled the system as a surface water balance with a stock of water at the end of the basin, Lake Chapala. These two different approaches concluded with opposite root causes of the crisis and opposite solutions.

Since Conagua (2011) identified agriculture as the main culprit of the crisis, no compensation to farmers was considered in the new reallocation agreement. Molle & Berkoff (2006) argued that authorities are reluctant to discuss compensation because it would "expose the hidden consequences of reallocation", undermining their own legitimacy, and faith in their capacity to solve the problem. Such consequences would generally mean farmers: 1) going out of business, 2) using wastewater, 3) over-exploiting groundwater, and/or 4) improving irrigation efficiency (ibid.). Some publications warned about farmers going out of business, especially poor farmers who solely relied on surface water (Torres-Gonzalez & Perez-Peña, 2005; Wester, 2008: 214; Flores-Elizondo, 2013), and for whom improving irrigation efficiency is not a feasible option (Vargas-Velazquez, 2010). Instead, wastewater use for irrigation was gradually generalized (ibid). And finally, unsustainable groundwater use has proliferated and remained unabated until today in Guanajuato (Hoogesteger & Wester, 2017).

When the sanctioned discourse changed from the ‘hydraulic mission’ to IWRM, agriculture lost its central position in the water authorities’ policies. During the first crisis, agriculture needed to be protected and even increased. This position changed during the second crisis when the sector was perceived as inefficient. Jalisco and Conagua formed a steady alliance by building a discourse with elements of IWRM and environmental protection. Such discourse was solid enough to force the water allocation agreement in the basin despite the uncertainties and hidden consequences to agriculture and groundwater.

2.5.2 IWRM and the role of politics in science and decision-making

Some authors have argued that normative recipes like IWRM do not work in the real world (Biswas, 2008; Ingram, 2008), because the approach can prove to be too restrictive, at least in terms of avoiding infrastructure development (Woodhouse & Muller, 2017). Therefore, the solution of the Lerma-Chapala conflict was celebrated as a non-normative approach to IWRM (Lenton & Muller, 2009).

Still, IWRM principles like public participation, management at the river basin scale and sound knowledge were said to have been exercised during the conflict (Güitrón, 2005; Hidalgo & Peña 2011). These authors suggested that the water allocation agreement of the Lerma-Chapala basin was the result of IMTA’s scientific assessment of the basin’s water resources and of the stakeholder participation in the process. Güitrón (2005) argued that IMTA’s model gained legitimacy and trust through the participation of the stakeholders, and because it could reproduce the lake’s behaviour.

Although participation is supposed to be a central tenet to water governance in Mexico, its weaknesses are widely recognized in practice (Mollard et al., 2010; Wilder, 2010; Herrera, 2017). These authors suggested that a combination of weak institutions, politicisation and elite capture is the largest risk of the participation process.

The Lerma-Chapala case was allegedly different, because of how the modelling process influenced the conflict. Ananda & Proctor (2012) argued that modelling can be a tool to fill information gaps for decision-making and collaborative planning, and GWP (2000) argued that modelling could help depoliticize conflicts. However, too much trust in models may not be justified, as Savenije (2009) argued that although a model can mimic reality, is not the same as reality and cannot predict the future. Sanz et al. (2018) argued that since policies informed by models generate winners and losers, they can be used to promote legitimacy to top-down decisions and acceptance among stakeholders. Since scientific assessments can have so many repercussions in reality, Molle (2008b) argued that they can be influenced by different political and economic interests.

The modelling process in the Lerma-Chapala case lacked legitimacy, since CEA-Guanajuato remained reluctant to accept what they perceived as a flawed modelling solution that would protect Guadalajara's interests and harm its own. IMTA's basin approach left out any policy alternative involving Guadalajara's water use, despite its important role as an out-of-basin user. Although Conagua commissioned a socio-economic assessment of water reallocation (Goicoechea, 2005), their results only concluded the low profitability of agriculture, which contributed to the policy of reducing agricultural water use. This study did not evaluate any socio-economic consequences for agriculture, institutionalizing asymmetrical consequences to farmers.

The water allocation agreement that followed was a solution to solve Lake Chapala's crisis, but only a partial solution to the overall socio-hydrological problem. IMTA's model did not address groundwater overexploitation and negative socio-economic consequences to farmers. This is because a purely physical model of the system would necessarily omit socio-political and economic considerations, as Budds (2009) concluded in the case of Chile. Conagua did not consider alternatives like compensating farmers nor supporting bottom-up institutions like groundwater users' association (COTAS) to regulate groundwater over-exploitation.

This apparent IWRM success story seemed to have become an instrument to mask a business-as-usual political agenda based on infrastructure development, like Giordano & Shah (2014) suggested for other cases around the world. The water allocation agreement was achieved by the pressure exerted by the Governor of Guanajuato's political party (Flores-Elizondo, 2013), and the promise of an inter-basin water transfer. This infrastructural scheme would only transfer the conflict to the new donor basin (Ochoa-García, 2015). This was an exercise of power framed as IWRM, and modelling was just the continuation of politics by other means.

2.6 CONCLUSION

This research analysed whether and how implementation of IWRM principles solved a multi-dimensional water crisis in the Lerma-Chapala basin in Mexico. Although some scholars and policy makers have argued that indeed Conagua successfully implemented IWRM to reach a water allocation agreement that solved the social conflict and saved Lake Chapala, we claim that the agreement merely postponed a real and sustainable solution to the water scarcity problem and conflict in the basin. We have come to this conclusion by analysing the decision-making and modelling process in the conflict with the lens of political ecology and sociology of science.

Actors with decision-making capacity conditioned the agreement through the promise of two supply augmentation schemes: the Zapotillo Dam and inter-basin water transfers to Guadalajara and León. Furthermore, the agreement addressed only surface water for agriculture, and did not seriously consider other alternatives, such as urban demand management. Local IWRM institutions, like COTAS, were also not supported by Conagua as a plausible response to groundwater over-exploitation. This means that although Conagua's discourse encouraged public participation and used technical knowledge to find responses to the crisis, the alternatives were already restricted by politics and deals behind closed doors. This goes against principles of transparency and real public participation lying at the core of IWRM (van der Zaag, 2005).

We also researched how actors' perceptions had direct consequences for the hydrological models and the agreements based on them. We analysed this through the modelling artifacts that actors produced. We found that participatory processes can improve the quality of water distribution models, but due to large uncertainties some modelling decisions cannot be resolved through scientific debate only. This can result in an impasse, which can be exploited by political actors to impose top-down solutions. This negatively influences creative solutions by limiting policy responses to pre-defined alternatives.

Our findings call for improved scientific transparency, and social scrutiny and evaluation of the water knowledge generated to avoid an inequitable distribution of impacts on certain actors. Further research is needed to find mechanisms to meaningfully involve and inform actors in the design, understanding, implementation and assessment of hydrological and optimisation models for decision-making.

3

Unravelling intractable water conflicts: The entanglement of science and politics in decision-making on large hydraulic infrastructure[4]

"How can I be substantial if I do not cast a shadow? I must have a dark side also if I am to be whole."

—Carl G. Jung, *Modern Man in Search of a Soul*

"Genuine tragedies in the world are not conflicts between right and wrong. They are conflicts between two rights."

—G. F. Hegel, *Lectures on Aesthetics*

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[4] Based on Godinez-Madrigal, J., Van Cauwenbergh, N., and van der Zaag, P.: Unraveling intractable water conflicts: the entanglement of science and politics in decision-making on large hydraulic infrastructure, Hydrol. Earth Syst. Sci., 24, 4903–4921, https://doi.org/10.5194/hess-24-4903-2020, 2020.

Summary of the chapter.

The development of large infrastructure to address the water challenges of cities around the world can be a financial and social burden for many cities, because of the hidden costs these works entail and social conflicts they often trigger. When conflicts erupt, science is often expected to play a key role in informing policymakers and social actors to clarify controversies surrounding policy responses to water scarcity. However, managing conflicts is a socio-political process, and often quantitative models are used as an attempt to de-politicize such processes; conveying the idea that optimal solutions can be objectively identified despite the many perspectives and interests at play. This raises the question whether science depoliticizes water conflicts, or whether instead conflicts politicize science-policy processes? We use the Zapotillo dam and water transfer project in Mexico to analyze the role of science-policy processes in water conflicts. The Zapotillo project aims at augmenting urban water supply to Guadalajara and León, two large cities in Western Mexico, but a social and legal conflict has stalled the project until today. To analyze the conflict and how stakeholders make sense of it, we interviewed the most relevant actors and studied the negotiations between different interest groups through participant observation. To examine the role of science-policy processes in the conflict, we mobilized concepts of epistemic uncertainty and ambiguity and analyzed the design and use of water resources models produced by key actors aiming to resolve the conflict. While the use of models is a proven method to construct future scenarios and test different strategies, the parameterization of scenarios and their results are influenced by the knowledge and/or interests of actors behind the model. We found that in the Zapotillo case, scenarios reflected the interests and strategies of actors on one side of the conflict, resulting in increased distrust by the opposing actors. We conclude that the dilemma of achieving urban water security through investing in either large infrastructure (supply augmentation) or alternative strategies (demand-side management), cannot be resolved if some key interested parties have not been involved in the scientific processes framing the problem and solution space.

3.1 INTRODUCTION

Urban water systems around the world are experiencing various urgent challenges to address water scarcity, flooding, and bad water quality (Zevenbergen et al., 2008; McDonald et al., 2014). The scope of these challenges is such that individual scientific disciplines and traditional approaches fall short of addressing them in a thorough manner to unequivocally inform policy (Funtowicz & Ravetz, 1994; Larsen et al., 2016; Hoekstra et al., 2018). Any solution to the challenges facing urban water systems will have manifold uncertainties in projected costs, benefits and risks, and this is especially true when large infrastructures are considered (e.g., see Flyvbjerg, 2009 and Crow-Miller et al., 2017, for a general description of the contentious process of cost-benefits assessments of large infrastructures, and for specific cases, see Berkoff, 2003, for China; Hommes et al., 2016, for Turkey; Hommes & Boelens, 2017, for Peru; and Molle & Floch, 2008, for Thailand). How the perceived costs, benefits and risks are shared among the stakeholders is one of the causes of water conflicts (Delli Priscoli & Wolf, 2009).

Since these conflicts are politically perilous situations, many policymakers seek specialized scientific knowledge that is perceived as neutral and unbiased to serve as the basis of making difficult decisions over controversial issues (Schneider & Ingram, 1997). In recent years, political ecology literature has acknowledged that this specialized scientific knowledge can act as a form of stealth advocacy in politically charged socio-environmental problems (e.g., Pielke, 2007; Budds, 2009, and Sanz et al., 2019, for groundwater over-exploitation and allocation; Godinez-Madrigal et al., 2019a, for water scarcity and surface water allocation). However, literature related to science-policy processes in contexts of intractable conflict due to large infrastructure development is scarce.

This chapter has two objectives, 1) to identify the causes of failure in science-policy processes to solve intractable conflicts and promote well-informed water management solutions; and 2) to explore the multiple influences in the production of water knowledge in a context of conflict, and its political use by actors. We contribute to the literature on science-policy process by analyzing the conflict over the Zapotillo dam and water transfer project, perhaps the most politically charged water conflict in Mexico in recent years. This case is of special relevance due to what is at stake: the water supply for the two most important cities in Western Mexico, the economic importance of its semi-arid donor basin, and the possible displacement of three communities lying in the reservoir's area. Furthermore, the conflict can be considered intractable, given its length (started more than 15 years ago) and that is still largely unresolved due to the intransigent positions of the stakeholders (Putnam & Wondolleck, 2003). The focus of this chapter is the scientific knowledge produced through a water resources model developed by an independent international team of experts convened by UNOPS (United Nations Office for Project

Services), hereafter referred to as the UNOPS team, as a means to clarify controversies, fill gaps in knowledge and depoliticize the Zapotillo conflict. We demonstrate how the process of scientific production, despite its intended neutrality, favored the Zapotillo project, ignored alternatives proposed by the dam-affected stakeholders based on demand management strategies in the recipient cities, and improperly managed core uncertainties related to climate change and future water demand.

The chapter is structured as follows. The first section analyzes the literature on science-policy processes in relation to epistemic uncertainties and controversies in water conflicts. We then describe the study area and the methods used to analyze the conflict. Subsequently, in the results section, we first describe the trajectory of the regions that would benefit from the Zapotillo project; we then describe the main knowledge uncertainties and controversies that articulate the positions and frames of the actors in conflict; and subsequently we analyze the scientific products that were developed to support decision-making in the conflict. Finally, we discuss the theoretical contributions of the case to the literature of the role of science-policy processes in water conflicts.

3.2 SCIENCE-POLICY PROCESSES AND WATER CONFLICTS

3.2.1 Uncertainties and ambiguity in science-policy processes

Effective science-policy processes in water management are those where water knowledge informs decision-makers as to what are the most appropriate solutions to water challenges, and what is likely to happen if nothing is done (Karl et al., 2007). However, Funtowicz & Ravetz (1994) have argued that complex socio-environmental issues (e.g., climate change) are confronted by uncertainties, ethical complexities, and policy riddles regarding societal values, from which no clear-cut policies can be concluded.

Uncertainties consist not only of matters of lack of precision and accuracy in the data being analyzed, but also of epistemic uncertainties, related to the functioning of a given system (Funtowicz & Ravetz, 1990; Di Baldassarre et al., 2016; Cabello et al., 2018) and of ambiguity, understood as the “simultaneous presence of multiple valid and sometimes conflicting ways, of framing a problem.” (Brugnach & Ingram, 2012). Scientists cannot address these levels of uncertainty by simply improving their techniques or computational prowess (Di Baldassarre et al., 2016). Epistemic uncertainties and ambiguity are entangled with controversies of what the real problem is and how to frame the solutions in the political arena between actors with different interests (Gray, 2003; Cabello et al., 2018).

When facing epistemic uncertainties in a complex socio-environmental problem, stakeholders stand on unexplored territory; even scientists face an ambiguous path in deciding which methodologies to use and how to interpret the phenomena (i.e., Melsen et al., 2018, and Srinivasan et al., 2018; see also Brugnach & Pahl-Wostl, 2008). Boelens et al. (2019) noted the relation of knowledge and power asymmetry between stakeholders in the context of large infrastructural schemes. Such asymmetry is characterized by hegemonic discourses that privilege technical knowledge as infallible, while other kinds of knowledge are disregarded to understand a socio-environmental problem (Schneider & Ingram, 1997; Wesselink et al., 2013). This may result in what Boelens et al. (2019) denominate 'the manufacture of ignorance', understood as the process of cherry-picking facts and knowledge to further one´s position, while discrediting ex-ante competing knowledge without a thorough debate (see also Flyvbjerg, 2009, Moore et al., 2018). In the case of large infrastructures, governments undertake this process often by invoking scientific evidence (Brugnach et al., 2011), which is often presented a-critically by downplaying the inherent risks and uncertainties (Flyvbjerg, 2009), and by presenting it as the only valid frame to understand socio-environmental problems.

When science-policy debates ignore intrinsic epistemic uncertainties and ambiguity, it is expected that uncertainty be present in their scientific recommendations to policy (Funtowicz & Ravetz, 1994), which makes such recommendations dubious, or at least contestable. Alternatively, Pielke (2007: 17) proposed that the role of scientists in issues of high uncertainties and politicization should be that of "honest broker of policy alternatives", consisting of expanding the scope of alternatives to decision-makers. Moreover, epistemic uncertainties and ambiguity can be made manageable through bottom-up approaches[5] consisting of the inclusion of local stakeholders, their knowledge, problem-framing and alternative solutions in the policy debates (for a general description see Brugnach et al., 2011, and for hydrological risk management see Lane et al., 2011, and Blöschl et al., 2013). Nevertheless, public participation in socio-environmental decisions is a political decision often aimed at improving the acceptability and legitimization of policies (Newig, 2007), rather than reducing epistemic uncertainty and handling ambiguity (Blomquist & Schlager, 2005; Brugnach & Ingram, 2012). In such situations the underlying causes for conflict remain un-addressed.

3.2.2 Water conflicts and co-production of knowledge

Water conflicts emerge for many reasons, but we will explore those that emerge from the imposition of large infrastructural projects. These projects may produce many benefits, but also socio-environmental costs and risks that are unevenly distributed between

[5] The difference between a top-down and a bottom-up approach is that the first focuses on highly technical assessments, while the second on the communities' vulnerabilities, making the latter more robust to a changing and unpredictable climate, no matter how low the probabilities of the occurrence of any event (Blöschl et al., 2013).

stakeholders. An example is the apparent urgency to implement supply augmentation and reallocation solutions to guarantee water supply to large cities. These solutions may hamper due processes of transparency, public participation and the rights of other water users and stakeholders. The absence of these processes may create social conflicts (Barraqué & Zandaryaa, 2011; Roa-García, 2014), which are defined as "two or more entities, one or more of which perceives a goal as being blocked by another entity, and power being exerted to overcome the perceived blockage" (Frey, 1993, cited in Delli Priscoli & Wolf, 2009). Thus, water conflicts may block such supply augmentation projects to alleviate water scarcity, while no alternative solutions are implemented. In doing so, actors in conflict may worsen the system as a whole (Madani, 2010), aggravating the social conditions by rationing water, and deteriorating hydrological conditions by further depleting available water reserves like aquifers or dams.

When these conflicts are prolonged in time, the positions of the actors in conflict tend to harden and the conflict may become intractable with small chances for a negotiated solution (Putnam & Wondolleck, 2003). Intractable conflicts are often characterized also by ambiguity, in which actors with different systems of knowledge (engineers, communities, policymakers, etc.) perceive the problem with different frames, as well as its possible solutions (e.g., Table 3.1 presents the multiple frames of the actors in the Zapotillo conflict). A diversity of frames is possible since water problems are often unstructured and riddled by uncertainties in information and cause-effect relationships (Islam & Susskind, 2018). Even within stakeholder groups, stakeholders can make sense of the conflict using different frames (Brummans et al., 2008). Politicians typically expect scientists to contribute to unravelling what the problem is, and to offer solutions supported by all actors (Schneider & Ingram, 1997). However, studies have identified political biases in allegedly neutral scientific studies (i.e., Budds, 2009; Milman & Ray, 2011; Fernandez, 2014; Sanz et al., 2018; Godinez-Madrigal et al., 2019), which have lately discredited science as a fair knowledge creator in some controversial large infrastructural water projects around the world (Boelens et al., 2019). Due to this situation, among others, more attention has been given to include stakeholders in research and decision making (Armitage et al., 2015; Krueger et al., 2016).

Specialized literature provides some consistent recommendations regarding knowledge in contexts of conflict and a diversity of values in socio-environmental problems. Van der Zaag & Gupta (2008) recommend to consider five principles based on feasibility, sustainability, considering alternatives, good governance and respecting rights and needs before undertaking large infrastructural schemes; Funtowicz & Ravetz (1994), Van Cauwenbergh (2008), Islam & Susskind (2015), Armitage et al. (2015) Dunn et al. (2017) and Norström et al. (2020) argue that since no expertise or discipline can claim to have the monopoly of wisdom in complex socio-environmental issues, the problem definition and possible solutions need to include local and non-technical knowledges, therefore engaging in co-production of knowledge. This approach even provides the advantage of designing more robust and resilient solutions (Blöschl et al., 2013). This does not belittle scientific studies, but changes their role to become boundary objects, which cannot illuminate stakeholders´ decision-making, but rather elicit new relationships and innovative solutions among the different systems of knowledge and frames present in all stakeholders (Lejano and Ingram, 2009). True knowledge controversies have the potential to be generative events in the sense that they open the ontological question of what reality is and how it is framed, and redefine it in, hopefully, better terms (Callon, 1998; Latour, 2004; Whatmore, 2009).

However, little attention has been paid to science-policy processes in cases of intractable water conflicts based on the development of large infrastructures to solve urgent water problems. The next sections present the historical context of the conflict over the Zapotillo water transfer project in Mexico, analyze the knowledge controversies around the conflict and the scientific products developed by team of experts fielded by UNOPS and by Conagua (the federal water authority) to solve the conflict and generate acceptance and legitimacy for the project.

3.3 CASE STUDY AND METHODOLOGY

3.3.1 Study areas

Since the Zapotillo project entails the water transfer from the Verde River Basin in the northeast of Jalisco to two cities located outside of the boundaries of the basin, three different regions constitute the area of interest of this study. Figure 3.1 shows the two recipient cities of the projected water transfer, Guadalajara and León, and the contiguous donor basin, the Verde River Basin. Currently, Guadalajara has more than 4.5 million people, and is the capital of the State of Jalisco. León has a population of around 1.5 million people and is the most populous and economically most important city of the State of Guanajuato. The Verde River Basin is a sub-basin of the Lerma-Santiago-Pacífico basin and discharges its water to the Santiago River located north-west of Guadalajara. The area of this sub-basin is around 21,000 km^2 large and is mainly located in the State of Jalisco (55%). The sub-basin is considered as semi-arid in the north, with an average precipitation of around 360 mm/year, and sub-tropical in the south with an average precipitation of 900 mm/year; the average temperature varies between 11ºC and 18ºC in winter and 17ºC and 25ºC in summer; and the average potential evaporation in the basin is around 1550 mm/year (UNOPS, 2017a). The basin is home to around 2 million people, of which almost half inhabit the region of Los Altos, located in the part of the basin that belongs to the State of Jalisco. The northern part of the basin, located in the State of Aguascalientes, is characterized by a developed industrial sector; while Los Altos is characterized by a vibrant primary sector of the economy, contributing to the production of around 20% of the total animal protein produce of the country (Ochoa-García et al., 2014).

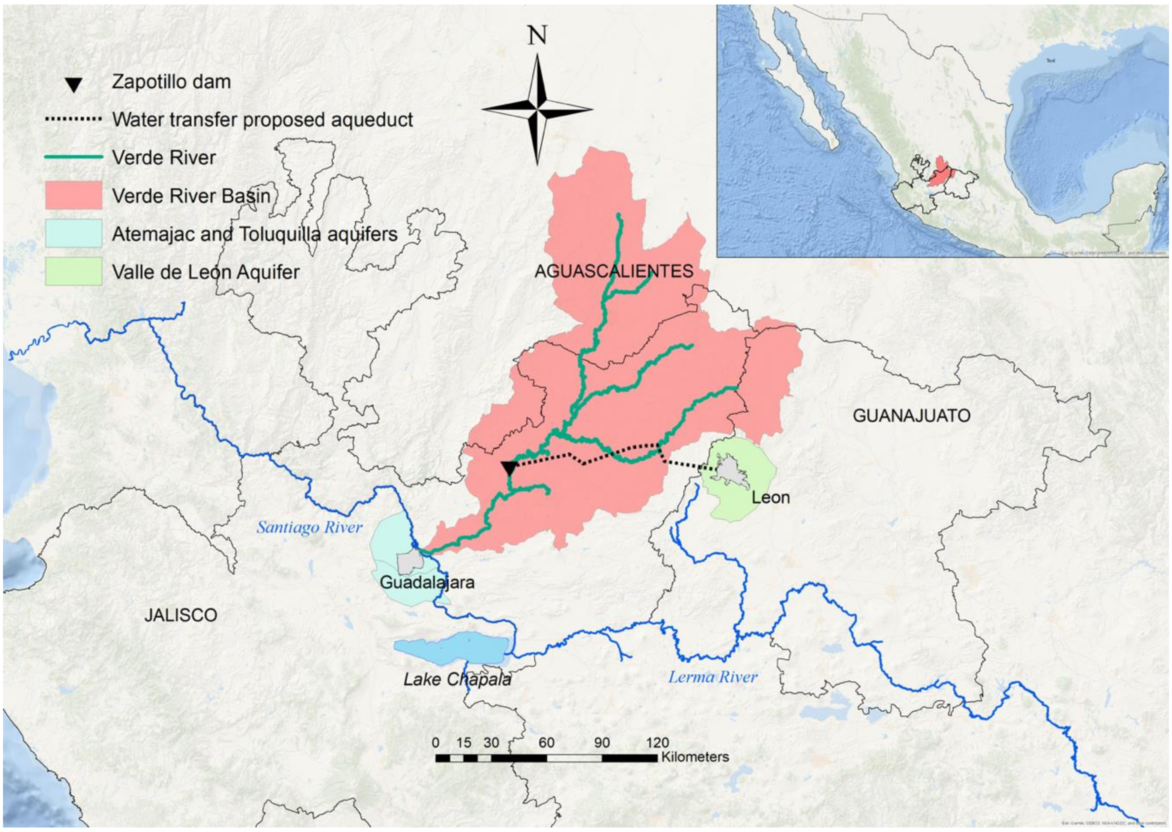


Figure 3.1 Map of the Verde River Basin and main cities (Source of GIS layers: © 2018 Conagua, and © 2019 Esri, Garmin, GEBCO, NOAA NGDC, and other contributors).

3.3.2 Methodology

To understand the science-policy processes in a context of an intractable conflict we adopted an interdisciplinary method to comprehensively analyze the technical as well as the social issues that are central to the conflict. The first author spent five months before the public release of the report by the UNOPS team in Guadalajara in 2017 and one month after. He conducted 22 in-depth, semi-structured interviews to most of the key actors of the conflict: members of Jalisco's government, national and state water authorities, NGOs, scholars, the Citizen Water Observatory (hereafter referred to as the Observatory) and representatives of the communities affected by the dam. Since the hotspot of the conflict was located in Jalisco, we decided to focus on Jalisco instead of Guanajuato; although we also collected information on Guanajuato through many actors in Jalisco that had close contact with key stakeholders in Guanajuato and through public statements and official documents of the local water utility and state water authorities. The semi-structured interviews consisted of exploring three main themes: the root causes of the problem and the conflict, what were the sources of controversy in the conflict, and what would be the preferred solutions to the conflict and the water scarcity problem. The interviews also served to identify the position and interests of the actors in the conflict after Fisher et al. (2000) that in turn allowed differentiation of stakeholders following Reed at al. (2009). Due to the delicate nature of the situation, all interviewees remain anonymous, and not all interviews could be recorded; in such cases we relied on fieldnotes taken immediately after the interview. The interviews that were recorded, were transcribed. We analyzed the interview transcripts and fieldnotes to extract the summarized viewpoint of the stakeholders, which are described in Table 3.1. We then conducted participant observation during five key meetings of the Observatory and Jalisco's government to analyze the discourses, knowledge claims, and main controversies on the coupled human-water system of the region. This allowed us to identify controversies and link the position of actors in the conflict to knowledge frames. Immediately after the presentation of results from the study by UNOPS' team, we conducted informal interviews with most of the key actors that were present to chronicle in our fieldnotes their reactions and opinions on the outcome of the study.

Afterwards, we requested from Jalisco´s government the full water resources model that the UNOPS team developed; we received it by the end of 2017. The model was developed using the Water Evaluation and Planning System (WEAP21) software (see supplementary material for a detailed description of the model) and contained the five scenarios that the UNOPS team used to test the viability of the Zapotillo dam project to reliably allocate water until the year 2069 (Figure 3.2). The five scenarios switched parameters under different reservoir storage volumes (at dam heights 80 m and 105 m), different water allocation volumes to Guadalajara, León, and the urban localities within the Verde River Basin (three aggregated flows of water were considered: 8.6 m^3/s, 4.8 m^3/s and 7.5 m^3/s; Figure 3.2 disaggregate these flows to the three users), changes in water availability related to climate change (RPC 8.5 or no climate change) and changes in agricultural water demand in the donor basin (static water demand since year 2018 or expected water demand in year 2030).

The UNOPS team recommended decision makers that the best possible configuration of the Zapotillo project was that of scenario 5: to build a dam at 105 m, with the only caveat of reducing the water allocation by 13%. However, many actors were negatively surprised that although the UNOPS team developed a scenario with climate change and future water demand (scenario 4, see Figure 3.2), these changing future conditions were not included in their scenario 5, which only considers current water demand and ignores reduced water availability due to climate change. Therefore, we considered it important to replicate the results developed by the UNOPS team, and to test and analyze its choice of scenarios and recommendation by developing an additional scenario (our) that included the variables climate change and future water demand as developed by the UNOPS team in scenario 4 to their scenario 5 (Figure 3.2). We then compared the results of our scenario with the original scenario 5 using the same indicators the UNOPS team used to assess their own scenarios. These indicators (reliability, vulnerability, and resilience) were based on the methodology of Loucks and Gladwell (1999). Reliability assessed the percentage of months the dam was able to supply its intended volume. The ideal score would be 100%. Vulnerability assessed the percentage of water supplied vis-à-vis water demand for all months. The ideal score would also be 100%. And resilience assessed the speed of recovery of the dam after a period of being empty by calculating the number of times a satisfactory value (when all water demand is satisfied) follows an unsatisfactory value (when not all water demand is satisfied) divided by the number of unsatisfactory values. The scores range from 1 to 0, being close to 1 represents a highly resilient system, and 0 a poorly resilient system.[6]

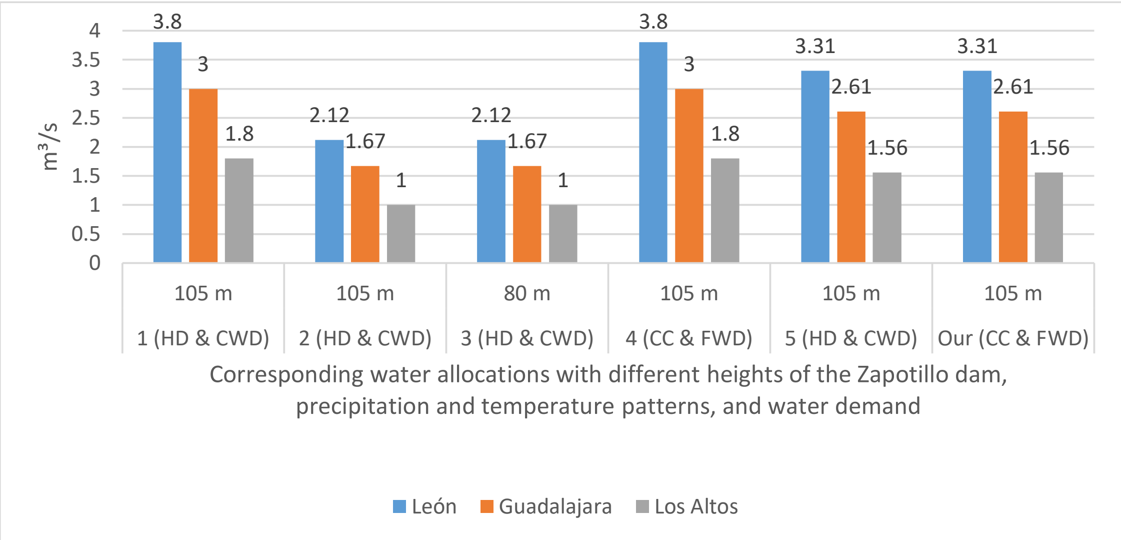


Figure 3.2 Key variables of the five water allocation scenarios (in m3/s for León, Guadalajara and Los Altos) developed by UNOPS (2017b) and ours ("HD & CWD" = historical run-off data and current water demand; "CC & FWD" run-off under climate change and future water demand.

[6] The resilience indicator is only useful when the system presents unsatisfactory values, therefore if the system does not present any unsatisfactory values, the indicator is non-existent, as seen in Figure 3.6 (below).

3.4 RESULTS

3.4.1 The Zapotillo conflict

Guadalajara and León are the most important cities of their respective States, Jalisco, and Guanajuato, in terms of population and economic size. Since the 1950s, Guadalajara's local water resources availability was overrun by the increasing water demand, and water managers sought to increase its water supply from Lake Chapala, the largest lake in the country. Currently, Guadalajara complements its water demand mainly through groundwater (see Table S1 in the supplementary material). However, due to their intense use, the aquifers are considered as over-exploited and with presence of nitrate and sulphate due to farming activities and wastewater disposal, and naturally occurring contaminants like lithium, manganese, fluorine, and barium due to mixing of hydrothermal fluids (Hernandez-Antonio et al., 2015; Mahlknecht et al., 2017; Moran-Ramirez., 2016). León, on the other hand, does not have large bodies of surface water in close vicinity and therefore it has historically relied solely on groundwater, which is now considered as heavily over-exploited with a drawdown of 1.5 m/year and with presence of chromium due to industrial activities, related to anthropogenic activities nitrate, chloride, sulphate, vanadium and pathogens, and naturally occurring contaminants like fluoride, arsenic, iron, and manganese due to the introduction of older groundwater with longer residence times (Esteller et al., 2012; Villalobos-Aragon et al., 2012; Cortes et al,. 2015; SAPAL, 2020).

During the 1980s, water managers in Jalisco were aware of the relentless growth of Guadalajara and sought to develop new sources of water besides groundwater and Lake Chapala (Flores Berrones, 1987). They analyzed that the only nearby region with enough water to supply Guadalajara was the Verde River Basin, located in the north of Jalisco (Figure 3.1). They calculated a potential of more than 20 m^3/s, enough to supply water for Guadalajara for the coming decades. However, it was technically complicated to develop the Verde River Basin and transfer its water to Guadalajara. The Verde River discharges into the Santiago River at around 500 meters below the altitude of Guadalajara, which skyrockets pumping energy costs. During the 1990s Jalisco developed many projects that failed to materialize due to financial and political issues (Von Bertrab, 2003). During this time and partially because of the inability of Jalisco to materialize a water transfer project, Guanajuato requested Conagua (the federal water authority) legal rights over a portion of the Verde River's water for the city of León. In 1995, Conagua accepted this request and added Guanajuato as a potential user of the river's water.

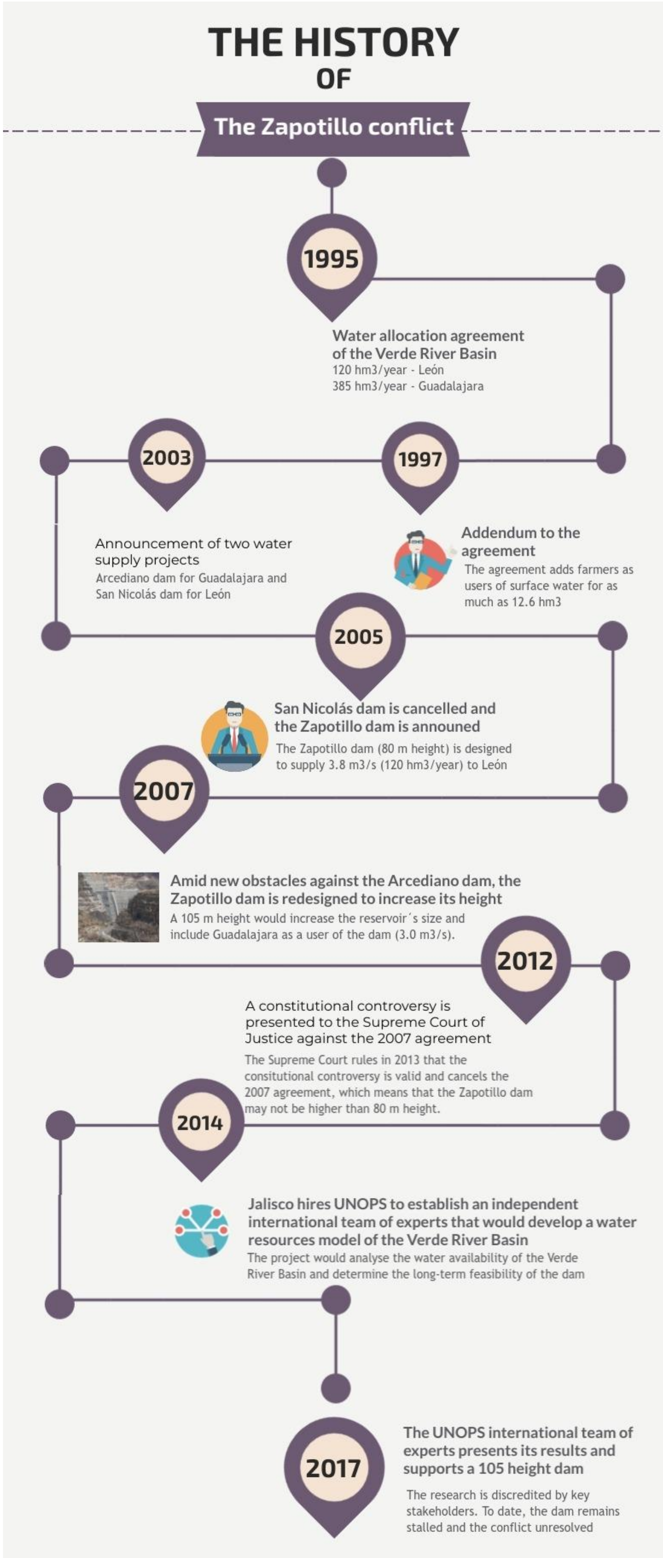


Figure 3.3 Timeline of the Zapotillo conflict.

During the year 2000, a drought started in the Lerma-Chapala basin that caused a water crisis for Lake Chapala, which decreased its volume to less than 10% of its capacity. Since Guadalajara heavily relied on the lake for its water supply and upstream farmers in Guanajuato used most of the surface water that fed the lake, the situation triggered a surface water allocation conflict between Jalisco and Guanajuato (Godinez-Madrigal et al., 2019). The conflict was resolved by reducing the water rights of upstream farmers to increase the volume of water reaching the lake. But, in exchange, in 2003 Conagua promised to build the San Nicolás dam in the Verde River Basin to transfer water to León, and the Arcediano dam in the Santiago River for Guadalajara (Godinez-Madrigal et al., 2019).

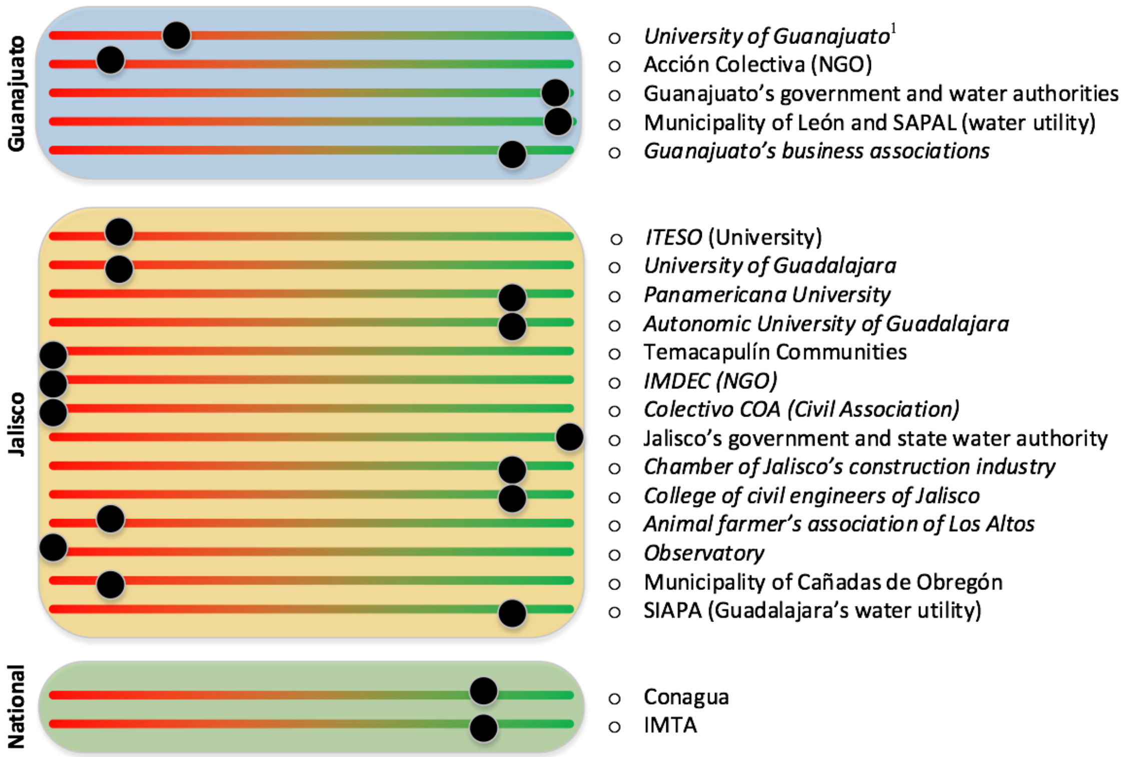
After a swift mobilization of the San Nicolás community, the dam was cancelled in 2004. However, in 2005, the Zapotillo project was unveiled, it was designed at 80 m height with the objective to provide 3.8 m^3/s only to León. It is at this moment in time when the authors pinpoint the start of the Zapotillo conflict, which is summarized in Figure 3.3. Nevertheless, because the water authorities could not solve important social, financial, and technical issues to build the Arcediano dam (López-Ramírez & Ochoa-García, 2012), Jalisco´s government advocated in 2007 to change the design of the Zapotillo project to include Guadalajara as a user and receive 3.0 m^3/s by increasing the dam's height to 105 m to increase its storage capacity.[7]

By this time, the dam-affected communities, Temacapulín, Acasico and Palmarejo (hereafter Temacapulín), had already started a fierce opposition against the project with the objective to avoid the flooding and relocation of their communities. Their representatives followed a social and legal strategy, which consisted of claiming that the 2007 agreement was unconstitutional because Jalisco's governor did not consult the State congress. In 2013, the Mexican Supreme Court ruled against the 2007 agreement and ordered Conagua to stop the construction of the dam, which by then already had reached 80 m height (DOF, 2013). The Zapotillo project has remained paralyzed since then. Although the dam wall has already been built, the reservoir has not been filled, because of the uncertainty of the dam's final height (Fig. 3.4).

[7] Several urban locations in the Los Altos region were included as well in the water allocation agreement of the project, which would receive 1.8 m^3/s.

Figure 3.4. Empty Zapotillo dam in 2021 (Source: Ir. Jorge Acosta, 2021).

Given the politicization of the conflict and the urgency of meeting the water deficits of Guadalajara and León without implementing any additional or alternative strategy, new actors have entered the political arena (see Figure 3.5 for a comprehensive map of actors of the Zapotillo conflict). Some farmers' associations of Los Altos coalesced and lobbied against the Zapotillo project using the argument that the region is semi-arid, already presents groundwater over-exploitation, that climate change will worsen the condition of the regional water resources, and that the region is one of the most productive agricultural regions in the country (Ochoa-Garcia et al., 2014). Additionally, due to the increased political pressure, in 2014 Jalisco's government supported the creation of a Citizen's Water Observatory, led by an active spokesperson of farmers of Los Altos, and composed of a wide range of representatives of universities and civil society organizations (see supplementary material for more information) that would, at least in theory, have the mandate to formulate binding recommendations to local and state governments of Jalisco. The Observatory, NGOs and local universities argued that demand management strategies in Guadalajara and León could be more sustainable and socially just than the Zapotillo project. In contrast, IMTA (the engineering body of Conagua) released a technical study concluding that the Zapotillo project was feasible (there was enough water availability in the basin) even in the context of climate change (IMTA, 2015).



[1]Universidad de Guanajuato has not released any official position on the project, however many of its academics have publicly supported its cancelation.

Figure 3.5 Position of key actors on a horizontal axis against (left, red) and in favor of (right, green) the Zapotillo dam project. New actors are highlighted in italics (for more details on the figure methodology and description of actors, see Table S2).

In 2014 Jalisco's government hired the United Nations Office for Project Services (UNOPS) to establish an independent international team of experts tasked to develop a water resources model of the Verde River Basin and formulate an informed recommendation to address, once and for all, the controversies regarding the possible negative effects in the Verde River Basin and analyze the optimal configuration of the Zapotillo project. The involvement of UNOPS was immediately seen as an existential threat to the recently created Observatory, because the latter assumed as its primary function to determine the future of the Zapotillo project and recommend actions to solve the conflict. In fact, the chair of the Observatory criticized the involvement of UNOPS as a political play by Jalisco´s government to decrease the Observatory´s influence. He also questioned the integrity of the UNOPS´ team due to the apparently suspicious high cost of the study (4.5 million USD); and refuted *ex-ante* the technical study of the UNOPS´ team. Based on these criticisms, the leadership of the Observatory lamented that Jalisco´s government had not funded them and the University of Guadalajara instead to do the research. However, a high-level official of Jalisco´s government (personal comm. 22/05/2017) characterized the criticisms from the Observatory as representing the political interests of the University of Guadalajara, who often lobby Jalisco´s government to receive more financial resources (Jalisco´s government determines the University´s budget) and research contracts. Moreover, Jalisco´s government had previously awarded environmental research projects to academics of the Universidad de Guadalajara, but, according to the official, the resulting studies were technically deficient and unusable. Related to IMTA, the appreciation of this official is that its function has been relegated to technically legitimize Conagua´s projects, and that it was reluctant to share any information. The official concluded that "the scientific debate is very poor, because it has been co-opted by politics." This explains why Jalisco's government neither trusted the University of Guadalajara nor IMTA and that it approached UNOPS as an alleged apolitical third party with proven independence (UN-affiliated) and technical capabilities that were locally absent to help solve the conflict. The government official said that "[Hiring] UNOPS will articulate a paradigmatic change in the way we make decisions on water management in Jalisco."

The UNOPS´ study took two years, and the process followed, and methods adopted were largely unknown by most actors. Finally, in 2017, the UNOPS team of experts recommended that the Zapotillo dam should be built at 105 m height and that the original water allocation should decrease by 13%, since Conagua had over-estimated the available water in the Verde River Basin and underestimated water demand (UNOPS, 2017c). The results of the study were discredited and discarded by some of the main stakeholders in the conflict as described in Section 4.3.

3.4.2 Controversies

Table 1 summarizes the main controversies and frames raised by the interviewed actors in the conflict. These can be divided into two: 1) what are the appropriate policies to solve the water scarcity problems in the recipient basins (Guadalajara and León); and 2) what are the risks, uncertainties and negative effects of a dam and a water transfer in the Verde River Basin, the donor basin.

Recipient basins: policies for urban water security

Since the 1980s, Guadalajara's per capita water use has remained above 200 l/cap/day (Flores-Berrones, 1987; Consejo Consultivo del Agua, 2010). Ever since, water authorities have strived to keep pace with the fast-growing city population, because they consider a relatively large per capita water use as an important indicator for water security. In a context of a decreasing per capita water availability because of population growth, the actors in favor of the Zapotillo dam project have emphasized the urgent necessity of supply augmentation for the cities of León and Guadalajara. Representatives from CEA-

Jalisco (Jalisco's water authority) and Sapal (León's water utility) argued that without supply augmentation, both cities might suffer a water crisis due to water scarcity derived from the over-exploitation of its aquifers.

Table 3.1 Main controversies and frames on the coupled human-water system of the regions and the Zapotillo project (ZP).

General controversies	Specific controversies	Frames
Recipient basins: policies for urban water security	– The urgency to apply supply augmentation policies to achieve water security. – Replacing supply-side policies for demand management policies and small-scale infrastructure: reducing physical losses in the network and implementing rainwater harvesting. – Financial burden because of increasing unexpected costs of large infrastructure. – Alternative, in-basin water sources for León and Guadalajara. – Sectoral water transfers to reduce groundwater over-exploitation.	– Actors in favor of ZP: alternatives are unrealistic. ZP is the only feasible solution to achieve water security. – Actors against ZP: Alternatives exist and can be cheaper, more sustainable, and socially just than ZP.
Negative consequences for the donor basin	– Dam's height in relation to the resettlement of the three communities and the water allocation commitments to León and Guadalajara. – Overestimation of surface run-off in the Verde River Basin. – Future water scarcity due to droughts and climate change in the Verde River Basin. – Underestimated official water abstractions in the Verde River Basin. – Regional socio-economic dynamic is growing, as well as water demand in the Verde River Basin. – Current groundwater over-exploitation will increase in the future. – The human rights of Temacapulín should be respected.	– Actors in favor of ZP: There is enough water in the donor basin for all existing and future users. And a 105 m height dam is the best and most efficient solution that benefits a great majority despite the social costs of relocating Temacapulín. – Only a 60 m height dam is socially feasible, since human rights are not negotiable. – Actors against ZP: There is currently not enough water in the donor basin, and a water transfer will have enduring negative effects for the region.

Water authorities from Jalisco and Guanajuato concluded that pressure on aquifers in both cities and Lake Chapala need to be decreased, as aquifers represent a safe backup in times of drought. An additional risk for Guadalajara is the aging Lake Chapala aqueduct, whose life expectancy has already been exceeded. Repairing the aqueduct may affect the water supply for the city for weeks or even months.

Against this argument, representatives of Temacapulín, the Observatory, NGOs and universities have argued that supply augmentation will always lag behind water demand. This group of opposing actors argues that there is an urgent need to curb the per capita water use, and to limit the cities' physical expansion and demographic growth, supported by a transition to a demand management paradigm that considers a reduction of physical losses, development of alternative water sources like rainwater harvesting, sectoral water transfers and full cost recovery of water utilities.

Regarding urban rainwater harvesting, a group within the Universidad de Guadalajara (not a member of the Observatory) has been developing and promoting this solution over the last decade (Gleason-Espíndola et al., 2018). They claim that harvesting rain through household systems distributed across the city could eventually make unnecessary a supply-augmentation project such as the Zapotillo project. However, according to their own estimates, the proposed system could harvest approximately 21 hm^3/year, which could account for only about 7% of the total water use of Guadalajara, which is 313 hm^3/year (SIAPA, 2017). Researchers at the University of Guanajuato calculated an approximate annual rainwater harvest of 27.3 hm^3/year for the city of León, amounting to 33% of the total water use of 81 hm^3/year (Tagle-Zamora et al., 2018). It should be noted, however, that both studies differed in their methodology and approach, and both did not account for implementation uncertainties, a reason for Jalisco´s water authority to dismiss rainwater harvesting as a realistic option.

The Observatory has argued that the municipality of León and the government of Guanajuato should integrate their water resources at the basin scale to save water and reallocate it to where it is most needed. For this, Jalisco´s Observatory proposed a two-way strategy for León: to abstract water from Sierra de Lobos, a mountain range located close to León, and to implement an agricultural water modernization program and to reallocate its savings to León. The Observatory claims such a strategy would increase available water for León with 360 hm^3/year, which is four times León's current water use (Del Castillo, 2018). However, even after request, the technical details of this alternative have not been shared nor made public anywhere. In fact, a member of the Observatory recognized that the technical members of the Observatory produce these claims based on "feeling" rather than on technical analysis (personal comm. 08/05/2017).

When looking at a reduction of physical losses, Fitch Ratings (2015) stated that the current losses of Guadalajara's distribution system account for more than 3 m^3/s (around 32% of distributed flow). Gómez-Jauregui-Abdo (2015) warned that this situation may worsen, because of the network's obsolescence rate, which is higher than the replacement rate. CEA-Jalisco has argued that Siapa's budget is not sufficient to replace the entire distribution system and that even if sufficient financial resources were available, it would imply a huge social cost by breaking the asphalt of the streets of the whole city and paralyze the traffic. This would also imply a political cost that no local politician is willing to assume. In León, Sapal's non-revenue water also amounts to approximately 32%. Although the replacement rate of their distribution system is higher than Guadalajara's, their distribution system's deterioration rate is not precisely known.

Representatives of CEA-Jalisco consider all these alternative solutions not only cumbersome and ineffective, but also too expensive to implement. However, IMDEC, the most outspoken NGO against the project, released public information of mounting costs of the Zapotillo project: the Zapotillo project's original budget (2006) was USD 750 million (USD 1,250 million in today's value), which according to officially estimates has increased to USD 1,800 million (IMDEC, 2019). Considering these escalating costs, the NGO argues that demand management solutions (i.e., reduction of physical losses) could be more economical than this large infrastructure and without its large social costs.

A key anonymous actor opposing the project (personal comm. 15/05/2017) pointed out that officials of Jalisco´s water authority are not interested in demand management strategies, because they benefit the interests of large real estate companies who need more water rights to keep building housing developments, "it is the nature of capitalism, to keep growing […] this [the Zapotillo conflict] is actually a class conflict."

Negative consequences for the donor basin

In the past decades Los Altos has experienced two major socio-economic changes. First, a decreasing rural population due to migration to the United States (Durand and Arias, 2014) and to nearby cities in Jalisco. Second, the increasing industrialization of the regional economy. In the 1990s, Mexico liberalized its markets and supported agriculture for export. These policies helped industrialize the agricultural sector of Los Altos (Cervantes-Escoto et al., 2001). Currently, the region is the second largest producer of animal protein in the country (Ochoa-García et al., 2014), and hosts one of the largest egg producers in the world (WATTAgNet, 2015). This economic development has increased competition for water, especially groundwater, due to the government´s restrictions on surface water use (DOF, 2018). Several water users confirmed the existence of a black groundwater market, and groundwater rights grabbing in hands of industrial farmers. Consequently, most aquifers present serious water balance deficits, which jointly amount to more than 150 hm^3/year in Los Altos' aquifers (CEA Jalisco, 2018); and many have presence of selenium, fluoride, and arsenic (Hurtado-Jimenez & Gardea-Torresdey, 2005, 2006). As agricultural outputs keep increasing around 9%/year (Ochoa-García et al., 2014), groundwater overexploitation may exacerbate in the future due to an increasing water demand. Although there are no clear numbers on the water balance for surface and groundwater separately, water authorities calculated a combined renewable water availability in the Verde River Basin, which also includes groundwater in Aguascalientes (Figure 3.1), of 1,624 hm^3/year, while current water demand was 1,804 hm^3/year (Conagua-Semarnat, 2012).

The Observatory´s leadership has defended the interests Los Altos´ farmers by pitching the human right to food as equally important to the human right to water, which is used by Jalisco´s government. Due to the water deficit in the basin and the effects of climate change, the technical chair of the Observatory has argued that there is insufficient water in the basin to fill the dam at the planned 105 m height, and that, based on the precautionary principle, the Verde River Basin should not be burdened with additional commitments due to a water transfer. Additionally, he stated that water information provided by gauging stations in the Verde River Basin cannot be trusted, as the network of hydrological stations is allegedly defective and unattended.

An interviewee from CEA-Jalisco (personal comm. 20/04/2017) did not deny the possibility of some defective hydrological gauging stations but claimed that even if it is true that run-off is overestimated in the basin, CEA-Jalisco is confident that the gauging station at the entry point of the dam is reliable. This station has measured an average flow of 599 hm^3/year (IMTA, 2015), which is enough to fill the Zapotillo dam in one year at a height of 80 m, or in two years at a height of 105 m. Currently the Verde River water flows to the Santiago River with only minor abstractions (UNOPS, 2017d). However, farmer representatives in Los Altos stated in a meeting that, even if these surface water resources of the Verde River exist (they insist that the flow of the river has dramatically decreased over the past years), these should be used to contribute to the potential growth of Los Altos.

The Jalisco´s government official addressed this continuous growth of agricultural groundwater demand as the main sustainability problem in the basin, and suggested farmers should become more efficient and stop groundwater over-exploitation (personal comm. 22/05/2017); but such an endeavour might be more complex, as described by a representative of a large industrial protein producer in Los Altos (personal comm. 02/05/2017) “[Groundwater over-exploitation] does not constrain economic development. […] If you need water, you can get it in the black market. Because of corruption, Conagua cannot stop groundwater over-exploitation.” The procedure to acquire or renew a groundwater right is a legal conundrum that forces farmers to hire *‘coyotes’* (literally: a relative of wolves, here are meant officials within Conagua that illegally ease the procedure for a considerable fee). This situation has forced smallholder farmers to sell their lands for a penny and migrate when they cannot renew their groundwater rights, since as three interviewees confirmed that “a land without water is worthless.” Large producers have the means to hire coyotes and have been grabbing water rights and large portions of land from impoverished farmers.

Regarding the dam´s height and the three communities under threat of displacement, the controversy lies in incompatible values. These communities reasserted their rights of consultation and consent, participation, and the protection of their cultural and historical heritage. In turn, the government of Jalisco reasserted the utilitarian argument of the greatest good for the largest number of people. Temacapulín's representatives proposed a dam with a height of 60 m, whereby the towns would be safe from flooding. However, a smaller dam would not be able to transfer the agreed volume of water to Guadalajara and León, since the dam's storage capacity would then be 145 hm^3, too small to sustain a steady water transfer of 8.6 m^3/s. At a height of 80 m, Temacapulín, Acasico and Palmarejo would be flooded. However, CEA-Jalisco's representatives claimed that the construction of dikes could prevent this, albeit only for Temacapulín. IMDEC, the NGO accompanying the affected communities, and representatives of Temacapulín are against this solution as it would create a huge unnecessary risk for the inhabitants in case the dikes fail. Moreover, an 80 m dam with a capacity of 411 hm^3 would not be able to allocate sufficient water for both León and Guadalajara. With a height of 105 m and a storage capacity of 910 hm^3, the dam could potentially supply sufficient water for both Guadalajara, León, and Los Altos.

Analysis of scientific products

The history of the conflict over the Zapotillo project has created several scientific products that have attempted to address the many uncertainties and risks of a project of this magnitude. But most of them have not analyzed the system in an integrated way. The first one (IMTA, 2005), assessed the relationship between the dam's size and its maximum water yield. Although this study explored scenarios of future water demand in the donor basin, it did not explore scenarios of the effect of climate change on precipitation, which is officially recognized as likely to decrease in Jalisco (Martínez et al., 2007). Moreover, the study did not consider the effect of increasing groundwater over-exploitation in the basin on the base flow of the river. The study recommended the most optimistic scenario where surface water use in the donor basin would not increase in the future.

Conagua (2006, 2008) subsequently released the Environmental Impact Assessment of the project, which dismissed any potential negative impact on the donor basin, based on the argument that local farmers have caused already most of the environmental degradation. However, the study analyzed the impact of the dam only at the dam site, not the overall regional impact (CACEGIAEJ, 2018). Later, when the dam design was redesigned to 105 m in 2007, IMTA did not release any complementary study to assess the implications of a larger reservoir area, of an additional water user (Guadalajara), nor of a higher water allocation.

In 2014, the Los Altos' Animal Farmers Association commissioned ITESO (the Jesuit University in Guadalajara) to study the possible social effects of the water transfer. The study (Ochoa-García et al., 2014) concluded that according to official data the Los Altos region already had a groundwater deficit of more than 100 hm^3/year and growing, due to the continuing growth of the agricultural output of the region. It also concluded that, since the region's climate is semi-arid, the region was especially vulnerable to droughts, hence the water transfer project would have serious negative socio-economic and environmental effects. However, the study could not make a surface water assessment nor a climate change analysis due to lack of information. Recently, the Observatory made public a haphazard water footprint analysis to assess the water needed for supporting the agricultural activity in the region (Ágora, 2018). It concluded that the water footprint of Los Altos agricultural output was 14,081 hm^3/year, therefore the 12 hm^3/year allocated to animal farming in the allocation agreement of the Verde River of 1997 was insufficient. However, this argumentation is flawed, since they did not consider that the water footprint of a given agricultural product includes the virtual water imported from other regions in the form of fodder. So, the actual water needed by the region is much less than 14,081 hm^3/year.

To counter the study of Ochoa-García et al. (2014), and to prove that there was enough water availability in the basin, CEA-Jalisco conducted a new water availability study (IMTA, 2015). Although this time the study included climate change as a variable in the water resources by using IPCC's regional models based on RCP-4.5 and RCP-8.5 climate scenarios, the study discarded the negative effects of climate change on the water balance due to its high uncertainty: "Climate change results should not be analyzed deterministically, but probabilistically… [we should not lose] perspective that climate change studies are still in an early stage, thus, their results cannot be taken as absolute truths, due to their low probability of occurrence… There is no certainty that projected rainfall and temperatures in climate change models will occur." (Our translation from IMTA, 2015: 212). The study did not consider possible future increases in water demand nor evaluated the dam´s behaviour according to input variables (river run-off) and output variables (water allocation and other losses). As a result, the study could conclude that sufficient water was available in the Verde River Basin to comply with the water allocation agreement and environmental flows for the coming decades. The study was discredited by the leadership of the Observatory, who accused IMTA of allegedly forging data.

What can be concluded from the previous studies is that there were at least four important uncertainties that were still ignored: (1) physical groundwater processes and the interaction between groundwater and surface water in the Verde River Basin, (2) the effect of future water demand in Los Altos' water resources, (3) the effect of climate change, and (4) potential impact on water quality and ecosystem services downstream in the Santiago River. Moreover, the studies did not consider other possible alternatives to the Zapotillo project for water supply to Guadalajara and León.

As previously mentioned, in late 2014, Jalisco's government hired UNOPS to develop a comprehensive water resources model of the Verde River Basin. UNOPS' multidisciplinary team of international experts addressed the four uncertainties in the following way. 1) They analyzed groundwater dynamics by using information from NASA's GRACE earth observation project. 2) For two years, the team collected social and hydrological information in situ from the Verde River Basin to estimate current water demand and project future water demand. 3) They used IPCC's RCP-8.5 regional model of climate change for Los Altos. And 4), they calculated environmental flows downstream of the Zapotillo dam. These analyses were used as input variables for the water resources model of the Verde River Basin using WEAP software, which allowed the simulation of future scenarios (for a more detailed description of the model see supplementary material).

After months of speculation over UNOPS' results, the team released a preliminary study, which found that current water demand was 50% higher compared to official data (UNOPS, 2017c). Months later, they presented the final results in a public meeting (29 June 2017). The UNOPS team developed five main scenarios with different variables (see Figure 3.2). Although UNOPS' team could have developed many other scenarios with different variables, the report of the study justified choosing these five scenarios in the following way "the definition of the number of scenarios is not absolute, but may be subject to future changes at any time that it is required to attend to different questions from those raised in the framework of this study […] Specifically, it is interesting to know under which configuration of the dam´s height and volume of water transfer can guarantee [the satisfaction of] water demand and what percentage of satisfaction corresponds to it, which leads to justifying technically the presence of the dam and its geometric configuration. It is important to be clear that this focus considers only the hydrological aspects related to the satisfaction of demands. Any other conclusion about the configuration of the Zapotillo project needs to be complemented by broader technical analyses […] social and economic evaluations, among others, which fall outside the scope of this study." (UNOPS, 2017b: 27-28). They assessed the performance of each scenario based on reliability (to supply urban water), vulnerability (volume of unmet water demand) and resilience (of the dam to recover its water levels after an empty period) indicators. The UNOPS team concluded that only scenario five scored positively on the three indicators. However, the good performance of scenario five (Figure 3.2) depended on reducing by 13% the volume of water to be transferred to León, Guadalajara, and Los Altos in accordance with the 2007 agreement. The UNOPS team recommended Jalisco's government to proceed with the project with such settings and a dam height of 105 m. Jalisco's governor immediately confirmed this decision during the public presentation of the results: “We are going after the benefit of the majority and what Jalisco needs […] May history single me out for being the harbinger of the services that our people need.”

The consultants immediately left the venue after the presentation, leaving no time to discuss with the attending stakeholders the key assumptions of the model, nor the justification and relevance of the five scenarios. Temacapulín’s representatives reacted negatively, as their community would be flooded, and took over the podium and declared: “[The government] paid 4.6 million dollars for this stupid study, it´s not a real study, it is a study of lies.” (our translation). Later, Temacapulín´s representatives demonstrated in front of Jalisco’s government main building and declared that “We do not accept the UNOPS team’s recommendation because the decision was made beforehand […] [the UNOPS’ team] did not research for alternatives, all the variables referred to the dam.” (our translation).

The local academics criticized the UNOPS team’s study for not considering climate change nor future water demand in scenario five, the limitations of the chosen indicators, and the still incomplete assessment of groundwater given the low reliability of GRACE’s coarse spatial resolution data. Members of the Observatory interpreted these omissions in the study as deliberate: “[T]hey applied a methodology that was biased to get the results that we heard [in the presentation]: a 105 m dam […] It makes me worried that organizations like this [UNOPS] be used to do this kind of research […] We will surely present a formal complaint in the United Nations.” (this is an excerpt from a public interview with the head of the Observatory, Radio UdeG Guadalajara, 2017, our translation).

To explore the possibility of a deliberate omission, Figure 3.6 shows a comparison between scenario 5 and our own scenario, which configures a scenario with the allocation variables of scenario 5 and the climate change and future water demand variables of scenario 4, as described in section 3 and illustrated in Figure 3.2. The results show a poor performance of the Zapotillo dam’s projected storage, and the three indicators chosen by UNOPS (Figure 3.7); whereas scenario 5 shows all three indicators (reliability, vulnerability, and resilience) on target, our scenario results into substantially lower performance, notably on vulnerability and resilience. Therefore, the poor results of these indicators do not seem to justify the implementation of the Zapotillo project as it is currently designed.

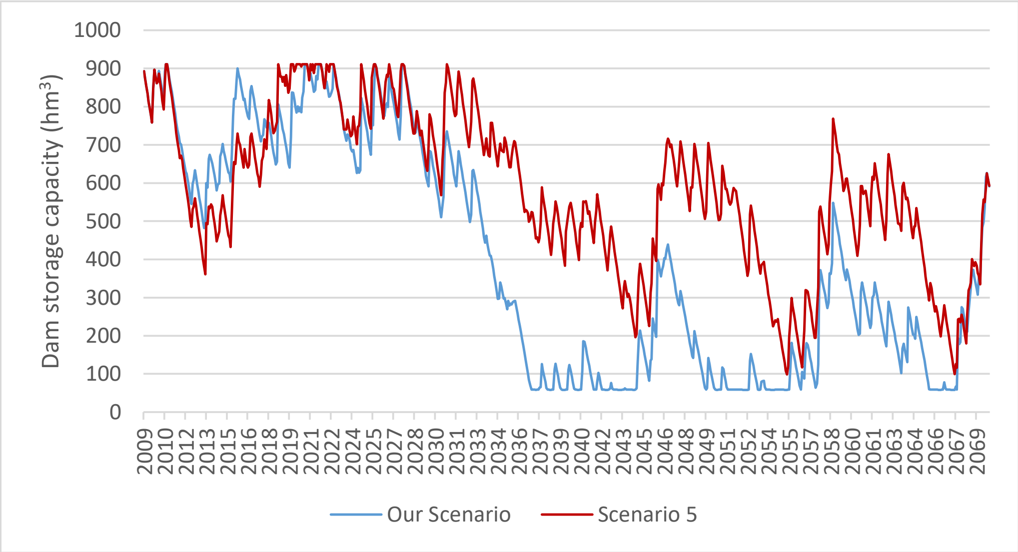


Figure 3.6 Comparison of Zapotillo Dam's behavior in scenario 5 (UNOPS, 2017b) and our scenario, which includes climate change and future water demand.

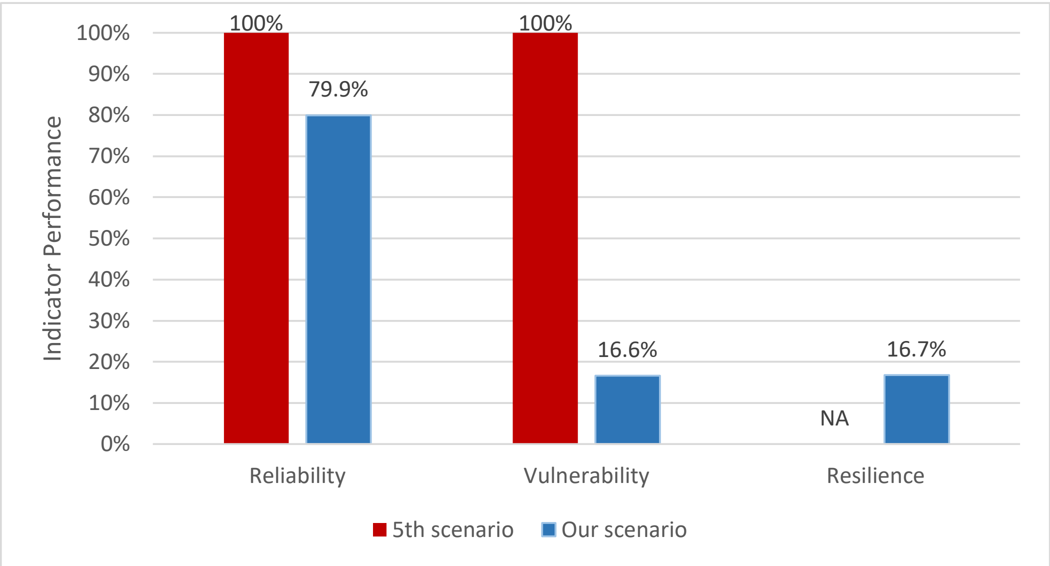


Figure 3.7 Performance of the indicators for the two scenarios.[8]

[8] NA (not applicable): the resilience indicator only applies when the scenario projects the water storage in the dam to reach the minimum level, impeding water supply to its users.

3.5 Discussion

Since large infrastructural projects are still depicted as the main solution to current water problems (Muller et al., 2015; Boelens et al., 2019), it is important to critically assess the uncertainties embedded in the scientific products that support such projects in the face of the social and environmental costs they can cause. In the case of the Zapotillo project, we found that although substantial effort had been made to reduce uncertainties, those efforts were directed towards reducing uncertainties of accuracy and precision, which partially addressed epistemic uncertainties, but not the ambiguity of multiple frames: is supply augmentation the only solution for Guadalajara and León or are there alternative solutions? Should the benefit of the majority trump the rights of a minority? The UNOPS team of experts improved the assessment of four uncertainties: climate change, future water demand, groundwater dynamics and environmental flows in the Verde River Basin. It however did not improve the understanding of the Zapotillo project's adequacy to improve the urban water problems of Guadalajara and León, nor of how and to what extent the Zapotillo project would negatively affect stakeholders in the donor region.

Regarding the efforts to reduce the four uncertainties of accuracy and precision identified in the previous section, the UNOPS study improved the knowledge of the system, but not without caveats. Since the effects of climate change depend on the severity (moderate or extreme) of the chosen IPCC climate scenarios, IMTA and the water authorities seemed doubtful to accept this uncertainty in their decision-making and removed climate change as a factor to consider when developing large hydraulic infrastructure. The water balance assessment by UNOPS (2017c) found that Conagua was underestimating water demand and revealed a serious over-exploitation of surface and groundwater in the Verde River Basin. Given the difficulty to properly estimate current water demand, future water demand became a large uncertainty. The third uncertainty is still largely unresolved: the groundwater situation in the Verde River Basin. Conagua lacks sufficient measuring infrastructure to gauge the state of the aquifers, and there are no long-term series of groundwater levels available. Also, UNOPS's use of earth observation (GRACE) to estimate groundwater added little new information; it may even have been inappropriate, given the very coarse spatial resolution of GRACE, rendering it only suitable for very large aquifers, much larger than the Verde River Basin aquifers (Castellazzi et al., 2018; Vishwakarma et al., 2018). Finally, as all previous studies, UNOPS' study also ignored possible downstream effects of the dam beyond the city of Guadalajara and until the natural outlet of the receiving Santiago Basin in the Pacific.

Since the UNOPS team did not address the epistemic controversies and ambiguity related to the (un)feasibility of the project, the possible alternatives for water supply in the recipient regions, the possible negative effects in the donor basin, and the injustice and unfair treatment of communities in the vicinity of the dam, the results of UNOPS' study remained contentious and mistrusted. Considering the goal of urban water security, UNOPS´ model seemed to answer the wrong research question to address the ambiguity of the conflict: how to optimize the management and operation of the Zapotillo project to guarantee the satisfaction of water demand in Guadalajara and León. Deciding this research question was a political choice that determined the outcome of the research, since it implied that the decision to proceed with the infrastructure is already taken, and that the only valuable decision criteria are those related to optimizing the water supply to Guadalajara and León with that infrastructure, leaving other controversies described in this chapter unaddressed. The reaction of actors to the UNOPS´ study is clear; their impression is that the study and research was restricted only to the dam configuration, which was only one issue, among many, of the problem and the conflict.

The importance of asking the right question is highlighted by DFID (2013) and Feldman and Ingram (2009) who argue that the impact of research and development may decrease when it lacks a deliberative process with stakeholders, including in the definition of what the research questions are. In general, and since the 1990s, research has been consistent in promoting knowledge co-production to solve pressing and disputed environmental problems (i.e., Funtowicz & Ravetz, 1994; Van Cauwenbergh, 2008; Brugnach et al., 2011; Islam & Susskind, 2015; Armitage et al., 2015; Norström et al., 2020). The UNOPS team therefore missed the opportunity for answering a much more relevant question for all actors in the conflict: and based on decision criteria (and indicators) agreed by all stakeholders; how does the Zapotillo project compare to alternative solutions for creating a sustainable and socially just urban water system?

The knowledge generated by the UNOPS team effectively filtered out other feasible solutions to the water problems of the three regions in conflict and did not take into consideration downstream users nor environmental flows for the Santiago River. If the goal is to achieve water security and solve a water conflict, then it was not justified to restrict the research and modelling to supply augmentation scenarios with the Zapotillo project. According to the best social and hydrological knowledge available, it can be inferred from our scenario that there are insufficient surface water resources to satisfy the demand of the three regions' explosive demographic and economic growth, which means that at least one region will continue to unsustainably deplete its groundwater resources. In fact, UNOPS fifth scenario generated positive results only because it considered null demographic and economic growth for the future and did not consider climate change in the Verde River Basin.

The case and the persistence of the conflict blocking the dam project, shows that water authorities have lost their power to impose their decisions and need the support and legitimacy of the incumbent social actors in the donor region. Given the absence of a legitimate authority to enforce decisions, actors from the three regions have entered the knowledge arena to build their cases that support their interests. Norström et al. (2020) proposed that pluralistic, goal-oriented, interactive, and context-based knowledge co-production can improve system understanding and reduce conflicts. The opposite also seems to be true - when actors in conflict produce knowledge only in relation to their interests and in isolation, they reinforce their frame and lose the overall perspective of emerging problems in the coupled water-human system at hand. In those cases, science is not able to depoliticize the conflict, but instead the conflict ends up politicizing the science-policy process. This became evident when most actors in the conflict produced or claimed unverifiable knowledge, which was never put to the test. In contexts of conflict, creating agonistic spaces to test knowledge is an important process to positively challenge knowledge claims and stakeholders´ frames (Krueger et al., 2016). However, there was a lack of systematic analysis, methodological transparency and open discussion from which firm conclusions could be drawn from the side of both the water authorities and opposing actors like the Observatory, academics, communities, and the NGOs. Especially the Observatory produced unverifiable but allegedly scientific knowledge that hardened the multiple frames at play and contributed to an increased ambiguity and partisan science.

Although the conflict is related to the control of surface water resources, groundwater seems to be a defining issue and emerging problem in the conflict. The three regions are competing for limited surface water resources aimed at protecting their available groundwater resources and their current and future demographic and economic growth. However, given the heavy reliance on groundwater for water supply, other threats seem to have been overlooked. Water quality and land subsidence has been almost absent in the debate, even though there is increasing evidence that groundwater quality is rapidly declining and land subsidence is increasing as over-exploitation intensifies (for Guadalajara see Hernández-Antonio et al., 2015; Morán-Ramírez et al., 2016; Mahlknecht et al., 2017; for León see Villalobos-Aragón et al., 2012; Cortés et al., 2015; Hoogesteger & Wester, 2017; and for Los Altos see Hurtado-Jiménez & Gardea-Torresdey, 2005, 2006, 2007).

This case study serves as a cautionary tale for actors in a water conflict, who are embroiled not in solving the problem, but in implementing their own preferred solution. Madani (2010) warned that the behaviour of non-cooperative actors might result in a worse condition for all. Although science has the potential to bridge the positions of actors, it can also be misused by hegemonic actors to support their own solutions. However, as this case exemplifies, that can be counter-productive and backfire instead.

3.6 Conclusions

This chapter sought to scrutinize and unravel the entanglement of politics and science in the production of water knowledge for intractable conflicts, by analyzing the case of the Zapotillo conflict in Mexico. The conflict is defined by epistemic uncertainties, ambiguity, and incompatibility of values. The first two consist of several knowledge controversies regarding water availability and the negative effects of the water transfer and dam construction in the donor basin, and the possible alternatives to supply augmentation strategies in the recipient basins. The latter consists of a dispute over the distribution of the environmental, social, and economic costs and benefits derived of the Zapotillo project.

This study has two main findings. 1) Intractable water conflicts tend to isolate the process of knowledge production, which foregrounds issues that are politically convenient for each actor, while other issues, perhaps more important for sustainability (like groundwater over-exploitation) are concealed and remain unaddressed. And 2), isolated knowledge has less potential for transforming the conflict by missing core epistemic uncertainties and pushing value-laden knowledge claims as facts. After analyzing the model of UNOPS, we found that its research team made a significant contribution to knowledge by reducing uncertainties related to precision and accuracy of future water demand, climate change, groundwater dynamics and ecological flow. But the team failed to address epistemic uncertainty around emerging problems induced by groundwater over-exploitation as well as ambiguity related to the negative effects in the donor basin and more sustainable and socially just alternatives to the Zapotillo project. We found some indications that the UNOPS team indulged into what Boelens et al. (2019) call the manufacture of ignorance, by recommending Jalisco's government to build a 105 m dam without considering climate change, future water demand, nor alternative water supply options. But this result may also be explained by the absence of efforts by the UNOPS team to facilitate the co-production of knowledge. So, even if the UNOPS team did not deliberately indulge in the manufacture of ignorance by building a water resources model based on political interests, its research suffered from tunnel vision by inadequately managing the ambiguity of the conflict. Nevertheless, the mere suspicion of deliberate manufacture of ignorance was enough to discredit UNOPS results by most stakeholders. However, contrary to the conclusion of Boelens et al. (2019), deliberate production of biased knowledge is not exclusive to powerful actors. Instead, this kind of knowledge was produced by most of the actors in the conflict.

Returning to the original question whether science can depoliticize conflicts or whether science is politicized in the process, this case has shown that attempting to depoliticize science-policy processes is very difficult, since these processes are inherently political.

Moreover, involving alleged neutral - or apolitical - third parties to depoliticize scientific knowledge to resolve water conflicts can backfire if they act - or are perceived - as stealth advocates of political interests. However, we identified two elements that can contribute to a possible transformation of the conflict and management of such politicization. First, scientists in contexts of conflict should be aware of not promoting specific solutions since that is the role of the political actors. When scientists assume the role of “honest broker of policy alternatives” (Pielke, 2007), it restrains them from offering a specific course of action and compels them to expand the scope of choice for the actors in the conflict. And second, to promote social mechanisms to filter as much as possible which knowledge claims are more value-laden, and which are less so, particularly in contexts of conflict and high uncertainties. There is an urgent need to design water resources models in a more open way to allow the participation of stakeholders and legitimize the data used in them (Islam & Susskind, 2018) as well as the values hidden in them; this can support the necessary task of reviewing alternatives to large infrastructures (Van der Zaag & Gupta, 2008). Additionally, fostering stakeholder participation could collaboratively bring about socially relevant research questions that open the decision space (Voinov & Gaddis, 2008; Zimmerer, 2008; Budds, 2009; Lejano & Ingram, 2009; Brugnach et al., 2011; Blöschl et al., 2013; Armitage et al., 2015; Basco-Carrera et al., 2017; Van Cauwenbergh et al., 2018; van der Molen, 2018; Norstöm et al., 2020). Brugnach et al. (2011) support this as one of the main strategies to handle ambiguity, albeit with the drawback of necessary high social skills to bring people together, which, in a context of conflict, is difficult to achieve. However, despite this difficulty, attempting such an effort could already improve the capacity to innovate by incorporating new perspectives, as suggested by Brugnach et al. (2008), and by identifying arbitrary decisions in public policies by hegemonic actors. Such transparency could decrease the capacity of powerful actors to capture the science-policy process. However, further research is needed to evaluate if co-production of knowledge can bring about cooperation and consensus between the stakeholders and limit the influence of politics and vested interests in decision-making in water conflicts.

4

THE LIMITS TO LARGE-SCALE SUPPLY AUGMENTATION: EXPLORING THE DISRUPTIVE ROLE OF WATER CONFLICTS AT THE CROSSROADS OF URBAN WATER SYSTEM DEVELOPMENT PATHWAYS[9]

"In my short experience of human life, the outward obstacles, if there were any such, have not been living men, but the institutions of the dead. It is grateful to make one's way through this latest generation as through dewy grass. Men are as innocent as the morning to the unsuspicious… I love man-kind, but I hate the institutions of the dead un-kind. Men execute nothing so faithfully as the wills of the dead, to the last codicil and letter. They rule this world, and the living are but their executors […] Even virtue is no longer such if it be stagnant. A man's life should be constantly as fresh as this river. It should be the same channel, but a new water every instant."

—Henry David Thoreau, *A Week on the Concord and Merrimack Rivers*

[9] Based on: Godinez Madrigal, J., Van Cauwenbergh, N., Hoogesteger, J., Claure Gutierrez, P., and van der Zaag, P.: The limits to large-scale supply augmentation: exploring the crossroads of conflicting urban water system development pathways, Hydrol. Earth Syst. Sci., 26, 885–902, https://doi.org/10.5194/hess-26-885-2022, 2022.

Summary of the chapter.

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 chapter 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.

4.1 Introduction

Urban water systems, 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, 2008a; 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). However, affected communities have constituted grassroots movements and a strong opposition against the implementation of these projects. In some cases, these movements have been effective in delaying or even cancelling these projects (Ahlers et al., 2017; Chapter 3 of this thesis).

Hundreds of water conflicts have emerged in the past decades, many of which are related to the implementation of large water infrastructure development (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 characterized by competing approaches either based on business-as-usual pathways like large-scale infrastructure or transitioning to alternative pathways (Chapter 3 of this thesis). This has generated an impasse, whereby large infrastructure projects 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 water 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.

To understand the 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 and analyse the concept of development pathway crossroads, 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 infrastructure project has caused a 15 years-old intractable water conflict between the cities and three villages within the projected reservoir's site who have fought not to be relocated. The villagers formed a grassroots movement that has been successful in stalling the implementation of the infrastructure project and lobbying for the implementation of alternatives strategies in the two recipient urban water systems. In this paper, we aim to 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 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.

This chapter is organized as follows. First, we discuss the relevant literature to develop our concept of development pathway crossroads in urban water systems. Second, we describe the methodology, which involved ethnographic techniques and conducting participatory modelling. Then, we present the results, and finally discuss the relevance of the case to the understanding of development pathway crossroads.

4.2 DEVELOPMENT PATHWAY CROSSROADS IN URBAN WATER SYSTEMS

With habitual news headlines of cities reaching tipping points and 'day zero´s' in urban water systems (Maxmen, 2018), academic articles and reports calculating future billions of people without access to water (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; Chapter 3 of this thesis). 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).

With a systems approach, Kallis (2010) conceptualised this phenomenon as the supply-demand cycle, which describes locked-in urban systems engaged in a constant dynamic of supply augmentation strategies followed by an increased water demand in different economic sectors that overshoots again water availability. Moreover, Di Baldassarre et al. (2018) further developed this concept by describing the reservoir effect, in which urban water systems become more vulnerable by increasing their dependence on external water sources that can be affected by future droughts.

This systems 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 (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.

Meanwhile, 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, 2008a; Molle et al., 2009, Budds 2008; Flyvbjerg et al., 2003, Flyvberg 2009; 2014; Hommes et al 2016; 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 important gap that needs to be addressed, because, as discussed by Castree et al. (2014), Zeitoun et al. (2019) and Rusca & Di Baldassarre (2019), scientists have a moral obligation to change (not only to interpret) the world. Moreover, Lave et al. (2014) consider 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.

4.3 METHODOLOGY

Considering the two research questions driving this chapter 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 study. First, we employed socio-hydrological and political ecology perspectives to analyse the long-term interplay of qualitative and quantitative factors that steer the co-evolution of the urban water systems of León and Guadalajara. We took inspiration from similar works that accounted for the political and socio-technical history behind these developments, such as Kallis (2008) on the co-evolution of water resources development in Athens, Molle & Wester (2009) on the longitudinal in-depth historic analysis of specific basins known as River Basin Trajectories, Hommes & Boelens (2017) on the role of imaginaries of modernity and progress in 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 29 semi-structured interviews with key stakeholders and decision makers of León and Guadalajara between 2017 and 2020. During that time, we also conducted participant observation in meetings, forums, and other workshops to which the first author was invited until the end of 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.

Second, as a method to showcase marginalized alternative narratives and their 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 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 in favour of the of the supply augmentation project of El Zapotillo — Conagua (National 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), and academics of local universities.

Supplementary material of this chapter describes in detail the variables and development of the model (Annex B), which we dubbed SimVerde (Craven, 2018, Godinez Madrigal et al., 2018b).

4.4 RESULTS

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

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. 4.1). This constitutes a water challenge (or a dilemma) since this level of growth and groundwater over-exploitation seems untenable in the long term.

The history of León's water utility 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 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.

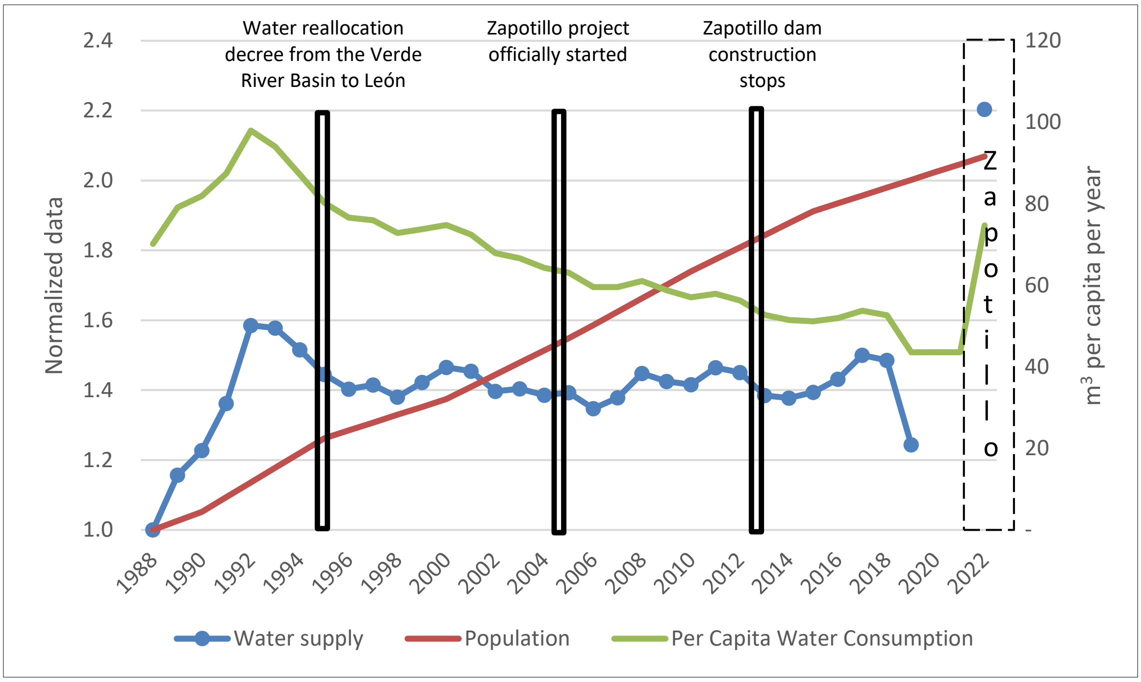


Figure 4.1 The reservoir effect in León (the dashed rectangle denotes the projected new water demand of a large new supply-augmentation scheme). Sources of data: INEGI, 1990, 1995, 2000, 2005, 2010; 2015; CONAPO, 2015; CEA-Guanajuato & Conagua 2018; SAPAL, 2020.

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 (Chapter 2 of this thesis). 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 beyond cost recovery (Tagle-Zamora & Caldera-Ortega, 2021). Two, since the 1990s, lobbying for a large water transfer (Chapter 3 of this thesis). These two strategies 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 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 public perception of the utility´s price hikes was that the utility operated as a business instead of a 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'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).

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). 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). In response to the growing water demand of the rapidly growing city, SAPAL 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, 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 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 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. 4.1's dashed 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). 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 (see section 4.2).

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).

Guadalajara

At the moment of writing this chapter (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: 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).

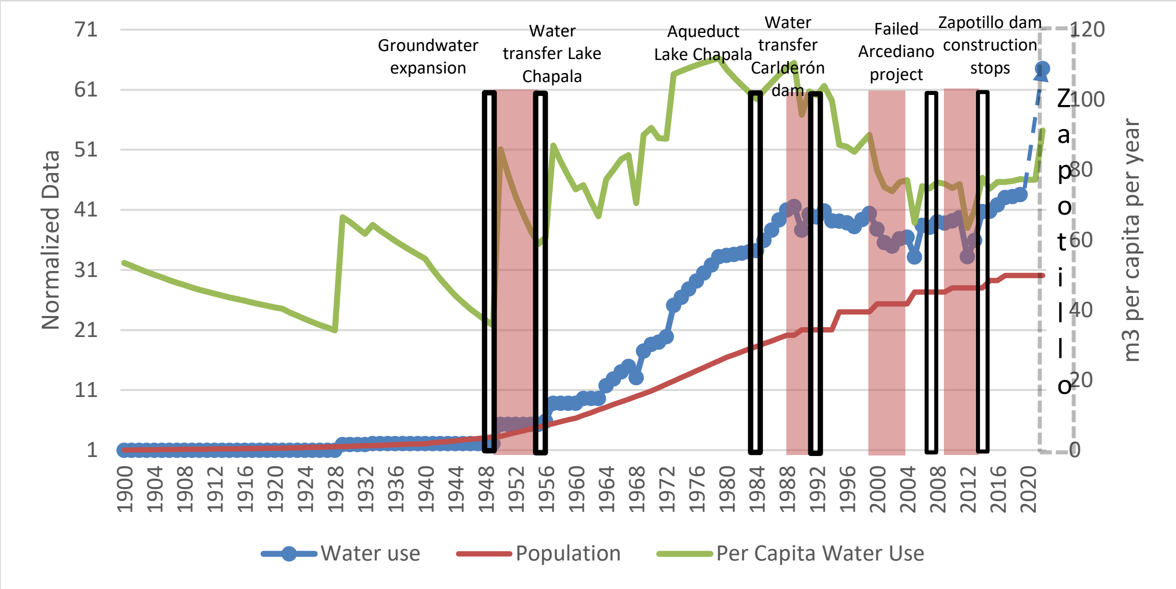


Figure 4.2 The reservoir effect in Guadalajara (the blue bars denote the implementation of a large supply augmentation schemes in 1947, 1956, and 1991; red bars the presence of droughts; and the dashed rectangle the official projected new water demand for the proposed large supply-augmentation scheme). 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.

Historically, Guadalajara has benefited from three large supply augmentation projects in the past (Fig. 4.2). The first was based on groundwater supply augmentation in the late 1940s that has continuously expanded until today. However, the accelerated population growth (higher than 6 % per year) typical of Latin-American cities of the time (Camisa, 1972), and a severe drought created an image of acute water scarcity. This generated a pressure to increase water supply sources. Therefore, in 1956 when the drought ended, Guadalajara's government decided to build the Atequiza sluice to make use of the largest natural lake in Mexico, Lake Chapala. The city also built a large drinking-water plant with an installed capacity of 9 m^3/s (more than twofold of what was needed) to increase water supply from the lake on demand. The governor of Jalisco considered this project "monumental" and a permanent solution to water scarcity for Guadalajara (Pérez-Peña & Torres González, 2001b). 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; Chapter 3 of this thesis).

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 (Sistema Intermunicipal de Agua Potable y Alcantarillado) in 1978, an intermunicipal water utility 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, 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 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 to meet an estimated future water demand of Guadalajara of 24 m^3/s by the year 2000, more than double of the city’s actual water use in 2021 (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 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). 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 domestic water 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).

Currently, the entrenched faith on large supply augmentation infrastructure continues while pressing issues of highly unequal access to water of poor quality, over-exploited groundwater and unabated urban growth are neglected, as are the high levels of unaccounted-for-water of the water utility. This omission could rapidly offset the benefits of a large supply augmentation project, because should the Zapotillo project be implemented, the state water authority expects water demand to grow to a level that would equalise the new water supply (represented by the dashed rectangle in Fig. 4.2; CEA-Jalisco & Gobierno del Estado de Jalisco, 2018).

4.4.2 Opening up the decision space

The previous subsection shows that the growth of both cities has 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. However, both cities experience water problems beyond a gap between supply and demand that a large new supply augmentation 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.

The 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 (Chapter 3 of this thesis). The main alternatives that have been debated in the 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. However, local and state governments and water engineers 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): "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 of a public talk of the Head of the civil engineer college of Jalisco, 22 Nov 2018). Even when the 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" (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).

However, 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 chapter collected the dispersed alternative solutions into an integrated water resources model (see Appendix B).

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 (Chapter 3 of this thesis). We compiled the most important alternative solutions and built them in 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."

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][10] 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 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

[10] See Chapter 3 for an in-depth description of the government´s model referred in the quote.

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, 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).

In this context, the public attention and federal public policies have shifted from the Zapotillo project as the only option, to the potential of alternative water solutions for Guadalajara and León. Currently (November 2021), the federal government has agreed to decrease the operation scale of the Zapotillo dam from 105 m to a maximum dam height of 50 m (which implies that the water supply from the dam to Guadalajara will reduce to 3 m3/s, and that the water transfer to León is cancelled)" (Conagua, 2021) in order to spare the dam-affected communities. Guadalajara and León 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 chapter.

4.5 Discussion

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 predicament of León and Guadalajara. Moreover, our political ecology analysis of the co-evolution of Guadalajara´s and León´s human-water systems shows that although water managers have warranted the 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.

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 would 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 2010, Di Baldassarre et al., 2018).

Analysing the case of Guadalajara through the lens of socio-hydrology we found that the city´s current water shortage and its concomitant socio-economic damage (as of June 2021) is the result of the increased water demand fostered by its intra-basin water transfers (Calderón dam and Lake Chapala), 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 peddled the Zapotillo project as the only solution to bring about water security for Guadalajara, despite that the supply augmentation will most likely attend new water demand. Thus, this project would further continue the supply-demand cycle and thus increase the vulnerability of Guadalajara in the future.

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 likely unintended negative consequences of such an infrastructure project, such as 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 personified by the *"oposi-todos"*. 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' planning actively excludes political processes such as deliberation and negotiation precisely to avoid further questioning and preclude the emergence of alternatives.

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 (Chapter 3 of this thesis), 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, alternative water supply strategies could 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 4.3. 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. 4.3) and/or decentralized small-scale supply augmentation strategies (positive feedback for water demand in Fig. 4.3) that could thwart the supply-demand cycle.

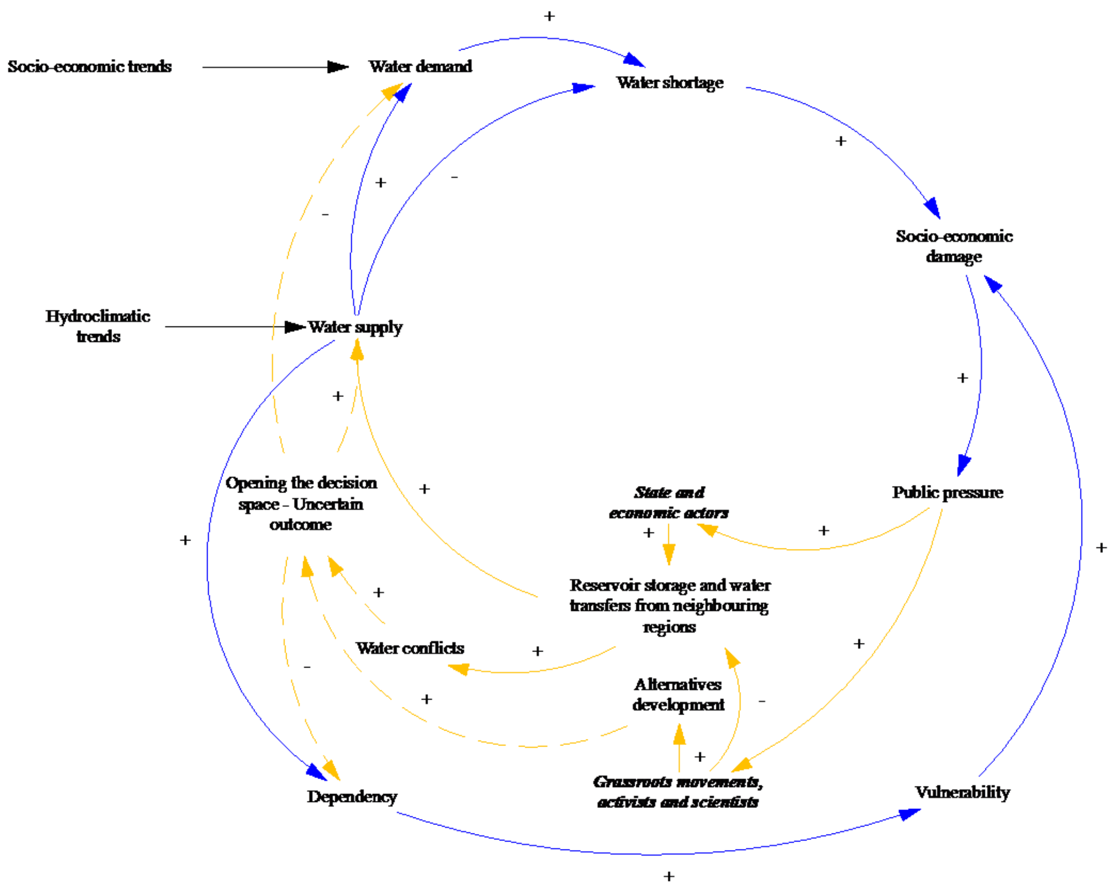


Figure 4.3 The water conflict disruption in the reservoir effect (the dashed lines indicate their hypothetical status, while the yellow lines indicate new variables not yet considered by the original conceptualization by Di Baldassarre et al. (2018).

4.6 Conclusion

This chapter conceptualized and investigated the current development pathway crossroads of the cities of León and Guadalajara to understand the role 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 exploring the socio-political dynamics of alternative future pathways proposed by actors in conflict.

The dominant development pathway in León and Guadalajara has been characterized by a techno-managerial 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 a grassroots movement opposing this 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 will embark on.

With a transformative spirit infused by the work of Leach et al. (2010) Di Baldassarre et al. (2019), Zeitoun et al. (2019), and Rusca & Di Baldassarre (2019) we aimed at analysing the development pathways of urban water systems with a transdisciplinary political ecology and socio-hydrology approach and explore the role of conflicts and grassroots movements in forcibly creating a 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 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 gap of water supply and water demand over time, but also to an unchecked and even sponsored economic and population growth, uneven water access, aging distribution infrastructure and neglected rural-urban dynamics related to groundwater overexploitation. This is relevant because a large water supply augmentation project will not solve the issues. With our participatory modelling workshop, we contributed to opening up the decision space by modelling most of the alternative solutions brought up by the grassroots movement.

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.

5

WATER CONFLICTS AS DRIVERS OF SOCIO-TECHNICAL TRANSITIONS IN WATER MANAGEMENT SYSTEMS

"The new always happens against the overwhelming odds of statistical laws and their probability, which for all practical, everyday purposes amounts to certainty; the new therefore always appears in the guise of a miracle."

—Hanna Arendt, *Human condition*

Summary of the chapter.

Many water conflicts are deeply interrelated to water crises caused by deficiencies of the socio-technical water management and governance systems. Therefore, conflicts can have an impact in transforming water systems. However, opposing approaches rarely engage with the socio-technical transformation of water systems and understand conflicts as events that need to be prevented, or as resistance movements opposing power asymmetries and unjust institutional and distributional arrangements. Therefore, we ask whether water conflicts driven by grassroots movements can influence a socio-technical transition of a water management system and if so, how? We selected an emblematic 16-year-old water conflict in Mexico: the Zapotillo conflict. We analyzed the trajectory of key actors´ agencies since the conflict´s inception, and the dynamic process of developing capitals, and the actors´ motivations. We conclude that the conflict altered the predominant water management system in Mexico based on large-scale infrastructure not only by putting on hold the implementation of a crucial large infrastructure project, but by garnering enough capitals to propose a competing water management system based on alternatives that are considered more sustainable and equitable.

5.1 INTRODUCTION

Several multi-faceted water-related crises are imminent in many parts of the world as water demand keeps growing beyond the sustainable limits (Srinivasan et al., 2012; Famiglietti, 2014; McDonald et al., 2014; Mekonnen & Hoekstra, 2016; Veldkamp et al., 2017; Flörke et al., 2018). Meanwhile, societies are responding or adapting in multiple ways to address challenges of water quality, quantity, and ecosystem conservation (Farinosi et al., 2018; Abel et al., 2019; Andrijevic et al., 2020). Different degrees of conflict and cooperation are seen in the face of water crises. In this context, studying water conflicts seems to be more relevant than ever, but they are currently underresearched (Di Baldassarre et al., 2019). However, the field is not monolithic and the studies on water conflicts have diverged; for analytical purposes, here we present two main different bodies of research.

The first body of research assumes water conflicts to be the negative consequence of water and governance crises, and currently their research frontier is on the effect of climate change on water conflicts (Mach et al. 2019; 2020). This body of research analyses water conflicts with data-driven methodologies of political and natural systems, and, as a result, their aim is to identify root causes to prevent conflicts from happening. This approach conceives feeble governance institutions as vulnerable to water crises. In that sense, conflicts are the reflection of governance failures, which mainly did not follow recipe-like best practices (i.e., Gleick, 2014, Mach et al., 2019). Allan (1999) considers that such best practices can be politically unfeasible at best; but also, they could be part of the problem by masking poor implementation and structural shortcomings with inequitable results (Chapter 2 of this thesis).

The second body originates from political ecology where water conflicts are viewed as the result of asymmetrical power relations, injustice, and water-based activism (Rodriguez-Labajos & Martínez-Alier, 2015). Since this school usually relies on qualitative methods and the analysis of power relations, their main objective is to show how water conflicts make visible the social and environmental externalities of current water management systems. This approach can fill the blind spot of the first one by avoiding any set of prescriptions to reform water governance systems. Water runs towards power and money; everything is power, they conclude (i.e., Zwarteveen & Boelens, 2014, Vos et al., 2020). However, if everything is related to power, then the role of science and technical knowledge could easily be dismissed (Chapter 2 of this thesis).

Although the understanding of water conflicts could benefit from the cross-fertilization of these approaches, the fundamental differences between these two bodies of research constitute a rift to the point that they tend to ignore each other in their publications (Le Billon & Duffy, 2018). Either water conflicts are understood as negative events derived from water crises that need to be prevented through top-down policies – that is, international best practices to change local dynamics and contexts -, or they are understood as bottom-up movements that defend territories from power asymmetries expressed in unjust policies or projects – that is, local communities resisting change. We challenge these understandings and argue that water conflicts co-evolve over time with water crises, and some conflicts driven by grassroots movements can invert their usual roles of resisting top-down policies and projects to instead promote a transition in socio-technical water systems through situated, bottom-up and context-specific alternative policies and projects.

In this chapter, we aim to address the knowledge gap between water conflicts and socio-technical transitions by focusing on the dynamic agency of grassroots movements analysed through social interfaces of the different actors involved in the conflict. We framed this analysis in the Transition Management approach, understood as "a process-oriented management philosophy, [to exert] societal transformation processes that occur in at least one generation (i.e., 25 years)" (Rotmans et al., 2000). We ask whether water conflicts driven by grassroots movements influence a socio-technical transition of a water management system? If so, how? To answer this question, we analyse the Zapotillo conflict in Mexico. This is a 15-year-old conflict triggered by the implementation of a large infrastructure project that aims at transferring water to two of the most important cities in western Mexico and is considered the most prominent intractable water conflict in Mexico (Ochoa-García & Rist, 2015). Currently, the conflict has evolved to a point where the main actors in dispute have enrolled diverse actors from academia, politics, and legal experts to support their claim (Chapter 3 of this thesis), resulting in the delegitimization of not only the infrastructure project, but the governance and management systems as well.

The conflict has been explained through a data-driven approach, by analyzing hydro-climatic trends and social dynamics that caused a water crisis in the region since early 2000s (CEA-Jalisco, 2015; Conagua 2015, Consejo Tarifario SIAPA, 2016), as well as by the political ecology approach, by analyzing the undemocratic imposition of infrastructure (Ochoa-Garcia & Rist. 2015; McCuligh & Tetreault, 2017). However, since the conflict seems to be in a state of impasse in terms of resolution and its understanding, we propose a third analytical approach, inspired by the theory of Transition Management (TM) developed by Rotmans et al. (2000). Our approach can contribute to understanding the underresearched role of water conflicts and grassroots movements in transitions of water systems. We focused our analysis on the confluence of political and socio-technical processes where grassroots actors adapt, learn, and consolidate different kind of capitals (Ribot & Peluso (2001) identified at least legitimacy, technical, network, funds, and infrastructure or legal) and respond to challenging situations to catalyse change in the status quo of the water management system represented by the socio-technical system in place.

In this chapter, we develop the argument in the following way. First, we analyse literature on the two main bodies of research on water conflicts and of socio-technical transitions. Second, we describe the conflict in detail, as well as the methodology we used. Third, we present our results by applying the TM approach to the Zapotillo conflict in Mexico. Finally, we discuss the results and present our conclusions.

5.2 Conflicts and socio-technical transitions

As mentioned above, one approach to water conflicts is data-driven and connects the notion of an increasingly variable climate as the main driver of socio-environmental conflicts (Farinosi et al., 2018; Mach et al., 2019; 2020). The data-driven approach can include mathematical models using machine learning to anticipate future conflict hotspots (Cederman & Weidman, 2017; Kuzma et al., 2020). The ethos is to monitor different indicators and intervene when those are out of range to prevent conflicts and the many socio-economic negative effects they convey. The basic concepts that instrumentalize the analysis are coordinates of intensities of conflict and cooperation and the scale of research varies from domestic to international levels (i.e., Wolf et al., 1999; Mirumachi & Allan, 2007; Mirumachi, 2015).

This approach conspicuously showcased the Syrian conflict as an example of how social conflicts can be triggered by disruptions in hydro-climatic trends due to climate change (Gleick, 2014; 2019). Some authors embracing this approach recommend recipe-like conclusions like modernizing agriculture to improve water efficiency and negotiate better water allocation agreements among nations. Such recommendations had been a source of controversy when climate stressors correlated at best with conflicts, while it remains uncertain whether these are causally related (Selby et al., 2017a; 2017b). Critics of this approach argue that an excessive focus on an out-of-control climate as the main cause of violent conflicts promotes mundane actions (such as unfeasible best practices), and sometimes even promote the military securitization of water resources (Warner & Boas, 2019).

Alternatively, when water conflicts are analysed through the lens of political ecology, they are usually anchored in a Marxist perspective (Tetreault, 2017), whereby conflicts represent a further manifestation of the dispossessed against various forms of capitalism (Martinez-Alier, 2003). Exponents of political ecology like Mehta (2013) denaturalized the conceptualization of water scarcity, stripped it of the notion that it is the effect of purely natural forces and builds on the notion that water crises are mainly influenced by power relations, inequality and injustice. This approach conceives power as the main (often the only) explanatory concept to understand water systems.

Under this approach, grassroots movements are often the main actors in conflicts. Martínez-Alier (2003, 2020) uses the term “environmentalism of the poor” when marginalized communities dispute the imposition of projects detrimental to sustainable ecological systems. Therefore, these movements transcend the role of NIMBY (Not in my Backyard) often attributed to them (Rodriguez-Labajos & Martinez-Alier, 2015) to become forces for sustainability (Temper et al., 2018). Some movements even developing bottom-up IWRM and water justice institutions as a result of conflicts, as argued under the constitutionality approach by Ochoa & Rist (2018). Recently, Vos et al. (2020) further developed this perspective through what they dub as Rooted Water Collectives, conceived as defenders and promoters of just water management systems.

However, even when grassroots movements succeed in their demands and promote innovative governance processes, this does not necessarily mean that the water problems that originated them are solved. For example, Cochabamba is one of the most emblematic cases of water conflicts in the world, where the privatization of water utility failed to solve its many management problems; however, the subsequent return of the water utility to the public domain did not fix issues of corruption and inefficiency either (Shultz, 2008). Almost two decades after the conflict, close to half of the residents of Cochabamba still lack access to water and sanitation services (Razavi, 2019); while the system has a rate of non-revenue water of around 50% (AAPS, 2017). Luis Suarez, one of the leaders of the Cochabamba revolt concluded that the only way to fix Cochabamba´s urban water system would be to combine social pressure with expert regulation: “We need intervention from above and from below” (Shultz, 2008: 39).

Therefore, as much as political ecology approaches explain socio-political change in their case studies, they mostly do not engage with technical aspects nor with the drivers of change for socio-technical systems. Wesselink et al. (2016) perceptively observed that “[t]he prioritization of theory and the weak treatment of physical elements are at the detriment of a potential focus on supporting transformations by water users, water managers and water regulators.”

Based on the previous review, we consider that the research on water conflicts could be enriched by using approaches that explicitly address transitions and transformations exerted by water conflicts that go beyond the governance system or institutional channels alone. Therefore, we mobilize the TM approach to track the dynamic change exerted by grassroots movements not only through institutional innovation, but including also long-term structural changes in dominant technologies, routines, and cultures (Loorbach et al., 2017). Since TM understands transitions as multi-staged processes involving multiple levels, conflict and cooperation are re-interpreted as complex political dynamics that are subject to different capitals mobilized by grassroots actors.

The multi-staged concept analyses transitions in four stages: 1) pre-development: when the dominant regime is increasingly questioned but new ideas are insufficiently developed; 2) take-off: when the dominant regime is reaching a critical point and competing ideas challenge it; 3) acceleration: when the new idea is displacing the dominant paradigm; and 4) stabilization: when the challenging idea becomes the new paradigm (Loorbach et al. 2017). The multi-level perspective considers a landscape level (where major socio-political dynamics take place), regime (the dominant actors, institutions, and structures in the social system) and niche (localized places where new ideas are being developed). As a synthesis, two preconditions need to take place for transitions to happen: the dominant regime needs to destabilize, and new ideas need to challenge the dominant regime (Loorbach et al. 2017).

Until now, most transition management studies have focused on wealthy countries investigating transitions that have been implemented by the government and a network of actors related to the government. Fewer studies have focused on middle- and low-income countries, and less, if any, on transitions driven by grassroots movements (Frantzeskaki et al., 2018). Moreover, the theory has been criticized for not incorporating human agency in its analysis (Rauschmayer et al., 2015). Therefore, there is a need to study such transitions in the Global South (Roy & Ong, 2011; Furlong & Kooy, 2017), and focus the analysis on the arsenal of strategies and mechanisms to exert change, among which are developing capitals, developing new alternative ideas, build coalitions and sell those ideas, recognize and exploit windows of opportunity, utilize the multiple venues of modern society, and build-up and manage networks (Ribot & Peluso, 2003; Huitema & Meijerink 2010). Based on Godinez Madrigal et al. (chapter 3 and 4, this thesis) we add the strategic questioning of sanctioned discourses through democratization of knowledge products and ambiguity management as a key mechanism to exert change. This chapter then aims to understand how water conflicts and grassroots movements create the conditions for socio-technical transitions in the water sector.

5.3 METHODOLOGY

We based our methodology on the extensive work by Loorbach et al. (2017) on Transition Management. First, we divided the evolving socio-technical transition in stages, each one characterized by the evolving actors´ motivations, strategies, and capitals at play in social interfaces. For Loorbach et al. (2017) the pre-development stage happens when "small networks of actors support novelties on the basis of expectations and visions". In contexts of conflict, we looked for the integration of actors into rooted social movements at a local scale. The following stage is 'take-off', which "is reached when certain innovations at the micro level […] are reinforced by changes at the macro-level" (Van der Brugge & Rotmans, 2007). In contexts of conflicts, we looked for moments or events in which the grassroots movement experiences success in some dimensions and scales its efforts to a broader arena. Then follows the acceleration stage, characterized by the regime enabling the transition, "through the application of large amounts of capital, technology and knowledge" (Van der Brugge et al., 2005), and the actors become aligned and stable, and an "internal momentum increases" (Loorbach, et al., 2017). By adapting this stage to conflicts, we looked for the symbiosis of the social movements developing alternatives, and dominant actors supporting them (i.e., the State).

However, the TM approach can be limiting in its analysis since the role of individuals and agency is still missing from the transition management theory (Rauschmayer et al., 2015), and has hardly been tested in middle- and low-income countries (Frantzeskaki et al., 2018). Therefore, we filled these gaps by mobilizing the theoretical and methodological work of Long´s actor-oriented research (2003) and Ribot & Peluso (2001) theory of access. We utilized ethnographic methods such as social situational and network analysis suggested by Long (2003) to study the agency of local actors enacted in social interfaces with external actors. The interface is understood as "a critical point of intersection between different lifeworlds, social fields or levels of social organization, where social discontinuities based upon discrepancies in values, interests, knowledges and power, are most likely to be located." (Long, 2003; pp. 243). This perspective highlights the continuous and evolving process of negotiation that determines the "often large gap between the rhetoric of national planning and policy and what happens on the ground." (Long 1984: 179).

As a result of this iterative social interface, actors change and develop strategies to advance their interests more effectively at every iteration. Ribot and Peluso (2003) outlined at least five strategies: social (legitimacy), knowledge (technical), relational (network), economic (funds and infrastructure), and based on authority, customs, or law (legal). These strategies provide the accumulation or depletion of what can be considered capitals, understood as (im)material assets put to (re)productive use (Bourdieu, 1986), in the sense that actors can mobilize them to leverage their position and interests in the conflict. We understand that when actors pursue a social strategy, they acquire legitimacy capital; with a knowledge strategy, they acquire technical capital; with a law strategy, acquire legal capital; and with network & economic strategies, pivotal to accumulating other capitals through relationships, acquire relational capital, and through funds, economic capital.

Then, we analysed agency expressed in actors pursuing their interests through strategies and capital accumulation in the context of a dominant socio-technical system, we focused on key actors driving an evolving socio-technical transition by tracking their strategies and dynamics of their capitals over the 16-year period of the Zapotillo conflict. Since 2008, two of the authors conducted participatory observations during events, demonstrations, and workshops of key actors of the social movement, specifically the dam-affected communities of Temacapulín, Acasico and Palmarejo. The first author conducted 31 in-depth semi-structured interviews with key actors in the conflict between 2017 and 2021, thus broadening the scope of the actors to also include those who support the Zapotillo project. Additionally, between 2017 and 2019 we organized several stakeholder workshops in Temacapulín. Later in 2021, the authors participated as technical advisors of the communities in the negotiation process with Conagua over the Zapotillo project and the future of the communities.

Since the conflict is yet to be resolved, we cannot define if the last stage in TM theory, i.e., stabilization of the system transition, will eventually happen. However, with our methodology we will check whether water conflicts rooted in social movements have the potential to trigger a socio-technical transition of water systems management.

5.4 SOCIO-TECHNICAL TRANSITIONS AND WATER CONFLICTS

This section describes the Zapotillo conflict in terms of first three stages of the Transition Management theory: inception, take off and acceleration.

5.4.1 The inception of the conflict (2007-2012): Socio-legal strategies

When the inhabitants of Temacapulín came to know about the Zapotillo project in 2005, they turned to the local priest for guidance and advice. At the time, the dam-affected communities did not immediately reject the project, because Conagua, the national water authority, mobilized its technical and legal capitals by promising that the "technical competence was so advanced that it is possible to develop large infrastructure in favour of the people without affecting them" (Espinoza-Íñiguez, 2010). However, without an effective public consultation Conagua increased the dam´s initial design height from 80 m to 105 m. At that point, the community publicly manifested their opposition to the project since it was obvious that the villages of Temacapulín, Acasico and Palmarejo would be flooded, and their inhabitants needed to be resettled.

The resistance had a clear motivation: the three communities needed to be spared and the dam relocated to somewhere else, as the priest explained: "when [the then head of Jalisco's water authority] came to Temacapulín, his position was that Temacapulín needs to get out [resettle]. And I remember my response was… I think it's even recorded… bring water to León from Tabasco or Chiapas [tropical regions in Mexico characterized by vast water resources but located more than 1,000 km away], build an aqueduct. I mean… I used to have a bit of a backwards mentality back then […]." (Interview 15/12/2018). This indicates an initial NIMBY type of perception of the grassroots movement.

During this time the government of Jalisco´s main objective was to mobilize its resources to offer a new housing development dubbed Talicoyunque as a compensation for expropriating the communities´ homesteads. This strategy worked at the beginning, as some of the inhabitants accepted this early transaction. However, soon the government was incapable to fulfil its promises of material compensations and many inhabitants, disappointed by the unfulfilled promises, joined the ranks of the activist group against the project. An engineering lobbyist in favour of the project who asked to be anonymized described that: "The government never fulfilled its promises to compensate [the communities], and everybody accepted, practically everybody [members of the community accepting the compensation in exchange for selling their land and houses]. Then, when things heated up because the state did not keep its promises [of properly compensating all the dam-affected persons], many organizations entered [to the communities] to change their minds [and reject the government´s compensation plan], especially ITESO [the Jesuit University in Jalisco]. […] The State has not kept its promises, it is a very serious thing that I am saying, but that is the reality." (Interview 14/04/2017).

Along the years, members of the communities have felt harassed by some of the government´s tactics to convince them to sell their houses, and their public portrayal as being responsible for stopping progress and be condemned to poverty (Espinoza-Íñiguez, 2010). Because of that, the priest, and other members of the community of Temacapulín sought legal advice to advance a human rights legal strategy and strive for internal social cohesion (socio-legal strategy to accumulate legitimacy and legal capital to foster access to justice, see Figure 5.1). COA Collective, a leftist *pro bono* organization provided free legal advice to the members of the communities and farmers to stand a fight against the project; IMDEC, the first NGO of Jalisco (1963), and the Fundación Lerma-Chapala-Santiago (FLCHS) provided organizational experience to support and bring about stability to the grassroots movement.

COA Collective and representatives of the communities elaborated a legal strategy nested in the human rights framework, and a discursive strategy aimed at mobilizing legitimacy capital by highlighting Temacapulín´s cultural heritage through running competitions and festivities. First, in 2009 they presented their case to the Interamerican Commission of Human Rights in Washington D.C. Later, they took advantage by the constitutional reform of 2011, which elevated numerous international human rights treaties previously signed by Mexico to the highest rule of law. Referring to this reform, the lawyer of the communities said that "Not only verdicts were globalized, but also our rights […] a [social] fight that is not accompanied by a claim of rights is easily disarticulated and delegitimized." (Interview 10/05/2017).

In 2010, members of the communities sought to expand their *relational capital* by hosting the 3rd annual meeting of the Mexican organisation of dam-affected communities

(MAPDER) attended by hundreds of representatives throughout the country. Moreover, they found international support from Temacapulín's migrant network of *"Los hijos ausentes"* in the United States, who contributed financially and with media exposure.

These network and social strategies yielded benefits which marked a growing sympathy among the public in Jalisco for the inhabitants of Temacapulín and their cause, as analysed by Pacheco-Vega & Hernández-Alba (2014). The legal strategy also yielded benefits when in 2011 a federal judge resolved to suspend the dam construction works (Verduzco-Espinoza, 2019). However, the head of Jalisco's water authority did not comply with the suspension by exploiting legal loopholes.

These loopholes were caused by a weak legal framework concerning water transfer schemes, which are only briefly mentioned in the 1993 Water Law (Cabrera Hermosillo, 2018). Ultimately, this allowed the water authority to use discretionary decision-making and procedures. When asked about his impressions on the 2011´s court's ruling, the head of Jalisco´s water authority answered: "I firmly trust that The Zapotillo [dam] will continue, because it is the water supply for more than 2 million people […] hereby, we are undoubtedly favouring a majority against a minority." (Pese a amparo, 2011, Feb 02). This comment, as we will later see, would represent the main Jalisco´s government reasoning to warrant the dam´s completion.

This situation infuriated members of Temacapulín's movement and compelled them to undertake a more direct action: taking over of the Zapotillo dam construction site in 2011. They infiltrated the site by pretending to be construction workers and paralyzed the construction process for some days. However, they could not sustain such action for long and left the premises, exhibiting the lack of economic and legitimacy capital for exerting and sustaining actions outside the law.

However, the focus on a legal strategy also showed its limitations because of the power disparity between the actors: "If we want to litigate well, we are tied to the place, we cannot leave, we have no right to go on holidays. Two or three lawyers need to be there, so that if one wants to go to on holidays someone can replace you. Our lives are very stressed […] Lawyers that want to work on these issues are few […] There is an asymmetry of power, in the trials the communities are in complete disadvantage; we do not have a staff of lawyers. We used to say that Abengoa [the construction company in charge of building the aqueduct to the city of León] has more lawyers than engineers." (Interview with COA Collective lawyer 08/10/2018).

Therefore, in 2012, they explored a socio-legal strategy by lodging a constitutional complaint against the 105 m dam to the Supreme Court with the help of local congress people. In 2013, the Supreme Court ruled that the Zapotillo dam could continue, but never beyond the 80 m high mark, since the 2005 agreement was still legal.

5.4.2 Take-off stage (2013-2018): socio-relational strategies

Given the regional and national exposure of the grassroots movement of the dam-affected communities, several politicians during electoral campaigns intended to bank on their rising popularity for their own interests. This meant that their high legitimacy capital could be used or manipulated for political purposes. For example, Jalisco's governor of 2012 tweeted "I repeat it: Jalisco must be the main beneficiary of the decisions and not the one who is affected. We will not flood Temacapulín" (Sandoval, 30/01/2013). An anonymous water management think-tank representative (Interview 14/05/2017) considered that "[The tweet] complicated everything. It forced him to keep his promise [not to flood Temacapulín], especially because in those times when he was still looking "presidenciable" [a term used for any politician planning to become the presidential candidate of their political party]. Now he knows he no longer is. So, he is looking to "pass the hot potato" [to the next governor] and another six years will pass by [until the next presidential elections]."

In parallel, some farmers in the Los Altos region started to worry that the Zapotillo project might affect them negatively. IMTA (the technical branch of Conagua) mobilized its technical capital by conducting a study that concluded that the basin had more than enough water to guarantee a water transfer (IMTA, 2015), and that Los Altos farmers would not be affected. Moreover, the government actively promoted this notion to increase their relational and legitimacy capital in the region, especially to large agricultural producers in Los Altos. An anonymous interviewee within Jalisco's government confirmed that two top government officials visited the director of the largest egg producer of the region (and second largest producer of the world, WATTAgNet, 2014) to convince him that he would not be affected by the water transfer scheme, since it would be only surface water (most animal farmers use groundwater for their production processes due to its better quality compared to surface water). Instead, they claimed, the region would benefit from the scheme since the aqueduct would supply water to many urban settlements in the region on its way to León.

However, a group of farmers who were worried of groundwater over-exploitation, and doubtful of the government's promises, formed CONREDES, an NGO with the objective of promoting sustainable development in the Los Altos region. This organization, accompanied by other farmer associations and the catholic church in the region, sought a socio-network strategy to galvanize farmers against the Zapotillo project, lobby the government to cancel the water transfer to León, but supported the completion of an 80 m Zapotillo dam and use it instead to promote the region's future agricultural development.

These local actors further expanded their network strategy by coalescing with academic networks fostered by ITESO, a local university with ample legitimacy and (international) relational capitals. This coalition promoted the internationalization of the conflict by involving a representative of the New Water Culture Foundation from Spain, who publicly denounced the Zapotillo project as being short-sighted and a threat to the donor basin's development and to the human rights of the inhabitants of Temacapulín. The respected voice of this actor increased the legitimacy capital of the movement, plus the involvement of CONREDES marked a second stage in the conflict since it fostered the organization of farmers in the region to oppose the Zapotillo project.

In 2014, at the height of the movement´s socio-relational capital, the deadlock to the project imposed by the Supreme Court ruling in 2013, and the political aspirations of the Governor of Jalisco, led the latter to propose the creation of a Citizen Water Observatory. The Observatory was given the mandate to submit binding recommendations to the State of Jalisco and its local governments, and was composed of multiple universities representatives, civil agricultural and business associations, the church and international water associations. In theory, this boosted their legal capital.

However, neither Temacapulín nor IMDEC became part of the Observatory. An anonymous source explained that they were invited to be part of the Observatory, but they declined. An interviewee from a member of Temacapulín (15/11/2019) explained that they did not want to be part of anything proposed by the government. This snub created a rift between the Observatory and the block of actors led by Temacapulín that widened further over time. The grassroots movement from the communities prioritized their legitimacy capital based on antagonism with the government over an alleged legal capital.

Moreover, the eclectic nature of the Observatory triggered an internal struggle to steer the organization towards the interests of some of its members. Some members supported the Zapotillo project and others, including the head of the observatory and his posse supported the agricultural sector of Los Altos. Neutral members intending to drive the organization towards dialogue and negotiations were forced out through unsubstantiated accusations of conflict of interests. This negatively affected the legitimacy capital of the Observatory.

As the conflict progressed, trust and relational capital between the allies eroded, thus also eroding their legitimacy capital with it. Moreover, distrust was also present in the government coalition. There was a shared feeling among the key actors in the conflict that relevant information on the water system of the Verde River basin, and the urban systems of Guadalajara and León was sparse and insufficient. Likewise, within the government of Jalisco an anonymous interviewee said that Conagua did not share with them any information; in fact, "Conagua generates information as a function not to bring about sustainability to the territory or to protect aquifer recharge… Conagua's function is to provide [water] concessions." Additionally, the government of Jalisco did not trust

IMTA either. An anonymous interviewee within the government said that “IMTA’s function has been relegated to justify Conagua’s [infrastructure] projects”.

Given Jalisco´s government perception of an absence of neutral scientific teams within Mexico, in 2015 they hired UNOPS (United Nations Office for Project Services), to “depoliticize” the conflict and try to find an optimal solution based on more updated information (Chapter 3 of this thesis). In this context, this meant to follow a strategy to increase the legitimacy and technical capitals of the government. Hiring UNOPS to independently compile more than 60 years of data and develop a water resources model to explore scenarios with different solutions looked like a good idea at the beginning; even members of Temacapulín welcomed the team’s involvement in 2015. However, when UNOPS’ study results were announced in mid-2017, serious inconsistencies were immediately criticised by Temacapulín and the Observatory who denounced that the analyses and results were biased and tailored to legitimize the project (Godinez Madrigal et al., 2020). The hyped UNOPS involvement resulted in losing much of legitimacy capital of the government.

To capitalize on this blunder, both– former allies - grassroots movement and the Observatory - pursued a similar communicational strategy to increase their legitimacy capital: “Our bet is to talk to the society, the public opinion, so that it may be our greatest judge.” (Interview with a representative of the grassroots movement, 10/07/2017). Even if that meant describing the case in the media as a sort of dull mantra. By 2017, the relation with the media had gotten into a frenzy (more than one thousand newspaper articles on the conflict have been written from 2005 to 2020). Both, the grassroots movement, and the Observatory appealed to environmental journalists who would give them special coverage. As a result, an anonymous interviewee within the Observatory described her routine as: “every day is a new *periodicazo* [a newspaper article with high impact], so now who knows what happened! Hurry, prepare a report! Call this or that person and ask for a meeting! Every day I was reading the newspaper, expecting to read the following *periodicazo*.” (Interview 01/06/2017).

Although both collective actors followed the same strategy, they elaborated different messages to get across. The grassroots movement framed their position as the human rights of the communities that must be respected vis-à-vis a project with vast technical inconsistencies, disinformation, broken political promises, and irregularities. Furthermore, Temacapulín highlighted their cause not as NIMBY any longer, but as “La Revolución del agua” (water revolution), which can be seen printed in almost every corner of Temacapulín. This change in narrative framed the Zapotillo project and Temacapulín´s cause as a necessary evolution from a water management characterized by corruption, privatization, and unsustainability to an inclusive and sustainable water management paradigm under the motto of water for all forever. Their large social media following showed that this narrative resonated with the public.

The Observatory, in contrast, relied on a message that delegitimized the competence of the water authority due to unreliable hydrological information, warned of future violent confrontations, appealed to the human right to food (the region is one of the most important agricultural regions of the country) and mobilised the “precautionary principle” to opt for cautious alternatives when uncertainties are too large. However, this narrative failed with the public, reflected by the general indifference in social media of their message.

By 2017, new electoral campaigns commenced for the office of Jalisco´s governor, and again the Zapotillo conflict became a political arena to gain legitimacy capital. However, after the elections, Temacapulín´s cause was discarded. The new governor decided to continue with the Zapotillo project by diminishing the legitimacy capital of the project detractors. After losing many of its founding members, the governor publicly requested the Observatory to be disassembled due to its lack of internal plurality of opinions, democratic practices, and diminished relevance. Moreover, the governor implemented a legal strategy to circumvent the Supreme Court ruling that stopped the construction of the Zapotillo dam at 80 m high. Jalisco’s government lobbied to sign a new agreement with Guanajuato, this time supported by the congress of Jalisco, which had been the main constraint in 2007. For the first time in years, the conflict seemed to tilt towards the completion of the Zapotillo project.

5.4.3 Acceleration stage (2019-2021): Socio-technical strategies

During the second stage, members of the grassroots movement realized the limitations of their social and network strategy since interests made alliances fragile and put the conflict in an impasse. Therefore, their efforts diverted once again, this time to adopt a technical strategy by focusing on the technical alternatives of the Zapotillo project (IMDEC, 2018; 2019).

For many years, local academics from Guadalajara and León - linked to international experts and networks - had proposed alternatives to the dam, but such proposals were characterized as being either too abstract or unreliable. Some academics in agreement with the State Congress would argue that the dam would not be needed if only water resources be managed in an integrated manner (Aceves Avila et al., 2018). Others would insist in alternative solutions such as rainwater harvesting, but unable to estimate its potential or develop a cohesive plan to undertake it (Gleason-Espíndola et al., 2018).

With the new focus on technical alternatives, in 2018 the authors organized a participatory modelling workshop with key actors involved in the regional water conflict,[11] to analyze and collectively discuss on the potential of infrastructure and water management alternatives, increasing the technical and legitimacy capital of the movement. A representative of IMDEC welcomed this strategy by reflecting on the grassroot movement´s limitation to increase their own technical capital: "The adoption of this kind of alternatives have not been considered [by decision makers]. And it´s sad that the businesspeople and official [governmental] discourse is that the resistance only opposes but does not propose anything. And that´s the issue, not knowing how to propose solutions for aquifer recharge, water harvesting, modernizing agriculture and efficient water systems" (07/12/2018).

At the same time, the arrival of a new and ambitious left-wing president in 2018 who won the national election with a landslide created a window of opportunity in the socio-technical landscape for actors opposing the project. The Mexican President was known to be sensible for social causes, especially grassroots movements. He even held a personal meeting with representatives of the dam-affected communities and the Observatory to discuss the case. Members of the Temacapulín movement recall a markedly different approach compared to previous authorities. Now, they would actively listen to their grievances without interrupting and empathise with their situation. At the end of the meeting, the President reaffirmed his commitment to resolve and even transform the conflict: "The [dialogue] tables can start by asking an explanation from CONAGUA, which will provide all the scientific technical information; another table would be to present the civil society´s alternatives […] The legal dimension is important, but the most important thing for us is the social dimension and water management. We are not going to pressure you into anything; what we want is for you to listen to the other party and the other party to listen to you and we all listen to each other." The involvement of the President in opening up an official space to discuss alternatives increased the legitimacy capital of the grassroots movement.

In early 2019, the federal minister of natural resources management (which Conagua is part of) visited Temacapulín and declared that it would be foolish to destroy the towns and relocate the communities. During his visit, representatives of the grassroots movement aware of their low technical capital, highlighted the need to develop alternatives to the Zapotillo dam. As a result, the minister co-organized a stakeholder workshop with the grassroots movement in Mexico City to discuss and analyse alternatives to the Zapotillo project. This was only possible through their increased

[11] Temacapulín and other communities downstream along the Santiago River, NGOs, including IMDEC, Conagua, IMTA, Jalisco's government, academics from ITESO and engineering groups.

economic and relational capital by raising international funds to invite technical experts and allies working within the federal government. In late 2019, the first author attended two workshops and a public mediatic event organized by the ministry of natural resources, dam-affected communities and IMDEC to discuss alternative solutions, in which representatives of more than 20 international and national organizations were invited to propose the development of technical alternative solutions to the Zapotillo dam, democratize water management, minimize the impact, and observe the people's (human) rights.

During the first workshop, three alternative solutions were discussed from the ground up: improving groundwater management, decreasing non-revenue water, and developing household rainwater harvesting systems. In this context, the first author presented results of a model-based conjunctive use of multiple alternatives for Guadalajara and León, which drawn the attention of a multiple strategy scenario opposed to single alternatives (a version was made public later in Godinez Madrigal et al., 2019b). The media exposure of this socio-technical strategy shook the government of Guanajuato and the association of businesspersons of Guanajuato, who showed their disappointment in the federal government for publicly endorsing the workshops. And although Guanajuato's stakeholders did not oppose alternatives, they stated that the Zapotillo project should be completed at 105 m. The State of Jalisco dismissed the alternatives as being unrealistic.

The meetings with federal authorities and the President of Mexico were possible since IMDEC had developed a vast network of actors from grassroots movements, some of whom were appointed into the ministry of natural resources under the new presidency. A common background and experience of them was rural development, which has an affinity with ideals related to emancipation of the poor and social justice. In fact, the head of the ministry himself had published several political ecology books (e.g., Toledo, 2019). This network proved essential to drive the conflict to a different stage.

Recently (November 2021), the federal government and Conagua have agreed with the communities to retrofit a lower spillway in the Zapotillo dam to protect the communities from flooding. The grassroots movement set up an international technical supporting team to advise them at every step of the technical negotiation process with Conagua. This agreement means that the yield of the dam will be significantly reduced. Consequently, León will not receive a water transfer, and Guadalajara´s allocation will be halved. However, at this stage it is still unclear which alternatives will be adopted by the governments of Jalisco and Guanajuato in response to this event.

5.5 Discussion

Why is the Zapotillo case relevant to understanding the relation between conflicts, crises and change of socio-technical systems? The two most important bodies of knowledge that study water-related conflicts show limitations in fully understanding the Zapotillo conflict. As mentioned in the introduction, the data-driven approach would focus on how to prevent the water conflict, disregarding the role of the dam in the development pathway of the cities (Chapter 4 of this thesis). And political ecology would focus on the success of the grassroots movement but overlook the legitimacy and technical capitals accumulated by the grassroots movement. Conversely, TM with a thorough understanding of agency conceptualizes the water conflict as a catalyzer for change.

We argue that Transition Management theory offers potential to address these gaps and improve our understanding of conflicts. Loorbach et al. (2017) argued that socio-technical transitions undergo certain stages before a system transition occurs. Figure 5.1 visualizes the different stages undergone in the Zapotillo conflict discussed in the previous section. In the first stage, the local actors aimed at cancelling the dam and suggested to relocate the dam to a water-rich area. As theorized in the Transition Management literature for the pre-development stage, the actors´ scope in terms of actions and motivation was very localized at a niche level, like taking over the dam construction site and suing the government. Although that troubled the reproduction of the tried-and-trusted strategies of the system - large infrastructure development, it did not threaten its dominance.

However, as the members of the dam-affected communities and farmers became aware that the water management system was producing what they considered injustices throughout the country, they mutated their initial goal of cancelling the dam to leveraging alternative solutions that would disrupt the water management system and change it. This indicates that some conflicts can become a force for sustainability, as argued by Temper et al. (2018), and not only events causing socio-economic damages that need to be prevented (Mach et al., 2019).

However, the social movement in the conflict is not unidirectional. Grassroots actors undergo social processes of successes and failures that affect their trust, commitment, and vision with other actors. This means that the trajectory of the conflict at its earliest stage is contingent upon the actors´ experiences of successes and failures, represented in Figure 5.1 with the up and down arrows at the first stage.

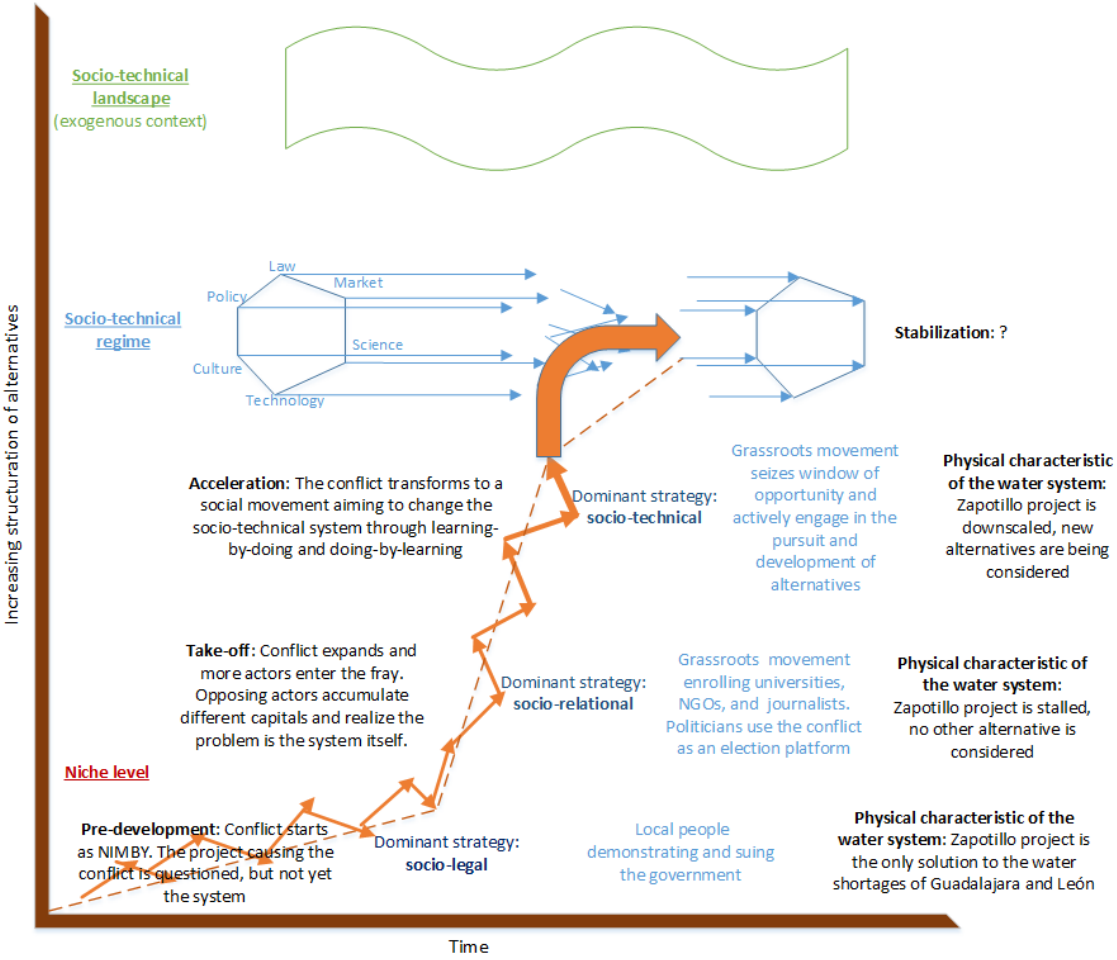


Figure 5.1 The evolution of the Zapotillo conflict (based on Loorbach et al., 2017).

During the take-off stage the movement increases its internal momentum and the actors´ strategies become aligned (Loorbach et al., 2017). In the Zapotillo case, following Long's (2003) approach and ethnographic methods, we argue that this stage was met when the dam-affected communities expanded their legitimacy and relational capital by engaging with a network strategy to enrol actors with crucial legitimacy, legal and relational capitals they initially lacked. The involvement with the national movement against dams (MAPDER), and the lawyers' support made them realize that relocating the dam somewhere else would cause another injustice for other communities. Then ITESO and other scholars infused the movement with technical capital to consider other alternative solutions to the Zapotillo dam. Finally, IMDEC infused the movement with legitimacy and relational capital to mobilize and increase the awareness of the situation to a larger part of society and actors with different capitals. The development of all these capitals culminated in the Supreme Court ruling against the Zapotillo dam with a height of 105 m in 2013, and the creation of a Citizen Water Observatory in 2014 (legal capital).

It is at this stage that the political ecology approach shows its limitations. Vos et al. (2020) described that for social movements to be effective they need rootedness, internal structure dynamics of decision-making and capacities, and impacting multiple scales, innovativeness, creativity, and legitimacy. However, the Zapotillo case shows that it may not be enough even when they achieved many, if not all, of the characteristics suggested by Vos et al. (2020) to be effective; they also need to transform themselves from a NIMBY movement and have the ambition and capitals to exert a socio-technical transformation of the water management system. The reason is that the system is determined by a socio-technical regime (Fig. 5.1: policy, law, market, science, technology, culture) that does not easily allow change, even less a transition, to happen. This resistance to change is seen when observing politicians who have used the social movement as a political trampoline to increase their popularity but, once in office, betrayed their own promises and backed the ready-made Zapotillo project that fits within the existing socio-technical regime. Alternatives are actively discouraged by water managers of the existing socio-technical regime and are framed as “too difficult, expensive and complex” to implement them (Chapter 4 of this thesis). The constitutionality approach also faces limits in its argumentation of effectiveness when considering only institution building. The failed strategies of the Observatory in achieving change show the dynamic nature of actors in relation to their capitals, they traded their legitimacy in exchange of their institutionalization (legal capital).

Following a different strategy, the dam dam-affected communities never compromised their legitimacy and complemented it by promoting technical and infrastructural solutions that are currently underdeveloped in the socio-technical landscape in Mexico. A serious disadvantage for grassroots movements is, however, the lack of economic resources and access to key information and technical expertise, while their main strength is found in social relations and support networks. For the grassroots movement to succeed, they sought strategies to collaborate with internal and external actors, funding, and learning. That would precisely need a window of opportunity to exert a next stage of the socio-technical transition: acceleration.

This third stage of the transition seems to be the most challenging since it requires windows of opportunity to appear over which local actors may have little control. Huitema & Meijerink (2010) argue that policy entrepreneurs need to develop new ideas, build coalitions, and sell those ideas, and recognize windows of opportunity. The grassroots actors opposing the Zapotillo conflict acting as policy entrepreneurs followed these strategies to exert change in the socio-technical system. With this ample network backing them, grassroots actors learned technical concepts of water systems and handled academic concepts to propose new alternative solutions to mitigate water scarcity for Guadalajara and León, they built an international, multi-sectorial and multi-level coalition to exert change in the system and recognized the window of opportunity that represented the electoral victory of the new leftist President. What the Zapotillo conflict shows is that actors who have developed a sound and varied network of allies, learned-by-doing and did-by-learning have more chances in taking on windows of opportunity when some of these allies access positions of power, as shown in the later stage of the Zapotillo conflict.

However, at the moment of finalising this chapter, the acceleration stage is just starting, and is not clear whether the grassroots movement will have sufficient capacity to orchestrate and manage a network of actors (a fourth strategy of policy entrepreneurs according to Huitema & Meijerink (2010)) and continue to learn-by-doing and do-by-learning within that network (essential capacities to exert the final transition stage, according to Loorbach et al., 2017). We argue that these capacities and strategies seem to be essential for the actors in the Zapotillo case, and that they therefore should be included in the characteristics of social movements described in Vos et al. (2020).

The grassroots movement still faces several threats. One is internal divisions, already present between the Citizen Water Observatory and the communities-led network of actors. A second threat may be the failure to implement alternative solutions due to unforeseen social or technical constraints, particularly those related to the latest negotiation on the dam operation and infrastructure adjustments as well as water management at regional level. A third one could be an imposition by force of the Zapotillo project by future governments with different political inclinations. Further research can follow up the Zapotillo case to analyse how the case unravels, as well as investigate whether the dynamics analysed in the chapter can be found in other similar cases of conflict.

5.6 CONCLUSION

This chapter contributes to the literature of water conflicts as catalyzers of change by studying the evolution of the emblematic Zapotillo case over a period of 16 years through the lens of Transition Management. The case has shown that actors in water conflicts can become policy entrepreneurs for a socio-technical transition of the dominant water management system. The actors closely related to the dam-affected communities by the Zapotillo dam defied an emblematic infrastructural project that directly affected them, but also challenged the dominant water management system and exerted pressure to implement a new one under the principle of water for all forever. This was also done through the window of opportunity opened by the Mexican President, which although external to the social movement, he was attracted to act in the conflict since he was a presidential candidate.

Two of the main approaches studying water conflicts present analytical deficiencies to fully grasp the significance of a conflict like Zapotillo. The case study departs from two main approaches to study water conflicts: data-driven and political ecology. The data-driven approach struggles to look beyond causal relations and quantitative indicators to prevent conflicts, understood as negative events, but it overlooks unjust power imbalances in water systems. Conversely, the political ecology approach focuses on the description of imbalances in power, but not necessarily on how these imbalances shift during and through the conflict.

The Zapotillo case shows that conflict and cooperation need to also be analysed as social processes characterized by key actors developing capitals and changing their motivations and objectives through different stages of the conflict. The dam-affected communities started with the basic legitimacy capital, which is the legitimacy of their cause and a rights-based contestation of the Zapotillo project, and their motivation was limited to defending their communities. Later, the movement evolved when the communities developed their relational capital by enrolling a diversity of actors that supported their cause, which allowed the interaction and development of additional legal and technical capitals. With the legitimacy and legal capitals, they stalled the implementation of the Zapotillo project. Moreover, their motivation scaled up to also address the political system and decision-making arena of the water management system.

However, when it became clear that the water management system was so fossilized and locked-in on large supply-augmentation projects as the only strategy to bring about water security, the actors of the movement started aiming at developing technical capital to develop alternative solutions to the Zapotillo project to transition to a more sustainable water management in the region. If effectively implemented, these alternatives would transform the material aspects of the socio-technical system of Guadalajara and León. Nevertheless, at the current acceleration stage of the transition, it is still unclear if it will stabilize and replace the dominant water management system in this part of Mexico, or if the movement will fail at developing viable alternative solutions. Further research is needed to follow the unravelling of the conflict and analyse other conflicts with the same approach.

Since transitions of socio-technical systems can take decades, the study of other water conflicts under this new approach could represent a big challenge. However, considering conflicts not only as negative events, but as complex evolving social phenomena that can rip what is assumed to be realistically possible, to allow new, and hopefully better, possibilities and realities to happen, is a challenge worth the effort.

6

POST SCRIPTUM

"My formula for human greatness is amor fati: that one wants nothing to be different, not in the future, not in the past, not for all eternity. Not only to endure what is necessary, still less to conceal it — all idealism is falseness in the face of necessity — , but to love it…"

—Friederich Nietzsche

"Think about it. Think about saving yourself. Your spiritual self. Your gut self. Your singing magical self and your beautiful self. Save it. Don't join the dead-in-spirit. Maintain your self with humour and grace and finally if necessary wager your self as you struggle, damn the odds, damn the price. Only you can save yourself. Do it! Do it!"

—Charles Bukowski

6.1 A DREAM COME TRUE?

On August 22nd, 2021, I arrived in Temacapulín with high expectations for the afternoon´s meeting with Conagua. Lopez Obrador, the Mexican president, had been clear that "if the inhabitants [of the three dam-affected communities] do not want the Zapotillo dam, it will be stopped". Almost every corner of Temacapulín had a political statement stitched to the walls: "Temacapulín resiste"; "Salvemos Temaca, Acasico y Palmarejo"; "¡Viva la Revolución del Agua!"; "No a la presa El Zapotillo".[12] AMLO, as the President is commonly known, saw those same signs a week ago when he visited Temacapulín and proposed the inhabitants a solution to end the 16-year-old conflict. The head of Conagua, he said, would come next week to explain in detail the proposal. "It will be in your hands" he reiterated to the communities.

My Dutch weather app, Buienradar, had predicted a 165 mm rainfall that day, as if a promissory weather foretold the crossroads of a conflict that has lasted almost a generation. As soon as I arrived in Temacapulin, I recognized some of the leaders of the grassroots movement walking near the event´s location at the town square. It seemed natural to congratulate them, so I did: '¡Congratulations!' But I was met with a half-smile and a laconic answer: 'Ya veremos!'.[13] With genuine curiosity, I asked, 'what do you mean?' Gabriel, the former priest of Temacapulín and now leader of the movement, looked at me with wondering eyes, trying to recognize me through my face mask. 'The most difficult moment is yet to come," he replied.

At the town square, an intense rain started to fall. Conagua had put up a tent to protect us from the incoming storm. We were one of the first to take place. More than a hundred chairs were placed to accommodate the press and all interested inhabitants of Temacapulín, Acasico and Palmarejo. The event started when the head of IMDEC, the long partner NGO of the inhabitants of Temacapulín, welcomed Conagua, the press and other guests invited by the communities (such as myself and my colleagues from ITESO, the Jesuit university in Jalisco). Wary of the great national media attention that the conflict had attracted, and the presence of multiple interests and egos present in the event, the IMDEC representative warned the attendees that this was an event for and by the people of the three communities and no one was allowed to voice comments nor questions or any kind of interaction save the inhabitants of Temacapulín, Acasico and Palmarejo.

Conagua's director explained the President´s proposal. The Zapotillo dam would not be decommissioned, but it would operate at a lower water level, namely at 50 m (30 m lower

[12] English translation: Temacapulin resists; Save Temaca, Acasico and Palmarejo; Long live the water revolution; No to the Zapotillo dam.

[13] English translation: We'll see.

than the top of dam) to avoid flooding the communities. The dam would also see its spillways finished to the original 80 m height. Conagua's director highlighted how the dam design was more than capable to drain excess water to a maximum of 2,500 m^3/s, 30% more than the maximum recorded runoff of 1973, when the river's flow was 1,700 m^3/s. In principle, this meant that the proposal was based on a 70-year return period. "The design of these outlets is so unnecessary, but they guarantee the safety of Temacapulín. This proposal, argued Conagua's director, would mean the cancellation of the water transfer to León, but it would at least contribute 3.5 m^3/s to the water supply of Guadalajara.

Regarding the safety measures of the proposal, Conagua considered the use of automatic gates to control the flow. A manual operation of the gates was also considered should the automated gates fail. In addition, Conagua would implement nine hydrometeorological stations upstream to gauge the climate and runoff to operate the automatic gates to release water from the reservoir, so that the villages would not be inundated, and to let the people know of imminent threats to their cellphones.

This was the most ambitious proposal to downscale the Zapotillo dam in order to protect the communities. This has been the closest Temacapulín, Acasico and Palmarejo had been to succeed in more than fifteen years. Nevertheless, was this proposal safe and sound in the long term for the communities?

Inhabitants of the three communities lined up to directly interrogate Conagua's director. One by one expressed not only questions but long-term grievances, and he exercised what in the water diplomacy literature is known as active listening. For more than an hour, Conagua's director patiently listened numerous questions and diatribes, exposing their almost two-decade suffering and anxiety generated by the conflict. To the question of "Are we going to be compensated for our psychological pain of all these years?" the head of Conagua, visibly surprised, acknowledged that he was a technical man, ignorant of such issues, but that he would consult his advisors. He even publicly apologized when confronted by the fact that members of Conagua had taken some large posters off the entrance of Temacapulín, critical of the President´s visit. Such public displays of ministries are very uncommon in Mexican politics; historically proud, dismissive, contemptuous, and unrepentant and dismissive of any mistake.

And as uncommon attitude for a ministry as it was, it had an effect to lower the defences of distrustful inhabitants. "Cuando el gato se ha quemado con leche, hasta al jocoque le sopla"[14] would be a common phrase of Temacapulin's leaders, regarding the general mistrust to the government based on previous experiences. However, by the final

[14] English translation: When the kitty has burned itself with milk, it blows even to sour cream.

interventions, some people even appealed to the ministry's good heart to advocate for their interests. The tense mood at the start of the meeting had changed to a hopeful ending. Apparently, the federal government had given huge concessions to the inhabitants of the three communities: cancelling the water transfer to the city of León and reducing the volume of water supply from the Verde River to Guadalajara. By the end of the meeting, some people from the grassroots movement were visibly celebrating with loud music with beer in hand, singing along classical Mexican songs like 'No volveré' with a twist in the lyrics: '¡No volverá esta pinche presa…!'[15] Even on the horizon, the heavy rain had stopped, and a beautiful rainbow painted the evening sky.

Figure 6.1. The rainbow in Temacapulín after the meeting with Conagua.

The federal government had played its part to solve the conflict, they proposed a seemingly good solution for the communities, now it was the turn of the communities to either accept or reject the proposed solution. While some people were celebrating, the most active leaders of the grassroots movement were already discussing with the technical advisors the next moves. That was the reason other scientists, technical advisors and I were invited to the event. The IMDEC representative explained that "The communities have never been so vulnerable as today. The technical advisors need to have a central role

[15] English translation: I won't come back. This damned dam won't come back.

to relief the communities of this burden bestowed upon them." But how could the best opportunity to succeed make the communities vulnerable?

6.2 LOPEZ OBRADOR´S TECHNO-POLITICAL MASTER PLAY?

The year of 2021 was a terrible hydrological year throughout Mexico in terms of drought and floods. Guadalajara experienced water shortages for the first half of 2021 due to below average rainfall and insufficient volume in the reservoirs supplying water to the city. On July 14th, Jalisco´s government even supported a water supply alternative that they had criticized and dismissed as unachievable for many years: rainwater harvesting. Jalisco´s government developed a project to install 4,600 rainwater harvesting systems in Guadalajara.

This certainly came as a good sign for a transition towards a new water paradigm, but the good news lasted briefly. Representatives of the grassroots movement had been summoned in June to Conagua's headquarters to discuss the Zapotillo project. IMDEC's main representative told us in a WhatsApp chat that "things are moving very fast, the director of Conagua is pressuring us into accepting the 105 m dam. We are under a lot of pressure!" The unusual dry year of 2021 had made Conagua's director wary of a looming water crisis throughout the country. The Cutzamala system (a key water transfer for Mexico City´s water supply system) was also experiencing one of the worst years in history. As a result, Conagua's director assessed that abandoned infrastructure such as the Zapotillo project needed to be completed to face this and future water crises (Encizo, 2021).

On August 16th, 2021, Lopez Obrador announced a visit Temacapulín to solve the 16-year-old conflict during his administration (Fig. 6.2). The announcement took everybody by surprise. Why so sudden, and without consulting first with the communities? They knew about the meeting about the same time as everybody else. But the President was laconic, "If the inhabitants [of the dam-effected communities] do not want it, the Zapotillo dam will not be completed […] [Former administrations] built a dam without consulting the people, and the dam is already built but no one can use it, and it is water allocated for Guadalajara and León. I´ve got to talk to the people [of the dam-affected communities] to figure out how to solve this. They [the dam-affected communities], rightly so, do not want [the Zapotillo dam] because the three communities will be flooded. Even when they´ve been offered alternatives, we must understand them. Their dead are buried there, their churches are there. It is their towns; but the infrastructure is also there. It is the tax-payers money and the possibility to have water. I´ve got to see all that next week." Such statement should have given hope to the communities, but their previous meeting to pressure them to a 105 m dam with Conagua's director back in June had made them suspicious.

Figure 6.2 Mexican President, Andrés Manuel López Obrador, in Temacapulin. (Source: IMDEC).

The grassroots movement deployed a communication strategy that had proven successful in the past, framing a message of holding politicians accountable for their promises in social media, to not let the public forget. López Obrador had visited Temacapulín three times prior to becoming the President and had vowed to the inhabitants to protect them against the Zapotillo project. Before the President's visit to Temacapulín "#AMLOEsTiempodeCumplir" became a trend in Twitter.[16]

During López-Obrador´s visit to Temacapulín, he announced a proposal developed by Conagua that they (the communities' inhabitants) could accept to end the conflict of reject and leave things as they were the following week. Then, he visited the dam´s site and filmed a short video addressing the nation. He framed the situation as an inherited conflict from previous administrations, and that unless external actors such as environmentalists and NGOs with different interests intervene in the decision-making process to manipulate

[16] English translation: #AMLO it is time to fulfill your promises.

the communities, then the conflict would finally be resolved with a win-win. This turned the red flags within the grassroots movement, because even the governor of Jalisco, a strong advocate of the Zapotillo project, seemed unexpectedly pleased with the President and Conagua's proposal.

On the Saturday night of August 21st, after hearing Conagua's proposal (described in section 7.1), the technical advisors had a heated debate of what López-Obrador´s proposed solution represented for the communities. Was this a triumph for the communities, should they accept the proposed solution, what are its associated risks, is there a hidden intention we need to unearth? After much discussion we concluded that Temacapulín´s grassroots movement was in danger of being finished. Thinking of the situation as a chess game, whatever move available for Temacapulín, the legitimacy of the grassroots movement was compromised. If the inhabitants of the communities accepted the offer, then the conflict would be considered resolved and there was no point to keep on with the so-called "Water Revolution" that for so many years they have been flighted for. If the inhabitants rejected the proposed solution, they could easily be criticized as incongruent. Why would they reject the proposal to keep the movement alive when their main objective was within their grasp? Apparently, the Water Revolution would need to wait some more.

Meanwhile, in Guanajuato, Conagua's director announced a visit to León to discuss alternative supply augmentation projects to the Zapotillo water transfer project. However, Guanajuato´s governor framed the meeting as to discuss the future of the Zapotillo project. Thus, these incongruent statements created confusion about the real intentions of the federal government. Was the water transfer really off the table or only furtively postponed?

Some issues in Conagua's proposal did not check up. Why spending money on finishing the physical spillways at 80 m high if Conagua's director was so sure "that the reservoir would be filled to a maximum level of 50 m high? Considering only a 70-year return period seemed unwarranted. In a group meeting with my supervisors, Pieter, Nora, and I explained them that it felt as if Conagua's proposal real interest was to start operationalizing the Zapotillo dam with the approval of the communities and just wait for the leaders of the movement to dissipate; or even worse, given the 70-year return period wait for a flood to evacuate the communities at some point in time. After a flooding, it would warrant the government to utilize the full potential of the Zapotillo dam.

The grassroots movement needed to negotiate better conditions and assurances that this should not happen.

6.3 NEGOTIATION AND POLITICAL UNCERTAINTY

In Chapter 3, I briefly discussed literature that outlined how scientists had a similar role to forensic detectives in figuring out what is the real cause of social and natural complex phenomena. At least in the case of the Zapotillo conflict, I can certainly argue that this was the case. All facts could be interpreted in many ways. What was the real intention behind López-Obrador´s proposed solution? Was it a real opportunity or just a wolf in sheep's clothes? Further inquiring and a counterproposal would unveil the real intentions.

The following weekend after the meeting with Conagua, Temacapulín organized its annual festival "El festival del chile" where they celebrated their future with next generations with children´s games, culture and gastronomy with a hand-made spicy salsa, and a public competition and a 5k and 10k running competition across the towns to witness their rich history. I was invited to become a judge on the hand-made salsa of local "chiles de arbol" competition. Along with three other judges, we awarded the 1st place to a woman resident in León with roots in Temacapulín. Her green tomato salsa with toasted homegrown red hot chili peppers delighted the mouths (and fired the tongues) of the judges (Fig. 6.3). Even in critical high-stakes situations like this, people needed to cultivate light-hearted activities and joy. Children playing, singing music, tasting food.

Figure 6.3 Salsa competition at Temacapulín.

In the evening, I was invited to a behind-closed-doors meeting with representatives of the communities to analyse Conagua´s proposal and what it would entail for the communities. Is Conagua´s proposal fair and risk-free? Should they ask for a change in the proposal? To our understanding, Conagua´s proposal had two shortcomings, one considering natural risk and another a political risk. First, Conagua´s calculations considering only a 70-year return period could be insufficient given the aleatory uncertainty of hydro-climatic events.

Second, nothing would prevent future administrations to continue building the Zapotillo project as initially intended.

Although these two propositions were easy to convey and argue, the central issue of the situation, at least for me, was how to communicate them without suggesting a position or influencing the internal decision making of the communities. It was obvious that to solve the two proposal's shortcomings the dam would need to be retrofitted with a lower than 50 m spillway. However, at the moment it was impossible to know what the negotiation space with the President and Conagua really was. I feared that an ambitious counterproposal could affect the negotiations, especially if the President or Conagua would find it economically unfeasible. A retrofitted spillway could cost more than a billion pesos (≈ $50 million dollars).

Some participants in the meeting also did not want to run the risk of jeopardizing a once-in-a-lifetime opportunity by requesting a counterproposal, besides "we [the grassroots movement] have argued for more than a decade that the Verde River is drying up, why are we worrying now that we could get flooded?" a long-time member of the grassroots movement argued. However, to this argument, other participants resorted to our two main concerns of the unpredictability of hydro-climatic events and future administrations. Eventually, they trusted our expert opinions to make the decision and present a counterproposal to the President.

In the meeting we also discussed practical matters such as the language to use in the negotiations and public statements. We needed to use technical terms to sound as a serious and knowledgeable counterpart. Terms such as retrofitting spillways, dam decommissioning, and return periods ought to be used, instead of run-of-the-mill language like destroying the dam. In such an important crossroads, we needed to be careful on how to frame a counterproposal to the top water authority of Mexico and to the media, which would convey the message to society at large.

Delft's research team proposed the grassroots movement to hire a Swiss hydraulic infrastructure consultancy to properly assess Conagua's proposal and eventually develop a counterproposal on behalf of the communities based on a ≈ 50 m spillway for the Zapotillo project. In a meeting, four community members and a representative of IMDEC discussed these two tasks. Eventually, although the collaboration could not occur because of the high costs of the consultancy, and the urgency with which the grassroots movement needed the assessment, the importance of the meeting consisted of the possibility of the grassroots movement to have access to international experts to discuss their problematic with neutral technical experts. Even the leader of the grassroots movement reflected on the crucial role of the internet "to be able to connect to experts around the world. Without the internet Temacapulín would have been flooded a long time ago."

Some weeks after that meeting, on October 10th López Obrador announced his second visit to Temacapulín. This time he wanted to know what the communities' decision was. In a period of a few days, the communities contacted us again to draft a statement of our IHE Delft research group about Conagua´s proposal and the idea of a ≈ 50 m spillway. The statement would be handed over to the President and Conagua's director (appendix). We exposed as concise and clear as possible the arguments to modify Conagua´s proposal by including a retrofitted spillway designed to handle a flood with a 1,000-year return period. However, the grassroots movement decided to demand for a 10,000-year return solution.

This meeting was probably the most important meeting ever attended by the grassroots movement. It was unprecedented that a sitting President would visit a small town twice in the period of two months. The outcome would be definitive to the grassroots movement, and they knew it. They were nervous, stressed, and hopeful. The only way I thought to support them was to remind them to stay strong because the truth was on their side.

To everyone´s surprise, when the President heard the grassroots movement counterproposal, he almost immediately accepted it and even offered additional budget if needed. He then requested Conagua´s director to analyse and handle the counterproposal along with the communities.

However, even with the support of the President, the grassroots movement needed to face the possible backlash of actors in Jalisco, Guanajuato and the federal government who opposed the counterproposal. Most notably, the governor of Jalisco also visited Temacapulín to accompany the President, and was visibly upset on the grassroots movement counterproposal, calling it non-sensical.

On October 12th, the grassroots movement organized a press conference with the technical support team, including the three members of IHE Delft´s team (Pieter, Nora, and myself), to describe the risks associated with Conagua's proposal and to support the communities' proposal to the press. However, the role of the technical team was not only to support with technical arguments the grassroots movement, but also to demonstrate affinity and public solidarity. Therefore, as an example of this, Pieter finished his intervention in Spanish by stating that he was proud of the grassroots movement and in favor of "Ríos para la vida",[17] a long-time motto of the communities. The crowd felt emotional and cheered. The press conference finalized with representatives of the grassroots movement criticizing the position of the governor of Jalisco, as the last obstacle for the movement's success.

[17] English translation: Rivers for life.

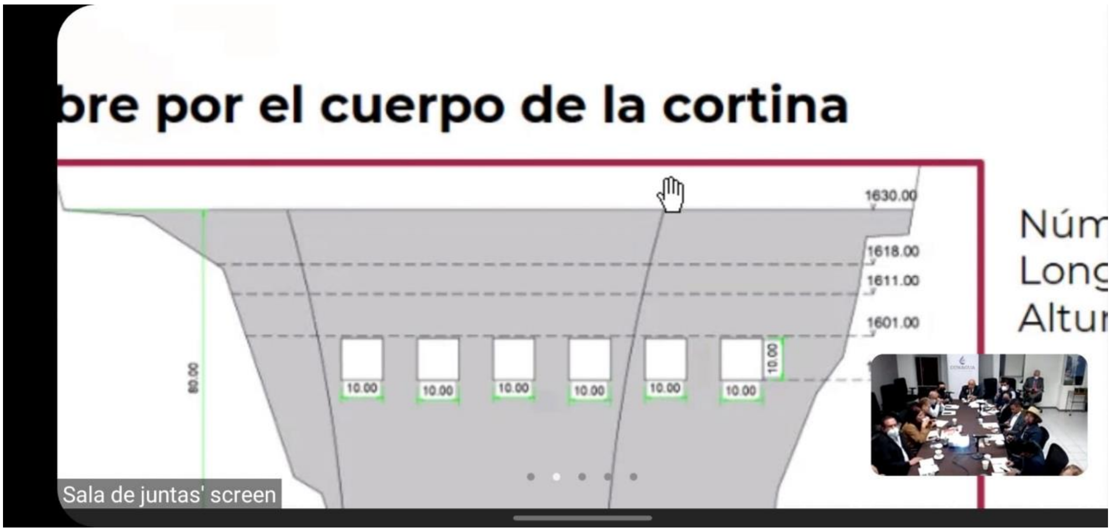


Figure 6.4 Conagua's retrofitting proposal to resolve the conflict. (Source: Conagua, 2021. Presa Zapotillo, Jal.; Propuesta conceptual para transitar avenida de diseño sin afectar a pobladores. Conagua, Mexico City.)

The next day Temacapulín was in most newspapers not only in Jalisco, but also throughout Mexico. Front pages and columnists analyzing the case populated the newspapers the following day. Some columnists praised Temacapulin for pulling what looked like an impossible feat and a symbol of genuine resistance against powerful and corrupt interests, and some others vilifying the agreement for fear of Guadalajara's and León's future water security. "The opinologists have multiplied", mentioned someone from IMDEC. The grassroots movement had learned how to influence public opinion through media exposure, especially with the weight conveyed with the intervention of international experts supporting Temacapulin's counterproposal.

On October 26th, the grassroots movement, the supporting team of experts and representatives of Conagua gathered in a meeting to discuss the counterproposal and to propose a design to retrofit a 50 m spillway. Conagua had designed a spillway consisting of 6 "windows" along the 50 m mark, each 12 m wide and 9 m high and more than 60 m in depth (Fig 6.4). To the surprise of the grassroots movement and the supporting experts, we really had few questions to ask besides corroborating the calculations that such spillway could protect the communities from floods with a 10,000-year return period.

Conagua's representatives left the meeting room for us to deliberate. Our main concerns were if such spillway design could deter future administrations to revamp the Zapotillo project and if the "windows" would be sufficient in a 10,000-year return period. We had considered that a free-flow spillway cutting across the 50 m high mark would be ideal. But six such a large 12 m by 9 m windows were large enough as well. In our expert opinion if future administrations would want to revamp the Zapotillo project, it would be extremely expensive. When Conagua's representatives came back they wanted to know if the grassroots movement accepted "at least in principle" Conagua's proposal. It felt so strange for them to finally, after 16 years, to agree with Conagua, but they did accept… in principle. The grassroots movement achieved its main objective, a secure infrastructural solution, without compromising their interests at any moment.

On November 8th the representative of IMDEC called me with urgency, the President had scheduled his third meeting in Temacapulín with all his Cabinet by November 10th. "Have you checked Conagua's data?" She asked me. Unaware of the sudden President´s decision to revisit Temacapulín, I had not thoroughly checked Conagua´s data, which had only been shared a couple of days before. The most important thing was to guarantee that the six "windows" in the dam would be able to evacuate a flood with a 10,000-year return period. I immediately consulted with Miroslav Marence, an IHE associate professor who is an expert on dams and tunnelling. On the fly, he calculated the potential of evacuation of these six windows, and his result coincided with that of Conagua. In a meeting with all the technical supporting team, we all agreed that Conagua´s second proposal did not have any foreseeable reason for concern. However, there was still a hint of mistrust among the people of IMDEC, "the assholes wanted to screw us up [with the first proposal of Conagua]." In our collective reflection, we concluded that it was much more complicated. If that was their plan, why would they had been so open to feedback and a counterproposal?

Apparently, our early suspicion that this techno-political play to solve the conflict was a subterfuge to neutralize the movement and later retake the original Zapotillo project was wrong. At least partially, because the favorable reaction of the governor of Jalisco to the early Conagua's proposal had changed to irritation by the movement's counterproposal. This change of heart indicated a feeling of frustration. The different levels of government are not a monolith, and different interests are embedded in the federal and state governments. Despite these differences, by November 10th, the President with all his Cabinet and the governor of Jalisco attended the third and last meeting in Temacapulín to consolidate and enact the agreement that resolved the 16-year-old conflict.

The first speaker of the meeting was Mari Chuy, one of the eldest and charismatic leaders of the movement. She described the intrinsic sense of rebellion within the movement: "I used to think before that I was a good person because I was a catholic, apostolic and… dumb. Today I keep being catholic, apostolic… but now I am an *hija de mi madre*.[18] I now consider myself a very rebellious woman, because they gave us no option." Later, the former priest of Temacapulín framed their movement as a steppingstone to a more transcendental and ethical transformation in the management of water systems that the movement sparked: "On November 10, 2010, we were in the heart of Guadalajara marching 3,000 people when we declared what is now called the water revolution, which has borne fruit, but there is a long way to achieve water for all and water forever. For this, we will have to remain vigilant until we achieve comprehensive water management, not only for the next 9, 12 or 20 years, we need water management that goes beyond infrastructures and that respects the natural water cycle for the sustainability of the planet. Today our communities become the heart of Mexico seeking to eliminate the corruption of which you speak, Mr. President in New York. Corruption cannot continue to reign in water affairs in this country. … We celebrate the victory of the existence and permanence of our territory for which we have fought tirelessly with painful costs, irreparable losses, corruption, irregularities, and serious human rights violations. It is the result of our struggle, of our collective effort, of our hopes in other possible worlds." In response, the President acknowledged and exalted their movement "I think your struggle is exemplary: for a long time – many years – you persevered, and you achieved the goal of not flooding these three towns. This is quite an achievement."

What is left for Guadalajara and León now without the supply augmentation project? A key lesson of Chapter 2 is that conflict resolutions and agreements that do not address the root problems that cause them in the first place will not be durable; they will simply defer the conflict in time and/or space. Although the spillway solution will resolve the conflict

[18] A polite phrase to replace a common Mexican phrase "hija de la chingada", which denotes a fiery and incontrollable person.

of Temacapulín, it remains unclear how León and Guadalajara will solve their water supply problems. For instance, it is not precisely clear if there are nearby sub-basins with surplus water available to replace the Zapotillo project. If both cities do not implement alternative water supply solutions, the resolution of the Zapotillo conflict can lead to future conflicts between Jalisco and Guanajuato. Will the government of Guanajuato defy the water allocation agreement of 2004 to protect Lake Chapala (see Chapter 2 of this thesis) and develop a water supply augmentation project in the Lerma River?

Only time will tell if this unexpected outcome leads to a future water conflict or a long-lasting change in water management decision making and opening up the decision space of alternative solutions to water supply in Guadalajara and León. In the meanwhile, Temacapulín, Acasico and Palmarejo's extraordinary and unprecedented success may encourage other grassroots movements to keep on against all probabilities, to let them dream that, as the Dutch say, de *wonderen zijn de wereld nog niet uit*.[19]

6.4 FINAL REFLECTION ON THE ROLE OF SCIENTISTS IN SOCIETY

It is clear that scientists' main goal is to advance science. Scientific careers and salaries depend on demonstrating their (quantitative) contributions to science. There are numerous courses on how to improve scientific skills to get better at writing proposals, scientific papers, presenting at conferences, designing posters, etc. However, it is much less clear role a scientist has to play in society. What exactly does it mean to have a social impact? And more importantly, why and how?

I will answer these questions through my own personal experience and through the reflection with an interview with Bich Tran who approached me to get to know my research and impact. PhD programmes and scientific projects mainly consist of developing new ideas (technologies, approaches, perspectives) and later find what can be its social relevance or how it can contribute to solving some social problems. The other way around tends to be more of an exception: finding an acute social problem and then find how contributing to solve it can also contribute to science, be scientifically relevant and innovative. It is arguable if both approaches can be comparable, or if one is better than the other, but the truth is that is more difficult to find PhD programmes like the latter.

Personally, I had the privilege to choose the latter PhD model since my PhD was funded by the Mexican government. That gave me the freedom to choose the case study I wanted and, to a certain extent, how I wanted to study it, which perspectives and tools to use. I know for a fact that other PhDers do not have that luxury. On many occasions, I met

[19] English translation: Miracles still happen in the world.

PhDers dissatisfied with their research because they did not see much social relevance in it, beyond publishing some papers to elevate their career indicators. I actually met some colleagues that found more meaning in volunteering to applied research projects than their own PhD research project, which was perceived as a burden.

I believe this is the case because we humans find more existential meaning in serving others than serving ourselves. To put it simply, it is more meaningful to give than to receive. And to invest four years and even more in a PhD can become a more pleasant journey when one has worked and served for the benefit of others.

In my case, I knew that I needed to make my research actionable to find meaning in the substantial effort that represents obtaining a PhD. I knew not since the start of my PhD how I was going to exert an impact, if any; I just knew I needed to try it, be it small or big. Therefore, my ambition was, in a way, quite small. The idea was not to arrive at a destination, but to set the direction. Knowing the right way can be more valuable than presupposing the destination. It is understandable that universities seek to reduce failure rates of PhDers by establishing clear goals and objectives, but it should not be at the expense of reducing the risks, freedom, and sense of meaning of the PhD journey.

In the case of the grassroots movement and their long journey to success against all odds, I dare not to presuppose what was my precise contribution. However, if some clues give me some indication, is that opposing such a large project, allegedly to the benefit of millions of fellow citizens can be a harsh burden to carry. And having the solidarity of experts and scientists contributing to their cause by counselling them into the murky waters of decision-making, expert knowledge and language, uncertainty, and complexity, can be a huge relief for them.

When Bich interviewed me, she asked me what I could advise PhDers who may venture into increasing their social impact with their research. And my answer was to let go for a moment their position of experts and listen. People will tell you what they need, if one can only listen. Many scientists have the habit of presupposing solutions and shove them without knowing if people need such solutions. Sometimes what is needed is much simpler. Disposition to listen and serve those who have never been listened to nor served.

7

CONCLUSIONS AND RECOMMENDATIONS

7.1 MAIN CONCLUSIONS OF THE RESEARCH

This thesis aimed at answering the following questions:

- How are water paradigms affecting, and affected by water conflicts? Can paradigms be challenged, and if so, how and to which extent?
- Which kind of influence/challenge do scientists face in their practice when requested to play a significant role in water conflicts? How does that influence further translate into the artefacts and research design choices that scientists employ in their practice? Can some of these scientific tools and artefacts be refurbished and repurposed to give voice to the interests, positions, and propositions of previously unheard and marginalized actors in conflict?
- Can water conflicts have the potential to exert development pathway transitions to large and complex urban water systems? If so, what is the motivation of the actors in the conflict? Which challenges do they face? Which strategies do they follow? Which are deadends and which have the potential to flourish?

While Chapters 2 and 3 focused on answering the first two set of questions, Chapters 4 and 5 focused on answering the last set.

Chapter 2 analyzed the crises and conflicts of the Lerma-Chapala basin throughout the 20th century and offered four main conclusions. First, that the dominant notion of what constitutes the hydrological cycle in relation to society varies over time. The driving forces of this variation are the constant interaction, conflicts, and antagonisms between different groups of actors. In the case analysed in Chapter 2, during the first half of the 20th century, when the main objective of the Mexican government was to achieve food security, the hydrological cycle was seen as a mere component for food production, which could – and should – be optimized, even at the expense of biophysical processes such as the evaporation of Lake Chapala. The lake´s evaporation was seen as a waste, and dominant actors would act accordingly to reduce that waste by increasing water storage upstream in Guanajuato. This era in Mexico was known as the Hydraulic mission, whose mandate was that every drop of water should be used before being ‘wasted’ when discharged to the sea.

Second, hegemonic ideas do not exist without competition, other actors may have different conceptions of what the hydrological cycle is, and these actors come into conflict when the values derived from their own perspectives are affected. This clash of narratives is exemplified when the government had the intention of reclaiming land from Lake Chapala and environmental groups defended the lake under an environmentalist discourse that was in opposition to the government´s discourse based on the Hydraulic Mission.

Third, crises and conflicts have the potential to open up windows of opportunity for other actors to challenge the hegemonic notion of what constitutes the hydrological cycle. Thus, hydrological crises are not only biophysical and social but also political, since they question the validity of the sanctioned discourse, and allows for other actors to rise and posit an alternative discourse of what is it that constitutes the hydrological cycle in relation to society.

And fourth, scientific knowledge can also be influenced by the sanctioned discourse. The development of knowledge through hydrological models in the Lerma-Chapala case supported only one solution that involved farmers reducing their water use and discarded other possible solutions. The water shortage in the basin forced the social system to decide which economic activity to prioritise. Agriculture was seen as an inefficient activity and giving water to it seemed like a waste when compared to giving water to highly efficient cities. The 2004 water allocation agreement, supposedly based on scientific optimization, clearly favored Guadalajara´s interests despite the negative impact of the farmers of Guanajuato.

Chapter 3 analysed the science-policy processes in the Zapotillo conflict and offered two main conclusions. The first conclusion, closely related to Chapter 2, is that conflict resolutions and agreements that do not address the root problems that cause them in the first place will not be durable; they will simply defer the conflict in time and/or space. As the Lerma-Chapala conflict did not reach a satisfactory conclusion, the conflict moved to a different sub-basin when the government devised the Zapotillo water transfer project.

The second conclusion is that scientific knowledge can be influenced by politics by asking a leading research question that is only relevant to one actor in the conflict, and, as a consequence, the conflict becomes more intractable. In the Zapotillo conflict, the research question posed by the international team of UNOPS seemed to be how to optimize the Zapotillo project to guarantee water supply to Guadalajara and León? The question was leading as in all of the scenarios it tacitly implied the presence of the dam as the only solution to the water scarcity problem of Guadalajara and León. The team of researchers neglected to consider alternative strategies proposed by the opposing actors, such as demand management or alternative and low-scale supply augmentation infrastructure like rainwater harvesting. Therefore, the opposing actors perceived these research design choices as a result of partisan science, entrenching their positions even further. However, other actors opposing the project also engaged in partisan science by realizing haphazard and unsubstantiated analyses.

If Chapters 2 and 3 provided a bleak image of the many challenges and socio-political dynamics preventing actors to achieve agreements towards a more sustainable and socially just pathway in the water systems, Chapter 4 and 5 described the strategies and capacities that some actors develop to exert change in troubled urban water systems.

Chapter 4 employed a critical perspective to analyse whether the urban water systems of León and Guadalajara were immersed in a supply-demand cycle (Kallis, 2010), and participatory modelling to elicit the role of water conflicts and grassroots movements in interfering with this cycle. The chapter offers two conclusions. First, the historic analysis of the urban water systems of León and Guadalajara revealed that the development model of both cities is based on a continued population and economic growth, and that the Zapotillo project would probably foster a further water demand increase. This cycle renders any supply augmentation solution ineffective in the long run, since a new supply augmentation will be required to meet the future water demand it caused. Moreover, urban water systems become more dependent on external sources of water, as well as more vulnerable due to hydro-climatic trends in cases of drought.

Second, the use of participatory modelling showed the potential of this tool to elicit a wider decision space in a water conflict by integrating knowledge on alternative solutions. Therefore, the chapter concludes that in the socio-hydrological conceptualization of the supply-demand cycle, water conflicts driven by grassroots movements should be considered as a heterogeneous and highly political societal response to the continued development of new water sources for cities.

Chapter 5 analysed the development of the grassroots movement led by inhabitants of the dam-affected communities and yielded two conclusions. First, when actors opposed to the sanctioned discourse enjoy a high social legitimacy, as is the case for the dam-affected communities led by inhabitants of Temacapulín, their grassroots movement begins to incorporate actors of different social dimensions. These include social, political, technical, and academic actors. Therefore, the grassroots movement followed a network strategy. The close contact between these motley actors challenges and influences the original perception and position of the initial actors, in this case, the dam-affected communities.

Based on these interactions, the grassroots movement transitioned from opposing an infrastructure project to rejecting the water paradigm as a whole, of which the project is only an expression, and proposing an alternative water paradigm based on more social and environmental values. However, and this is the second conclusion, the main challenge of the grassroots movement is to engage with the technical challenges and implications that are related to transitioning to a different socio-technical system and discuss and negotiate in technical terms with the water managers of the current socio-technical water system.

7.2 Contributions to science and recommendations for further research

This research has contributed to the following scientific fields: water conflicts, transition management, science-policy processes, socio-hydrology, and transdisciplinary action research. To the field of water-related conflicts, this research pointed out that there is a gap between two different approaches, one that we call data-driven approach, and the other based on political ecology. This divide is so profound that major publications of each approach ignore the other (cf. Rodriguez-Labajos & Martínez-Alier, 2015, and Mach et al., 2020). This has created blind spots in each approach that are rarely addressed.

The contribution of this research to the field of water conflicts is that between these two approaches lies a large space of opportunity to learn more about water conflicts, their causes, processes, outcomes, reverberations, resolutions and especially transformations. The analysis of the case of the Zapotillo conflict has shown that, although the conflict can be traced back to episodes of drought in the Lerma-Chapala basin – a kind of event overemphasized by the data driven approach -, the conditions that worsen the effect of these events of drought are anthropogenic. And these conditions are created by sanctioned discourses that determine practices, preconceived ideas, the decision space, and power dynamics – the conditions that are thoroughly analysed by the political ecology approach.

However, the analysis of the actors in the conflict has shown that it is necessary to explore beyond the limits of the knowledge coordinates of the current paradigm. This means, on the one hand, that when the data-driven approach recommends recipe-like solutions like obvious remedies without further exploring power dynamics, it is acritical, even unaware, of the limits imposed by the paradigm. On the other hand, when political ecologists criticize the recipe-like solutions at hand and point to the prevalence of power dynamics as a never-ending challenge, they seem to be aware of the limits of the paradigm, but dare not cross them to propose something new, in fear of becoming victims of the prevailing power dynamics they denounce. There is a great opportunity in researching water conflicts through a transition management approach that dares at supporting grassroots movements to propose and develop bottom-up solutions that are both technically sound and aware of power dynamics, but outside of the current decision space. Further research would need to test how transdisciplinary tools like participatory modelling could have a positive effect in transforming conflicts.

Thirdly, this research has also contributed to the field of science-policy processes in contexts of conflict. Although there is a large literature that states how scientific knowledge is often used in a top-down manner to provide legitimization to controversial issues and conflictive situations (Schneider & Ingram, 1997; Budds, 2009; Brugnach et al., 2011; Boelens et al., 2019), the findings of this research point out that unsubstantiated knowledge, or, at least, knowledge with critical uncertainties and ambiguity, is also used in a bottom-up manner by non-hegemonic actors to further their positions and interests. This is of great concern, because, as suggested by Chapter 3, this biased knowledge developed by both hegemonic and non-hegemonic actors may not care to address emergent socio-environmental problems for the sake of advancing their own political interests. Therefore, this is a research gap, since only the bias of knowledge generated by hegemonic actors has been the focus of political ecologists. Reflecting on our initial discussion of *Potentas* and *Potentia*, further research could address if and how grassroots movements also instrumentalize knowledge not for the sake of understanding the water system better or address unjust institutional and infrastructural arrangements, but to advance their interests. However, it is necessary to proceed with utmost caution in this respect since it is not advisable to deepen the power asymmetry between the actors.

Fourthly, this research contributed to the field of socio-hydrology, specifically by unpacking the supply-demand cycle experienced in cities that opt for implementing large-scale supply augmentation schemes in relation to conflicts and grassroots movements. The research combined aspects of socio-hydrologic and hydro-social approaches to show how specific hydrological, social, political and technical factors have led to a supply-demand cycle in the cities of Guadalajara and León, of which the Zapotillo project was a further expression of this phenomenon. The research further unpacked societal responses of the supply-demand cycle by considering the role of water conflicts and grassroots movements as feedback mechanisms that delay the implementation of large-scale supply augmentation projects and foreground alternative solutions. As a result, this research showed that the development pathways of cities can enter a crossroads that opens up their decision space with the potential to break the supply-demand cycle. This could inform the analyses of other case studies involving cities caught in the supply-demand cycle and pay closer attention to the social forces trying to transform it.

The last contribution involves the previous ones. If water conflicts require to be studied under a different approach than the two dominant ones (data driven and political ecology), and knowledge, albeit crucial, suffers from manipulation of both powerful actors and non-hegemonic actors, then it is necessary to design and conduct transdisciplinary and transformative action research. Both the highly technical discipline of socio-hydrology and hydrosocial studies recognize the need to engage with knowledge production that have more impact on the ground (Di Baldassarre et al., 2019; Zeitoun et al., 2020), but to date it is still not entirely clear how to design transdisciplinary research that makes use of different epistemologies and methodologies (Wesselink et al., 2015). Rusca & Di Baldassarre (2019) outlined possible pathways how social and natural sciences can further collaborate to increase social impact.

This thesis endeavoured to conduct transdisciplinary research, the results of which would not only contribute to science, but also be useful for the actors on the ground, substantiated by data, while also being aware of the power dynamics. There is an urgent need to support a transdisciplinary approach in conflict management, where technical tools, such as models and decision support systems, can offer the opportunity to non-hegemonic actors to show that their knowledge can also be valid and inform decision-making in water management. This is an imperative that goes beyond a sense of justice, as it creates the possibility of designing innovative systems that are more effective and sustainable than the tried-and-tested solutions of the current water paradigm. Transdisciplinary research could contribute to solve real world water crises and associated problems. As Rusca & Di Baldassarre (2019) stated, scientists have an ethical duty not only to interpret the world, but also to change it.

Although Baudrillard's iconoclastic position (1977), discussed in the introduction, may seem very extreme (to forget Foucault), this philosopher urges us to think outside the ontological framework where power is conceived only as mechanisms of domination and control. If power is in everything, then it is also within the same discourse that analyses power. To get out of this snake biting its tail, Spinoza proposes to think of power as the *Potentia* inherent to each human being to understand the world in freedom.

As a conclusion, I propose that scientists need to promote social transformations through a transdisciplinary alliance to develop knowledge that provides alternatives and can guide society – and also be guided by society – to paths that are appropriate to achieve sustainability and justice.

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APPENDIX A (CHAPTER 3)

SUPPLEMENTARY MATERIAL 1. DETAILED INFORMATION OF GUADALAJARA, LEÓN AND LOS ALTOS.

Table S1: Comparison of water demand and supply for Guadalajara, León and Los Altos (Source: CEA Jalisco, 2018; INEGI 2015; SAPAL, 2018; SIAPA, 2017; UNOPS, 2017)

	Population[1]	Total water supplied and per capita	Water source	Over-exploitation of aquifers[2]
León	1.5 million	2.56 m³/s (81 hm³/year) 140 l/cap/d	– **Aquifers** 2.42 m³/s (76.6 hm³/year) 95.3% – **Palote Dam** 0.13 m³/year (4.2 hm³/year) 4.7%	Deficit in Valle de León and Romita aquifers = 177 hm³/year
Guadalajara[3]	4.2 million	9.97 m³/s (313 hm³/year) 207 l/cap/day	– **Lake Chapala** 5.97 m³/s (188.5 hm³/year) 60% – **Aquifers** 2.72 m³/s (85.8 hm³/year) 27% – **Calderón Dam** 1.1 m³/s (35.4 hm³/year) 11% – **Local springs** 0.14 m³/s (4.6 hm³/year) 2%	Deficit in Atemajac and Toluquilla aquifers = 84.5 hm³/year
Los Altos	0.8 million	4.6 m³/s (146 hm³/year) 493 l/cap/d	– **Groundwater** 1.49 m³/s (46.9 hm³/year) – **Surface water** 3.14 m³/s (99 hm³/year)	Deficit in 17 aquifers = 155 hm³/year

1. This data is from 2015, the latest official data available.
2. The overexploitation counts all aquifer users, including agriculture and industry.
3. We consider only the municipalities of Guadalajara, Zapopan, Tonalá and Tlaquepaque.

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SUPPLEMENTARY MATERIAL 2. DETAILED INFORMATION ON THE KEY ACTORS IN THE CONFLICT.

Table S2. Detailed information on the key actors in the conflict.

Actor	Sector	Position
Universidad de Guanajuato	Academy	Although the university has not released any public position on the project, many of their academics and research groups have position themselves against the project, arguing that the project is not a reliable solution for León´s water scarcity.
Acción Colectiva	NGO	This NGO's area of influence is Guanajuato and promotes democratization of decision-making on water resources. They are against the project because they see it as an imposition.
Guanajuato's government and State water authorities	Government	This actor has been consistently lobbying for the project throughout many administrations since the 90s.
León municipality and SAPAL	Government	This is León's water utility and have publicly declared to be in favour of the Zapotillo project as central to the city's future water security.
Guanajuato's business associations	Social actor	Most of Guanajuato's business associations have publicly declared their support for the Zapotillo project, arguing that it is instrumental for León´s development.
ITESO (Jesuit University of Guadalajara)	Academy	This university has publicly released their position against the project, arguing that it is not based on principles of Integrated Water Resources Management nor respect to human rights, and that Mexican society should transit to a new water management approach based on demand management, instead of large infrastructure.
Universidad de Guadalajara	Academy	This university has publicly released their position against the project, arguing that the project is unfeasible based on the increasing water scarcity and higher temperatures in the donor basin, as well as the absence of an environmental management plan of the region.

Temacapulín	Social actor	As one of the central actors of the conflict, Temacapulín's representatives have always been against the Zapotillo dam to protect their communities from displacement.
IMDEC	NGO	IMDEC is an actor that has been supporting the affected communities of Temacapulín, Acasico and Palmarejo.
Colectivo COA	NGO	This NGO specializes in legal support for affected communities of large projects. As such, they have provided legal support to Temacapulín, Acasico and Palmarejo.
Animal farmers' associations of Los Altos	Social actor	Many associations from Los Altos have publicly been against the water transfer, arguing that the region is already affected by water scarcity.
Observatory	Social actor	Although from recent creation, the Observatory has been adamantly against the water transfer, arguing that the donor basin is already affected by water scarcity and that the region is the most important producer of animal protein in the country.
Universidad Panamericana	Academy	This university has publicly released their position in favour of the project, arguing that it is key to the water security for Guadalajara, León and Los Altos.
Universidad Autónoma de Guadalajara	Academy	This university has publicly released their position in favour of the project, arguing that domestic use has priority over other kind of uses.
Chamber of the industry of construction of Jalisco	Social actor	This actor has publicly released their position in favour of the project, arguing that the benefit of the majorities should prevail over the benefit of the minorities.
College of civil engineers of Jalisco	Social actor	This actor has publicly released their position in favour of the project, arguing that it is the only feasible solution to guarantee water supply to Guadalajara, León and Los Altos.
SIAPA	Government	Guadalajara's water utility has publicly declared its support to the project as a key element in the city's water security.
Jalisco's government and State water authorities	Government	Its position has changed over time from supporting different configurations of the Zapotillo project, but always supported the project.
Conagua	Government	The official position has changed from implicitly favoring the project to being neutral when the latest administration took over.

IMTA	Government	The official position has changed from implicitly favoring the project to being neutral when the latest administration took over.
Municipality of Cañadas de Obregón	Government	This is the municipality where the Zapotillo dam is located. Because the duration of local administrations lasts only three years, there has been many administrations throughout the conflict. Some majors have shown support for the communities of Temacapulín, Acasico and Palmarejo, while others have remained neutral, or at least with low profile.

SUPPLEMENTARY MATERIAL 3. DETAILED INFORMATION OF THE UNOPS´ VERDE RIVER BASIN MODEL.

UNOPS model of the Verde River basin is developed in WEAP software. This is a water planning software, functioning with the principle of water balance accounting. The software analyses the diverse water supply sources, as well as the withdrawal and transmission to water demand nodes. To start the analysis the software needs a "time frame, spatial boundary, system components and the configuration of the problem." (WEAP, 2020). The software uses two main features to analyze the water resources system. One, called 'Current accounts' analyses the present water demand, resources and supplies based on economic, demographic, hydrological trends to present a snapshot of a business-as-usual scenario. The other explores scenarios to evaluate different strategies such as supply augmentation or demand management.

To create the model, it is necessary to delimit the area and establish the system boundaries. UNOPS first delimited the study area to that of the Verde River Basin, which was 21,495 km^2. The main natural variables that condition the models is percolation, precipitation, run-off, evapotranspiration, infiltration, and interflow, while the variables derived from manmade interventions are reservoirs, groundwater draft, water transfers, water demand, derived flows and returns. UNOPS used the data of Table S3 to fill these variables. The basic parameters used by WEAP are the monthly variation of demand, climate data, and then uses the MABIA water balance method to compute the water balance. This method is based on the two-bucket structure that processes the root zone as the top bucket and what is below the root zone as the bottom bucket. The model proceeds to process 8 necessary steps to compute the water balance: 1) reference evapotranspiration, 2) soil water capacity, 3) basal crop coefficient, 4) evaporation coefficient, 5) potential and actual crop evapotranspiration, 6) water balance of the root zone, 7) irrigation, and 8) yield. Groundwater is calculated with through nodes that compute the natural recharge flows (the top bucket), demand returns, infiltration losses from aqueducts and reservoirs and river recharges as flows that replenish the groundwater storage, and groundwater draft and base flows are computed as flows that deplete groundwater storage.

Then, since the software is configured to create semi-distributed models, UNOPS created 18 sub-regions that were characterized by a similar climate by using data mentioned in Table S3 through GIS extrapolation procedures. To ascertain the validity of all these sub-regions, UNOPS integrated the following data layers of all 18 sub-regions: 1) the hydrographic network, 2) the artificial regulation and monitoring system (dams, sluices and hydrometric stations), 3) the overlaps of the limits of aquifers with the density of surface and groundwater extractions, 4) soil and soil cover characteristics, and the climatic distribution within the basin (UNOPS, 2017).

For the first layer, UNOPS used specialized algorithms to process in a digital elevation model a hydrographic network. For the second layer, the model used CONAGUA´s observed data of 7 reservoirs (flows, volume, and storage levels) and 8 hydrometric stations; this data was used to calibrate the model. For the third layers, CONAGUA´s georeferenced database of water rights (REPDA) was used to determine hotspot areas of groundwater draft. With the fourth layer the model was able to process the relation with the upper and bottom buckets of the MABIA water balance method, and used SGM´s, SSN´s, INEGI´s and CONAFOR´s data for the soil characteristics, and CLCICOM´s and INIFAP´s data for the climatic distribution.

Table S3. UNOPS´ Verde River Basin model variables (source: UNOPS, 2017).

	Source	**Spatial resolution**	**Temporal resolution**
Climate	CLCICOM (CONAGUA-SMN)	315 stations including a buffer of 50 km outside the contour of the basin	Daily (1943-2014)
Hydroclimatology	INIFAP	105 stations including a buffer of 50 km outside the contour of the basin	Monthly (2002-2014)
Hydrometry in rivers and reservoirs	BANDAS (CONAGUA)	Timeseries of 8 hydrometric stations	1941-2016
Groundwater	CONAGUA/GRACE	Studies of 21 aquifers of the region. Satellite images (1 pixel = 200 km^2)	1997-2010

Soil Cover	INEGI, CONAFOR	Soil cover maps 1:50,000, irrigation district maps 1:250,000, and images of SPOT 6 and 7	2012-2016
Water demand	REPDA (CONAGUA)	All georeferenced surface and groundwater rights	2016
Geology	SGM, SSN	Maps 1:50,000 and 1:250,000	2007
Population/returns	INEGI	Population of towns with more than 2,500 people	2010
Digital Elevation Model	CEM v2.0	Raster with resolution of 15m (1:20000)	2013

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APPENDIX B (CHAPTER 4)

SUPPLEMENTARY MATERIAL. DETAILED DESCRIPTION OF THE PARTICIPATORY MODELLING PROCESS.

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 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.

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). 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 infrastructure).

The model´s main assumptions

The water resources model of the Verde River Basin (the donor basin of the Zapotillo project) and Guadalajara and León (the recipient regions) that we used in the participatory modelling workshop is based on an existing water resources model developed by a team of experts from the United Nations Office for Project Services (UNOPS). This institution was hired by the government of Jalisco in 2014 to develop a model with the intention to improve science-policy processes and resolve the water. This model was developed in WEAP21 software to explore an optimal configuration of the Zapotillo project by developing scenarios with different configurations of dam heights and allocated water to Guadalajara and León (for more information on the history of this model in the context of the conflict consult Godinez Madrigal et al., 2020). We requested and received the complete model by the end of 2017. We thoroughly analyzed the model and systematically documented all its assumptions and what we consider its pitfalls and inconsistencies (Godinez-Madrigal et al., 2020). Based on our own assessment and the calibration and validation described in UNOPS (2017) we decided to invest our resources to improve the model instead of creating a new one.

We implemented two important changes into the model. In the first one, we expanded the system boundaries, and for the second, we developed and included alternative solutions to the Zapotillo project for urban water supply for both cities Guadalajara and León. Related to the first change, whereas the original model considered only the Verde River Basin, we incorporated the main social and hydrological variables occurring in both Guadalajara and León. For Guadalajara we added its main water supply sources: Lake Chapala, local springs and the Calderón dam (total yield: 7 m^3/s) and groundwater (3 m^3/s). We also added the average rainfall of the city and the depletion and recharge rate of the groundwater. In the case of León, we also added its main water supply sources (aquifers, 2.3 m^3/s, and the Palote dam, 0.5 m^3/s), the average rainfall and the depletion and recharge rate of its groundwater resources. Finally, while the original model considered environmental flows only for downstream the Zapotillo dam site; we calculated the environmental flows of the Verde River as a tributary of the Santiago River.

In the second change, we developed five alternative strategies to the Zapotillo project for addressing water scarcity in Guadalajara and León, and one strategy to prioritize environmental flows rather than urban water supply. These strategies were inspired by the interviews with key stakeholders of the conflict and the participatory observation of several stakeholder workshops and meetings during 2017.

Table S1 describes all these strategies and the values we used to run the scenarios. Firstly, we considered the four main configurations of the Zapotillo dam (decommissioned, 60 m height, 80 m height and 105 m height). Then, we considered the combination of these four Zapotillo dam configurations with alternative strategies in the following way: 1) the dam configuration with the implementation of only one kind of strategy (supply augmentation, demand management and water reallocation); 2) the dam configuration with the implementation of two different kind of strategies working simultaneously; and 3) the dam configuration with the implementation of three different kind of strategies working simultaneously. Finally, we ran all those scenarios prioritizing environmental flows.

Given the common resistance of water utilities to innovate, we restricted the simultaneous number of running alternatives to three (from the five we developed). We ran five groups of scenarios. For the first group we combined the alternative strategies with the 105 m dam and allocated the water volume according to the 2007 water allocation agreement (UNOPS, 2017) with and without environmental flows, which resulted in 30 scenarios. For the second one, we combined the alternative strategies with the 80 m dam and proportionally reduced the allocated water volume according to the 2007 allocation agreement with and without environmental flows, which resulted in 30 scenarios. For the third one, we combined the alternative strategies with the 60 m dam and decreased the water allocated in proportion to the reduction in storage volume of the reservoir with and without environmental flows, which resulted in 30 scenarios. For the fourth one, we considered only the combination of alternative strategies to supply water to Guadalajara and León, which resulted in 15 scenarios. And finally, we considered the three dam configurations with and without environmental flows, and without implementing any of the alternatives, which resulted in 3 scenarios. The characteristics we tested for each are shown in the repository for data availability.

Table S1: Summary of all strategies analyzed

New model input parameters	**Values**	**Strategies**	**Sources of calculated values**
Dam´s height and transfer volumes	• 105 m (León (L) = 3.8 m^3/s, Los Altos (A) = 1.8 m^3/s, Guadalajara (G) = 5.6 m^3/s)[20]	Supply augmentation	UNOPS (2017)

[20] The original allocation agreement states that Guadalajara would receive 3.0 m3/s out of the Zapotillo dam. However, the state water authority calculated that at least 2.6 m3/s of run-off is generated in-basin downstream of the Zapotillo dam, which besides the 3.0 m3/s (5.6 m3/s in total) can be transferred also to Guadalajara.

	• 80 m (L = 1.7 m^3/s, A = 0.8 m^3/s, G = 3.9 m^3/s) • 60 m (L = 1.6 m^3/s, A = 0. 72 m^3/s, G = 2.6 m^3/s) • Decommissioned dam		
Rainfall harvesting and stormwater management	Average historic rainfall for Guadalajara and León, plus the capacity of 50% of households to install rainwater harvesting systems, and cities to develop injection wells and urban trenches and bio-retention ponds.	Decentralized supply augmentation	Garrison et al., 2009; Page et al., 2010; Jarden et al., 2016; Escolero Fuentes et al., 2017; Jiang et al., 2017; Urías-Ángulo 2017; Vanegas 2017; Saraswat et al., 2016; Gleason et al., 2018; Tagle-Zamora et al. 2018; Conagua, 2019; Nguyen et al., 2019.
Reclaimed wastewater potential for industries + Reduction of water demand through implementation of water-saving devices	Average of 20% reduction in water demand for Guadalajara and 5% for León (see supplementary material)	Demand Management	Bidhendi et al., 2008; Furumai, 2008; Jimenez-Cisneros and Asano, 2008; Jimenez-Cisneros and Asano, 2015; Sharma & Vairavamoorthy, 2009; Velarde-Flores, 2017.
Reducing physical losses in the urban distribution system	Guadalajara reducing non-revenue water (NRW) from 32.4% to 20% León reducing (NRW32.77% to 15% water demand (see supplementary material)	Demand Management	Farley, 2001; Consejo Tarifario SIAPA, 2016; Molinos-Selante et al., 2016; Sapal, 2016; Liemberger & Wyatt, 2018; Marsalek et al. 2018.
Limits to urban and agricultural growth	Limiting urban growth to 1%/year, and limiting agricultural growth to 0%	Demand Management	INEGI, 2005, 2010, 2015; Martinez-Alier, 2005; Daly & Farley, 2010; Schneider et al., 2010; CEA Jalisco, 2015; IIEG Jalisco, 2017.
Transfer of inter-sectoral water rights	Re-allocate 20% of the volume of current agricultural water rights to the urban sector	Water reallocation	Richter et al., 2013; Richter, 2014; Hoogesteger, 2017.

Environmental flows	Prioritize environmental flows at the discharge to the Santiago fiver basin	Ecological protection	Salinas-Rodriguez, 2011; DOF, 2012

To assess the performance of the scenarios, we developed three meaningful indicators. According to the current objectives of Guadalajara and León, a first indicator is water supply coverage, and a second indicator is the rate of over-exploitation of groundwater. Other objectives are those of the actors opposing the Zapotillo project: avoiding the flooding of Temacapulín and protecting the environmental flows of the Verde River.

For water demand coverage we used the percentages of water demand covered by the hybrid infrastructure systems for both cities. Then, we filtered those systems when the average coverage over the 55 years was more than 95% for both cities.

Then, we assessed the sustainability of aquifers by taking the final result of the aquifer storage capacity and divided it by 55 (the number of years the model runs), to get the average yearly change of storage capacity. Then, we converted that result into the proportion of its current over-exploitation rate. A result of 100% would indicate that the over-exploitation persists at the same current rate, and 0% would indicate the hybrid system reversed the over-exploitation.

Related to the negative effects in the donor basin, for the indicators of unmet water demand and environmental flow requirements, we collected the monthly results and averaged them.

Lastly, we indicate what would be the situation regarding the communities and their potential flooding: a dam decommission, and a 60 m height dam do not flood the communities; an 80 m height dam would require additional infrastructural measures to avoid flooding the communities, such as levees; and a 105 m height dam would inevitably flood the communities.

Supply augmentation strategies

These strategies consist of centralized and decentralized supply augmentation systems. The centralized system consists of the different operational strategies of the already existing infrastructure of the Zapotillo dam. The decentralized supply systems consist of rainwater harvesting.

For the centralized systems we considered that the Zapotillo dam is already built at 80 meters height and was originally designed to be the water source solely for León. However, the water authorities and state and national governments are proposing to increase its height to 105 meters to supply water for both Guadalajara and León. The communities affected by the dam's reservoir have proposed to restrict its operational use to only 60 meters height to keep the communities from flooding. Other groups of actors have proposed for the decommissioning of the Zapotillo dam.

Table 1 presents the main characteristics of all these operational configurations of the dam. The information on water allocations was calculated under the principle of proportionality of the water allocation agreement (DOF, 1997).

Table 2. Proposed options for the dam variable.

	Decommissioning the Zapotillo dam	**Zapotillo dam 60 m**	**Zapotillo dam 80 m**	**Zapotillo dam 105 m**
Storage capacity	none	146 m^3	411 m^3	911 m^3
Operational storage	none	146 hm^3	352.5 hm^3	852.5 hm^3
Minimum volume	none	58.3 m^3	58.3 m^3	58.3 m^3
Situation with Temacapulín Acasico and Palmarejo	The communities are spared	The communities are spared	Acasico and Palmarejo are flooded, and to spare Temacapulín 10 m dikes need to be built	All communities are flooded

For decentralized systems we considered rainwater harvesting. The rainwater harvesting strategy is based on Gleason-Espíndola et al. (2018), who calculated Guadalajara's potential for rainwater to be 21 hm^3/year. In the case of León, Tagle-Zamora et al. (2018) calculated León's potential to be 9.7 hm^3/year. This difference is due to the precipitation patterns and the number of households currently counting with cisterns. However, this potential for rainwater harvesting is constrained by a marked seasonal precipitation pattern in just five months of the year (June, July, August, September and October).

Stormwater harvesting has also been proposed as a strategy by local university researchers in Guadalajara (Urías-Ángulo 2017; Vanegas-Espinoza 2017). Moreover, IMTA, the technical branch of the Mexican water authority compiled a book of all the pilots that are currently tested around the country to promote this technology as a viable solution to groundwater recharge (Escolero et al., 2017).

Water demand management strategies

Three strategies were selected: a) wide installation of water saving devices in urban households for Guadalajara and León; b) reduce physical losses in the urban water distribution system of both cities; and c) limit the urban growth of Guadalajara and León, as well as the agricultural production of Los Altos.

The first strategy was proposed by Conagua in a workshop in November 2018. (i.e., Sharma and Vairavamoorthy, 2009). We consulted national and international studies on the potential for decreasing water demand in urban settings through water-saving devices (Bidhendi et al., 2008; Sharma and Vairavamoorthy, 2009; Velarde-Flores, 2017), and also consulted the costs of such devices in the Mexican market (Gobierno de la Ciudad de México, 2009). We estimated that a wide adoption of these devices could reduce 20% total water demand for Guadalajara, but only 5% for León.

Reclaimed wastewater has already been adopted by the water utilities from Guadalajara at a very low scale, with industries reusing wastewater equivalent to 0.13% of its total water demand; and León with a large-scale reuse of wastewater by farmers, industries and watering green urban areas equivalent to 23% of its total water demand. Therefore, the larger potential for reclaimed wastewater lies in Guadalajara. Since reclaimed wastewater can only be reused for non-human consumption and restricted to industries and irrigation (Furumai, 2008; Jimenez-Cisneros and Asano, 2008; Jimenez and Asano, 2015).

The second strategy, reducing physical losses, was lobbied by NGOs and researchers from the University of Guadalajara. Guadalajara and León have more than 32% rate of physical losses (Consejo Tarifario SIAPA, 2016; Sapal, 2016). A natural strategy would be to reduce the physical losses in the distribution system before considering supply augmentation schemes. To design a coherent alternative we reviewed literature and material from Liemberger & Wyatt (2018) and Marsalek et al. (2008), as well as official data from SIAPA (2020) and SAPAL (2016) to find the costs for the strategy. We found that Guadalajara and León currently perform passive physical losses reduction based on reported (and visible) bursts characterized by large flow rates and short run times. What has been unattended are unreported bursts, which are non-visible, smaller but with a long run-time (Liemberger & Wyatt, 2018). These invisible leaks are only detected through an active program through specialized equipment. Water utilities can reach a level of 20% of physical losses if a combined approach of pressure management, pipe repair, and district-metered areas are employed (Farley, 2001; Molinos-Senante, Mocholí-Arce and Sala-Garrido, 2016).

Finally, during the stakeholder workshop in 2017, Temacapulín's activists complained that the unrelenting urban growth from Guadalajara and León demanded natural resources from the nearby rural areas. Therefore, as an effort to stop the negative effects to rural areas, the cities must have a limit to growth. This idea was in line with the idea of degrowth by ecological economics scholars (Daly & Farley, 2010; Martinez-Alier, 2005; Schneider et al., 2010). Therefore, we developed this strategy based on limiting the population growth of Guadalajara and León by 1 %/year. We used official data (INEGI, 2005, 2010, 2015; CEA Jalisco, 2015; IIEG Jalisco, 2017) to get the current population trends of both cities.

Water reallocation

We investigated two different kinds of inter-sectoral water transfers: one based on Richter *et al.* (2013) and Richter (2014) who drew from international experiences on urban-rural partnerships, where the basic principle is that cities fund irrigation modernization and the saved water would we transferred to the cities. However, according to Hoogesteger (2017; 2018), irrigation modernization rarely reduces water consumption, therefore a better strategy would be to buy water rights from farmers. We operationalized this strategy by reducing 20 % agricultural water use to make it available for urban use.

Securing ecological flows

Since the original plan of Guadalajara is to take water from the Verde River at the point where it discharges to the Santiago River, there was a social concern of communities downstream the Santiago River that this would impact water quality and have negative ecological effects. We therefore developed a minimum river flow from the official norm (DOF, 2012).

APPENDIX C (CHAPTER 7)

SUPPLEMENTARY MATERIAL. IHE DELFT´S STATEMENT REGARDING CONAGUA´S PROPOSAL OF ZAPOTILLO DAM.

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Date
9 octubre 2021

Subject
Análisis y opinión de la propuesta de Conagua respecto a la presa El Zapotillo

El conflicto por el proyecto El Zapotillo es un tema trascendental para la gestión de agua y de conflictos en el Estado de Jalisco y en México. Dada esta relevancia, el grupo de investigación en gestión y gobernanza del agua del Instituto para la Educación del Agua de IHE Delft en los Países Bajos ha estudiado el caso por los últimos seis años con el proyecto doctoral de Jonatan Godinez Madrigal, y supervisado por Dra. Nora Van Cauwenbergh y el Pr. Dr. Pieter van der Zaag. El doctorante Godinez Madrigal es un científico mexicano nativo de Guadalajara que ha estudiado el caso bajo una perspectiva interdisciplinaria, la Dra. Van Cauwenbergh es una científica belga experta en planificación hídrica, y el Pr. Dr. van der Zaag es un hidrólogo holandés reconocido internacionalmente.

Este grupo de investigación ha seguido muy de cerca los últimos acontecimientos en el caso y el acercamiento y disposición del gobierno federal para poner fin a este conflicto social de más de 16 años. Creemos que esta disposición y voluntad política de la Conagua y el Gobierno Federal será clave para concretar una propuesta aceptable tanto para los pueblos afectados por la presa, así como para la ciudad de Guadalajara.

En aras de contribuir a la consolidación de esta propuesta, este equipo de investigación analizó y evaluó la propuesta presentada por Conagua el pasado 21 de agosto de este año. Sucintamente resumimos la propuesta de Conagua y presentamos cuatro puntos que a nuestro juicio la fortalecerán.

De forma resumida, la propuesta de Conagua consiste en preservar la presa como se encuentra actualmente a 80 m de altura, y modificar su gestión y operación para que los niveles de la presa nunca superen la altura del poblado de Palmarejo, que se encuentra a la altura más baja de las tres poblaciones afectadas. Sin embargo, consideramos que esta propuesta asume ciertas condiciones hidrológicas y de gestión del riesgo que pueden ser problemáticas en el futuro.

1) Los cálculos que determinan la gestión y operación de la presa El Zapotillo para salvaguardar la integridad de las poblaciones fueron hechos con un periodo de retorno de 70 años. Sin embargo, consideramos que asumir esta condición hidro-climática para esta propuesta puede ser muy riesgosa, especialmente al considerar el cambio climático. Como muestra, durante el verano de este año murieron más de 200 personas en Europa central producto de inundaciones con un periodo de

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retorno de 1,000 años.[1] Y en los Países Bajos el periodo de retorno para infraestructura para protección de inundaciones es de 10,000 años.

2) El sistema automatizado de compuertas que regularían los niveles de la presa presentado en la propuesta, aunque conveniente, tiene la desventaja de que para funcionar de forma óptima, debe ser propiamente mantenido durante décadas por personal capacitado. Existen varios casos internacionales bien documentados donde fallos en la automatización ha conducido a accidentes y han costado vidas.[2] Y en el caso de los Países Bajos se canceló la propuesta de automatizar las defensas contra inundaciones por no ser completamente confiables. Adicionalmente, estas compuertas pueden no estar diseñadas para un flujo tan extremo, lo que podría crear una falla estructural para la integridad de la presa.

3) La propuesta no considera el riesgo de combinación de eventos de baja probabilidad y grandes consecuencias. Aunque por separado, cada riesgo puede ser gestionado y propiamente prevenido, casos donde se subestimaron la combinación de varios eventos ocasionaron catástrofes al excederse la capacidad de todas las medidas de prevención.[3] Para el caso de la presa El Zapotillo, una tormenta con periodo de retorno incluso menor a 70 años, aunado con derrumbes de laderas de cerros y falla en el sistema automatizado de compuertas puede ser suficiente para ocasionar una catástrofe en las poblaciones de Temacapulín, Acasico y Palmarejo.

4) En virtud de los tres puntos anteriores, juzgamos necesaria la implementación de una medida de seguridad adicional. Es necesario reacondicionar la presa con un vertedor a una altura más baja que el poblado de Palmarejo. Este vertedor garantizaría la seguridad de los tres poblados aún cuando se presenten tormentas con periodo de retorno mayor a 1,000 años y la combinación con otros eventos perjudiciales a la operación y gestión de la presa El Zapotillo.

En conclusión, celebramos la disposición y voluntad de la Conagua y el Gobierno Federal para salvaguardar la integridad de las tres poblaciones, pero creemos que es necesario fortalecer la propuesta mediante el reacondicionamiento de la presa con un vertedor a una altura menor de Palmarejo. Esta obra adicional garantizaría la seguridad de las tres poblaciones al tiempo que aseguraría el abasto de agua a la ciudad de Guadalajara.

Jonatan Godinez Madrigal | Dra. Nora Van Cauwenbergh | Pr. Dr. Pieter van der Zaag

[1] German Floods Raise the Bar on Extreme Weather Events". The New York Times. 16 July 2021. Consultado el 9 de oct. de 21.

[2] Véase el reporte del Banco Mundial: Stip, C., Mao, Z., Bonzanigo, L., Browder, G., & Tracy, J. (2019). Water Infrastructure Resilience. Disponible en: https://openknowledge.worldbank.org/bitstream/handle/10986/31911/Water-Infrastructure-Resilience-Examples-of-Dams-Wastewater-Treatment-Plants-and-Water-Supply-and-Sanitation-Systems.pdf?sequence=1

[3] Véase el caso del reactor nuclear de Fukushima, la explosión en la plataforma petrolera Deepwater Horizon y el huracán Katrina: Park, J., Seager, T. P., & Rao, P. S. C. (2011). Lessons in risk-versus resilience-based design and management. *Integrated environmental assessment and management*, 7(3), 396-399.

LIST OF ACRONYMS

CEA Guanajuato	Comisión Estatal del Agua Guanajuato
CEA Jalisco	Comisión Estatal del Agua Jalisco
Conagua	Comisión Nacional del Agua
CONREDES	Consejo Regional para el Desarrollo de la Educación y la Sustentabilidad
COTAS	Consejo técnico de Aguas subterráneas
DOF	Diario Oficial de la Federación
EJOLT	Environmental Justice Organizations, Liabilities and Trade
FLCHS	Fundación Lerma-Chapala-Santiago
IMDEC	Instituto Mexicano de Desarrollo Comunitario
IMF	International Monetary Fund
IMTA	Instituto Mexicano de tecnología del Agua
INEGI	Instituto Nacional de Estadística y Geografía
ITESO	Instituto Tecnológico y de Estudios Superiores de Occidente (The Jesuit Univeristy of Guadalajara)
IWRM	Integrated Water Resources Management
MAPDER	Movimiento de Afectados por Presas y en Defensa de los Ríos
OECD	Organization of Economic Co-operation and Development
PRI	Partido Revolucionario Institucional
PAN	Partido Acción Nacional
RBC	River Basin Council
SAPAL	Servicio de Agua Potable y Alcantarillado de León

SIAPA	Servicio Intermunicipal de Agua Potable y Alcantarillado
UNOPS	United Nations Office for Project Services
WEAP	Water Evaluation and Planning System

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About the Author

Jonatan was born in Guadalajara, Mexico, and he has always been interested in Mexico's socio-environmental problems, and passionate to find new ways to address them. He first graduated from International Relations (2007) in ITESO, the Jesuit University of Guadalajara, where he learned how economics, culture, and politics influence international conflict and cooperation, but above all, the ethics of serving the underprivileged and the urge to transform the world. He worked in the Political Ecology research program of ITESO, where he met inspiring colleagues that soon became close friends. He then proceeded to study a master's in social sciences with specialization in Sustainable Development (2010) in the University of Guadalajara. He studied and analysed the socio-environmental complexity of the most polluted river in Mexico. He concluded that grassroots movements are key actors in transforming this bleak reality, because the configuration of legal, technical, and socio-political dynamics of actors maintained the polluted status quo of the Santiago River, Mexico.

For the next years, he embarked on a quest to actively change the state of the environmental problems of different parts of Jalisco. First, he co-managed a team of interdisciplinary researchers to understand the environmental problems of the Chapala basin, a region comprising several municipalities and Lake Chapala, the largest in Mexico. He proposed a route map based on territorial planning to ensure the sustainable development of the basin. Second, a colleague and he launched the project Recuperación de Ríos, funded by the Gonzalo Río Arronte foundation, to develop low-tech infrastructure through citizen science to provide clean water for rural communities.

In September 2015, he received a scholarship from CONACyT, the National Council of Science and Technology of Mexico, to embark his PhD at UNESCO-IHE. During his research, he decided to embrace inter- and transdisciplinarity by learning technical water knowledge and tools to better understand a water conflict and transform it. Through learning-by-doing, he familiarized with water resources models and other engineering tools to tinker and experiment new approaches and methods such as participatory modelling. He will try to keep his curiosity and passion intact for the rest of his professional career (and life) to pursue the extravagant and exhilarating sense of the possibility in the horizon.

Journals publications

Godinez Madrigal, J., Van Cauwenbergh, N., Hoogesteger, J., Claure Gutierrez, P., and van der Zaag, P.: The limits to large-scale supply augmentation: exploring the crossroads of conflicting urban water system development pathways, Hydrol. Earth Syst. Sci., 26, 885–902, https://doi.org/10.5194/hess-26-885-2022, 2022.

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, 24, 4903–4921 https://doi.org/10.5194/hess-24-4903-2020, 2020.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Production of competing water knowledge in the face of water crises: Revisiting the IWRM success story of the Lerma-Chapala Basin, Mexico. Geoforum, 103, 3-15. https://doi.org/10.1016/j.geoforum.2019.02.002., 2019.

Other peer-reviewed publications

Godinez Madrigal, J., van der Zaag, P., & Van Cauwenbergh, N. (2018). A half-baked solution: drivers of water crises in Mexico. Proceedings of the International Association of Hydrological Sciences, 376, 57-62. https://doi.org/10.5194/piahs-376-57-2018.

Other publications

Van der Keur, P., Van Cauwenbergh, N., Lopez-Gunn, E., **Godinez Madrigal, J**., Le Coent, P., Giordano, R2. (In Press). Concepts in Water Security, Natural Assurance Schemes and Nature-Based Solutions. In Lopez Gunn, E., et al., (eds.) Greening Water Risks: Natural Assurance Schemes. Springer

Ochoa-García, H., Arrojo-Agudo, P., **Godínez-Madrigal, J.,** et al.: Agua para el desarrollo regional en los Altos de Jalisco. Gestión del agua e impacto social del proyecto El Zapotillo. ITESO: Tlaquepaque, México, 2014.

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Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Los límites del aumento al abastecimiento de agua urbano. Explorando la encrucijada de las sendas de desarrollo de ciudades y cuencas, y el rol disruptivo de conflictos por el agua. Oral presentation at Diáspora Hídrica: Jóvenes Mexicanos Explorando las Fronteras del Agua, IMTA, Mexico, 2021.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Opening the decision space for stakeholders in large infrastructural projects. Oral presentation at the

International Environmental Modelling and Software Society Conference, Brussels, Belgium, 2020.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: La paradoja de la seguridad hídrica basada en presas y sus alternativas. Oral presentation at Jornadas de análisis científico para encontrar alternativas al abastecimiento de agua, Guadalajara, Mexico, 2019.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Transformación de conflictos y ciencia ciudadana. Oral presentation at Primer Foro de Medio Ambiente y Cambio Climático, Gobierno de Jalisco, Guadalajara, Mexico, 2019.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Mapeando controversias y alternativas: el rol político y emancipatorio de la construcción de conocimiento en conflictos por el agua, el caso del proyecto El Zapotillo, México. Oral presentation at the WATERLAT-GOBACIT X, Luchas por el Agua: Interseccionalidades de Clase, Género y Etnicidad, Concepción, Chile, 2019.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Power, data, modelling and decision making. Oral presentation at the International HH9 Empowering hydro-diplomacy, The Hague, The Netherlands, 2018.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: A half-baked solution: Drivers of water crises in Mexico. Oral presentation at the International Association of Hydrological Sciences, Port Elizabeth, South Africa, 2018.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Achieving urban water security: Can Science Solve Water Conflicts? The Case Study of Zapotillo Dam, Mexico. Poster presented at 2nd CSDS Conference: Critical Perspectives on Governance by Sustainable Development Goals: Water, Food and Climate, Amsterdam, The Netherlands, 2018.

Godinez Madrigal, J., Van Cauwenbergh, N., & van der Zaag, P.: Juggling with water scarcity. Hybrid modelling on water allocations, Poster presented at 34th International System Dynamics Conference, Delft, The Netherlands, 2016.

Netherlands Research School for the
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D I P L O M A

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The Netherlands research school for the
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(SENSE) declares that

Jonatan Godinez Madrigal

born on 29th November 1984 in Guadalajara, Mexico

has successfully fulfilled all requirements of the
educational PhD programme of SENSE.

Delft, 26 April 2022

Chair of the SENSE board

Prof. dr. Martin Wassen

The SENSE Director

Prof. Philipp Pattberg

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

The SENSE Research School declares that **Jonatan Godinez Madrigal** has successfully fulfilled all requirements of the educational PhD programme of SENSE with a work load of 46.1 EC, including the following activities:

SENSE PhD Courses

- Environmental research in context (2016)
- Systems thinking and systems simulation. Modelling dynamics feedback systems with Vensim (2016)
- Companion Modelling (2016)
- Research in context activity: "'Initiating and organizing for the IHE Wicked Debate series 'A tale of two disciplines: A conversation between sociohydrology and hydrosocial research to understand the dynamics of water and humans' (2017)"

Selection of Other PhD and Advanced MSc Courses

- Principles of integrated water resources management, IHE Delft (2015)
- Water conflict management, IHE Delft (2016)
- Water Accounting Plus, IHE Delft (2018)
- Leadership, teamwork and group dynamics & Achieving your goals and performing more successfully in your PhD, TU Delft (2016) & Becoming a creative researcher in academia, TU Delft (2016)
- Coaching individual students and project groups, TU Delft (2018)
- Creative tools for scientific writing, TU Delft (2019)
- Research Data Management & Software Carpentry Workshops, TU Delft (2021)

Management and Didactic Skills Training

- Supervising MSc student with thesis entitled 'Evaluating the role of participatory modelling in water conflicts.' (2019)
- Teaching in the MSc course 'Water Conflict Management & Water Resources Planning' (2020)

Oral Presentations

- *A half-baked solution: Drivers of water crises in Mexico*. International Association of Hydrological Sciences, 10-14 June 2017, Port Elizabeth, South Africa
- *Power, data, modelling and decision making*. HH9 Empowering hydro-diplomacy, 5-6 October 2018, The Hague, The Netherlands
- *Mapeando controversias y alternativas.* WATERLAT-GOBACIT X, Luchas por el Agua: Interseccionalidades de Clase, Género y Etnicidad, 7-11 October 2019, Concepcion, Chile
- *Opening the decision space for stakeholders in large infrastructural projects.* International Environmental Modelling and Software Society Conference, 15-16 September 2020, Brussels, Belgium

SENSE coordinator PhD education

Dr. ir. Peter Vermeulen

This thesis is about a number of rural communities resisting flooding and the eradication of their ancestry, history and culture by opposing the implementation and imposition of a large dam in rural Mexico that would supply water to two large cities. The importance of this case lies in the unlikely odds of not only resisting a State-led, large-scale infrastructure project for almost two decades, but also building a grassroots movement that grew in extent, scope and scale to advocate for a comprehensive water management transformation in Mexico. The scientific analysis of the conflict and this grassroots movement, informally dubbed 'Temaca', contributed to several scientific fields including water conflicts, transition management, science-policy processes, socio-hydrology and transdisciplinary action research. The analysis of the case study shows how politics influences science by defining a limited decision space that can only superficially address the serious water problems of large cities. As a result, cities follow a development pathway that may deepen their water problems in the long term. Therefore, water conflicts and grassroots movements play a crucial role in opening the decision space. This thesis demonstrates that through transdisciplinary action research, scientific knowledge can become actionable and relevant; addressing power asymmetries and finding sound alternative water management solutions that are more equitable and sustainable.

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