Building sustainable water policy through mapping Mexico City's water sector

A landscape of stakeholder perspectives on critical issues and proposed solutions to Mexico City's water crisis

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Executive Summary

Hundreds of years in the making, Mexico City's water crisis has very real and imminent consequences for the health, economic stability, and cultural legacy of the region and its residents. Formerly surrounded by lakes and canals that have long since been drained, the city faces both frequent flooding and water scarcity simultaneously. With a population of over 20 million that relies on dwindling water resources, there is a sense urgency from stakeholders across the water sector to address these pressing issues.

This stakeholder mapping project aims to capture perspectives and insights from actors in Mexico City's water sector to support a working group convened by Claudia Sheinbaum, the city's incoming mayor, in the development of a water sustainability strategy. Through desk research and qualitative interviews with 32 actors from academia, government, nonprofits/NGOs, and the private sector, we documented the varying priorities and visions of diverse stakeholder groups and the level of consensus on different topics within the water sector.

Our study shows that while there is not unanimous agreement on the most important water issues facing the city, several common themes emerged:

Aquifer Overexploitation and Resource Management

- Overexploitation of the aquifers is a pressing concern for nearly all actors included in this study
- Increasing dependence on imported water from other basins is unsustainable in the long run because it is costly, energy intensive, and undermines Mexico City's autonomy
- Urban sprawl is a significant impediment to aquifer recharge and reliable water service delivery

Water Consumption and Culture

- Water culture and education has improved in recent years as shown by increased public awareness of threats to water security as well as more engagement from citizens with issues surrounding water
- Translating increased awareness to consumer behavior change, however, requires financial incentives and charging end users the true cost of water

City-Level Regulation and Infrastructure

- There is currently a disconnect between pro-environmental policies and effective implementation
- Integration of green and gray infrastructure solutions offers the most promising path forward for the city to achieve water resiliency, though a small subset of actors strongly disagrees with this concept
- There is a need for increased data accessibility and transparency as well as dedicated resources to support watershed-level research and cross-discipline collaboration

Despite lacking a unified vision for Mexico City's water sector, we found that the majority of actors agree that the solution to Mexico City's current water situation is multifaceted and that no single measure can create the improvements necessary for full mitigation of the water crisis. Some proposed solutions have strong consensus amongst stakeholders interviewed, while other solutions are points of contention.

High Consensus Solutions

- In the axes of Information and Data, Water Forest and Culture & Education, most proposed solutions are common among the actors and the development of policies around this axes should be some of the quicker to be resolved by reaching consensus among all stakeholders.

Potential Consensus Solutions

- In the axes of Hydraulic Infrastructure, Bodies of Water, Rainwater Harvesting, and Governance & Policy most proposed solutions seem to have a common ground, however there exists significant variability among the concerns and implementation that further communication among stakeholders needs to happen before developing policies.

Low Consensus Solutions

- In the axis of Infiltration & Recharge the variability and uncertainty of proposed solutions are translated into an axis of potential conflict among stakeholders. Further studies and communication will need to take place in order to lower the conflict potential. However, this axis is identified as one of critical significance by the actors, therefore an early start for policy development is recommended.

Unchecked, Mexico City's water crisis will increase and populations in economically precarious situations will bear the brunt of the health, financial, and political burden. While it can be politically risky to implement water policies that require long-term investments and behavior change, we will present politically feasible solutions by demonstrating consensus among water sector stakeholders. By championing sustainable water policy, the Mayor Claudia Sheinbaum and her administration can improve resiliency and reduce inequality within Mexico City's watershed.

Introduction & Background

The water situation in Mexico City is a contradiction — a city that was once built surrounded by water is now “dry”. The city’s first establishments in precolonial times consisted of a series of canals and floating *chinampas* (arable land on shallow lakes) on an existing lake. The lakes have long since been drained and the city now sits on the lakebed. After each rain, which can occur daily in the rainy season, the lake seems to reappear in the form of flashfloods before the massive drainage system can drain it once again. Even though there often seems to be a surplus of water in the region, many of its citizens lack a reliable water supply and must operate as if they were living through a drought.

In the matter of water management, a series of decisions by the authorities in the last couple of centuries seem to follow a pattern in which the city constantly needs to import larger amounts of water to accommodate the growing population, then needs larger drainage systems to accommodate the increasing impacts from the rainy season. The specific challenges that drove most of the high-level management decisions in the past are well-summarized in Tellman et al.'s 2018 work entitled "Adaptive pathways and coupled infrastructure". The city has made a lot of progress in managing aquifer depletion and ground subsidence by lowering water extraction rates; increasing the percentage of treated wastewater used for irrigation by building one of the largest wastewater treatment plants in the world; increasing the percentage of the population receiving tap water from the distribution system; and in mitigating flashflood impacts by constructing large hydraulic drainage and pumping systems.

Previous work has shown that these types of advancements are feasible and that they can be successfully implemented: "Mexico City's water supply: improving the outlook for sustainability" (The National Academies Press, 1995), “Challenges and realities of water management of megacities: the case of Mexico City metropolitan area” (Tortajada, 2008) and “CDMX Resilience Strategy: Adaptive, Inclusive and Equitable Transformation” (CDMX Resilience Office: 100 Resilient Cities, 2016). These and many other studies listed in Appendix 4 have laid the groundwork for our work with Isla Urbana. While these studies are rich and deep in content, our client Isla Urbana also needed to know the perspectives of other stakeholders in the water sector regarding the issues and solutions surrounding the current state of affairs in the city.

Although much progress has been made, much work still needs to happen before the city reaches a sustainable state. The city continues to face complex challenges - an aging water infrastructure system that yields 40% water supply losses in the distribution system, an intermittent supply that cannot ensure consumers reliable water quality, and the fact that the rate at which the aquifers underneath the city are being recharged is currently unknown. Some of the areas for improvement, as previously identified by Isla Urbana during their field work and collaboration initiatives, are the implementation of green infrastructure such as stormwater retention sidewalks, fixing leaks with trenchless technology, and rainwater harvesting for local use. These solutions seem straightforward at first, but their implementation may be difficult because of conflicts with other stakeholders in the sector. For example, rainwater harvesting seems like a promising solution to prevent local flooding and aid water accessibility. However, conflict may arise among stakeholders concerned with the physicochemical quality and how people may be using the water.

In the last 15 years there have been new proposals, both citizen- and government-led, focused on improving water supply, controlling floods, recharging the aquifer, and more. Our client, Isla Urbana, is a good example of a venture that set out with a proposal to this end. Our project takes on the task of mapping these types of water sector projects that propose solutions to the current water crisis in Mexico

City and to find consensus and conflicts among the stakeholders. This project will inform the development of a water sustainability plan for the incoming mayoral administration and it will help our client build stronger relationships with other stakeholders in the water sector.

Methods

As a framework for our research, we divided the water sector into eight axes that capture the scope of the water crisis in Mexico City: hydraulic infrastructure, information & data, infiltration, governance & policy, water forest, bodies of water, rainwater harvesting, and culture & education. This framework was developed collaboratively with our client, Isla Urbana, and members of a water sustainability working group convened by the city's new mayor. Informed by their guidance and our own desk research, we developed a qualitative interview protocol that is organized around the eight axes (a profile of each axis can be found in Appendix 1). Over the course of our first three interviews with members of the working group, we made minor adaptations to the protocol to better meet our project goals.

We selected interviewees for our study based on suggestions from the working group, our background research on important actors in Mexico City's water sector, and recommendations of other relevant water experts from interviewees. Not all stakeholders responded to our requests for interviews while we were not able to interview others due to scheduling conflicts.

Over the course of our interviews, we sought to understand what different stakeholders consider to be the most viable solutions, greatest barriers, and biggest gaps for addressing long- and short-term challenges within each axis. We also explored consensus across the sector by asking each actor to allocate 30 points across the eight axes representing their belief in the relative importance of each. These 30 points were physically represented by beans, as suggested by our client, to increase deliberation over axis importance.

The interviews were conducted in person in Mexico City. Typically, two team members were present, with one team member asking the questions while the other took notes. Seven interviews were conducted by only one team member. All interviews were recorded with the permission of the interviewees, except for one interviewee who only allowed note-taking. The recordings were either transcribed by team members or outsourced to a specialized provider for the purpose of verifying our handwritten notes. Most interviews were conducted in Spanish or a mixture of Spanish and English. Our team has varying levels of Spanish fluency, from advanced written comprehension to native speaker. The team members who conducted the interviews in Spanish have previously used Spanish in a professional capacity. Some interviews were time-constrained, so we were unable to ask all of our questions on a few occasions.

We began collaborating with the Pacific Council on International Policy in July while we were still conducting interviews. They offered samples of policy reports and guidance on using human-centered design for our initial analysis of interviews. Based on their suggestions, we created 'insight statements' of interviewee responses, which helped us generate an initial summary report that was delivered to our client in August. Both Isla Urbana and Pacific Council on International Policy offered feedback on our preliminary analysis and summary report, which has been considered and incorporated in this report.

Building upon our initial analysis, we have since utilized traditional qualitative coding methods to conduct a more extensive analysis of our data. With support from Leon Espira, a Dow PhD Fellow, we brainstormed a coding strategy that included themes and subthemes within each axis. Our framework (included in Appendix 2) is based on our desk research and preliminary analysis of our interview data and was adapted as we coded interviews to capture the breadth of ideas discussed by the interviewees. We then assigned a primary axis, and if applicable, themes, subthemes, and a secondary axis to each insight or quote pulled from the interview transcripts.

Given the small sample size and qualitative nature of our study, we did not conduct statistical analysis on the data. Instead, we developed a simple Excel model to synthesize the frequency of certain themes and subthemes within each axis to highlight commons trends, which were examined further in a qualitative manner.

Results & Recommendations

When asked about the most critical issues in the city, actors seem to find most issues tied to infrastructure (Figure 1). In a way there is consensus there. The varying issues within infrastructure range from operation and maintenance to ideology of how people continue to think infrastructure is the only solution. Meanwhile, the responses to how to address the problems in each axis (Figure 2) shows a much more leveled percentage of actors proposing solutions to the water crisis. This difference in the bar graphs points at the variety of solutions that stakeholders are proposing to fix problems mostly blamed on the infrastructure axis. For example, flooding can be identified as an infrastructure problem, but its solution is being proposed under Infiltration and Rainwater Harvesting. By looking at these trends and in addition to the repetition of themes that resulted after our coding analysis, we were able to determine a level of consensus among actors within the same axis. An allocation of 30 points by the interviewees resulted in the chart in Figure 3. The conclusions drawn from the chart is that most actors indeed are aware of the relative importance of work done in other axes. This result also fits the conclusion that water management is a multi-dimensional challenge because of the multiple applications of water as a resource.

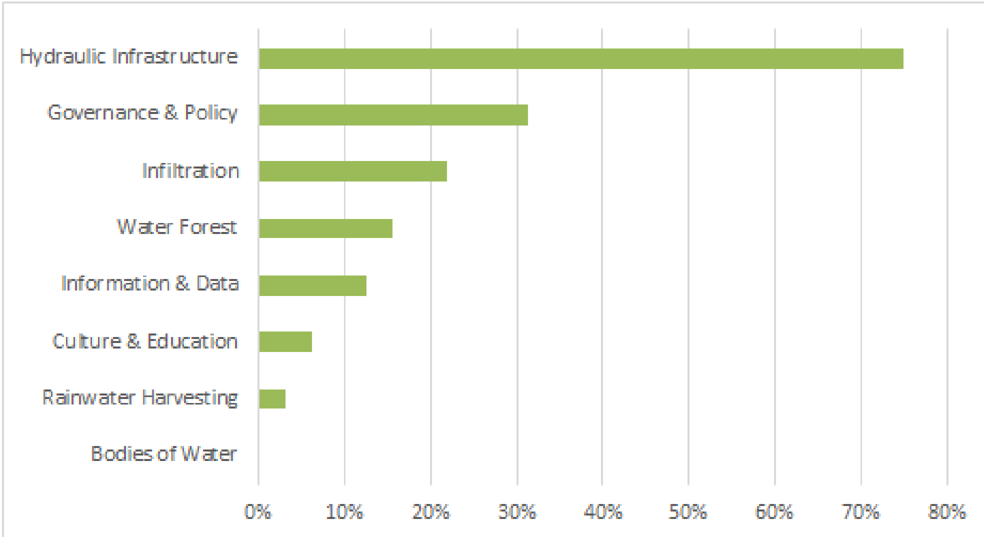

Figure 1. Percent of respondents that cited each axis as 'critical'

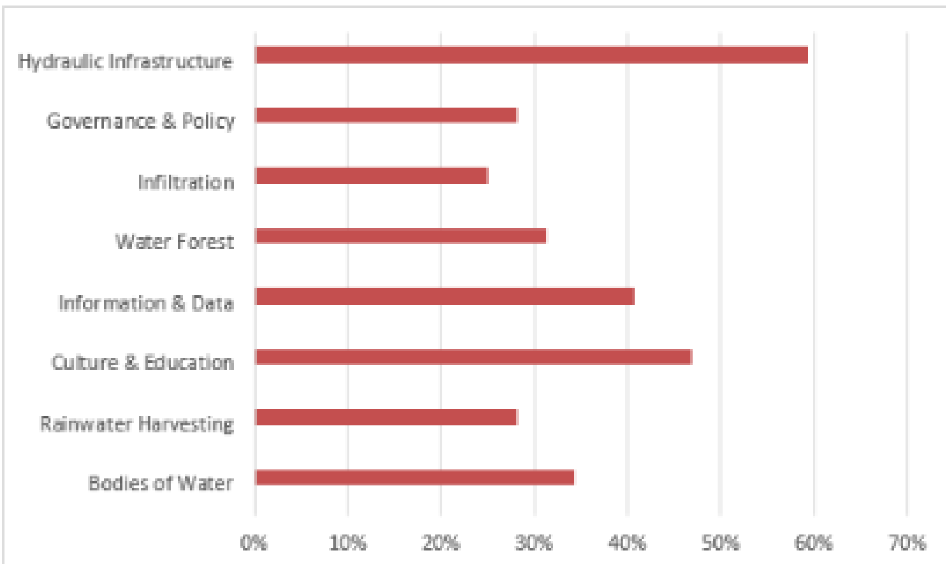

Figure 2. Percent of respondents that cited solutions to each axis.

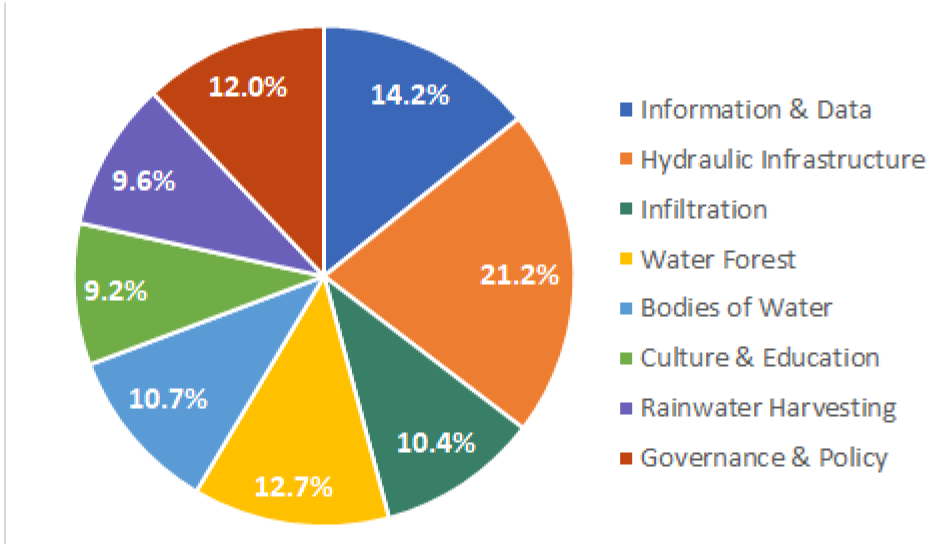

Fig 3. Average allocation of 30 points representing the relative importance of each axis.

For the purposes of the report, we are focusing on common themes that emerged from two key questions:

- What do you think are the most pressing/critical water issues facing Mexico City today?
- What do you think the city should do to address each axis?

The common themes and associated level of consensus help demonstrate where our primary stakeholders could dedicate resources. The level of consensus was drawn from qualitative trends found during the coding of the interview data. For our purposes 'apparent consensus' is derived from repeating themes within the answers of all the stakeholders to the same question. Consensus does not mean that all stakeholders were unanimous, but rather that there was overall support. 'Potential consensus' is derived from varying themes within the same answer. The variation depends on how the stakeholders think a common problem can be resolved. 'Potential conflict' comes from a larger deviation within the themes in a question. The potential conflict and potential consensus can be mitigated by further consulting and improved communication among the key stakeholders.

Hydraulic Infrastructure

- Critical Issues. Level of consensus: **Apparent Consensus**
  - Many actors see hydraulic infrastructure as either a critical issue that needs better management and resources and/or as indicative of larger social inequities. The three most mentioned problems were concerns over infrastructure maintenance, the utilization of a combined stormwater and sewage system, and an inefficient system that wastes water. We believe that there is consensus that addressing hydraulic infrastructure is a pressing concern, but that there is potential consensus on how it should be addressed. For example, while many actors think the stormwater should be separated from sewage, not all think the system needs to be circular or closed-loop. Multiple actors view the combined system as a threat to public health, such as when floodwaters contain raw sewage. Across sectors, actors saw leaks -- which occur due to inadequate long-term maintenance and planning, and vulnerabilities such as earthquakes -- as needing to be addressed, but their reasoning for addressing the leaks differed, e.g. because it is inefficient to pay for water imports when a significant quantity is lost in the distribution

system or because leaks allow for contaminants to enter the system and jeopardize public health.

- What the city should do? Level of consensus: **Potential Consensus**
  - As mentioned above, most actors identified this axis as critical. Most of the proposed solutions were consistent with improved water treatment, for potable use and non-potable reuse, operation and maintenance of existing plants, and improving the distribution system by fixing leaks. Further communication needs to happen between the actors to avoid conflicts. Even though the recurrence of the themes pointed towards similar solutions, the broad participation of actors within this axis may lead to different conclusions.

Information & Data

- Critical Issues. Level of consensus: **Apparent Consensus**
  - Metering to measure actual consumption is an important missing component of the utility, lack of generation of data, lack of integration and evaluation of data, quality of water because even though people receive it, most people don't know what the quality is.
- What the city should do. Level of consensus: **Apparent Consensus**
  - Proposed solutions were consistent among the various actors and suggest an improved documentation and accessibility platform. Stakeholders claim that the implementation and success of projects across all axes could be improved by the availability of data. Actors suggested a better plan on what type of data to obtain and how to obtain it. The data to obtain that we believe would be of higher order of consensus is location-based for the success of infiltration projects and rain data to facilitate the harvesting and retention of stormwater runoff.

Infiltration & Aquifer Recharge

- Critical Issues. Level of consensus: **Apparent Consensus**
  - Actors who addressed this axis mentioned the imbalance of the extraction rates to the recharge rates. High concern exists among actors not knowing what the actual rates are. Actors seem to agree that over extraction without an infiltration system, the city will continue to face subsidence problems, creating more flooding problems in the long run.
- What the city should do. Level of consensus: **Potential Conflict**
  - While most consistent responses mentioned the implementation of retention basins, deep-well injection pumps, and mapping soils underneath the city, we identify this axis as one where more communication needs to happen in order to reach a stable consensus. Most of the proposed solutions revolve around converting the city into a sponge city, i.e. to prevent runoff stormwater from reaching the drainage systems. However, some of the responses from other stakeholders mention lack of space to contain large amounts of runoff, an unknown profile of soils throughout the city, which in the case of locations with impermeable soils infiltration ponds would be counterproductive in solving flashfloods, and the complexity of water treatment required previous to deep-well injections.

Governance & Policy

- Critical Issues. Level of consensus: **Apparent Consensus**
    - As seen in Figure 1, this axis was the second most commented upon when asked about the most critical issues in the city. Although the high number may suggest a mutual agreement, we found a variety of responses on what about governance and policy is critical. Recurring responses mentioned the cost of the water being too low for the consumers while the budget for the utility is also low. The intermittent distribution system also was mentioned as one of the issues within this axis, some saying that the current state in which its managed creates inequity. The institutional capacity managing water systems in the city was also mentioned to be one of the critical issues.
- What the city should do. Level of consensus: **Potential Consensus**
    - A consensus could be achieved under the solutions proposed. The most mentioned solutions asked for a more transparent management, accountability, and capacity. Some actors commented that the water utility's management structure is currently shaped by changing political forces which constrains management decisions and thus recommended increasing the utility's autonomy, which would help with long-term planning.

Culture & Education

- Critical Issues. Level of consensus: **N/A**
    - The low commenting about critical issues pertaining to this axis makes it not possible for our analysis to estimate a level of consensus. This axis was mentioned by only two actors for this specific question. However, half of the actors proposed a change in the axis in order to make things better. In other words, many actors suggested a solution.
- What the city should do. Level of consensus: **Apparent Consensus**
    - Most actors commented on the population water culture. Most recurrent themes were knowledge, trust, and attitudes. This means that while the actors did not identify this axis as one of the most critical ones, they identified this axis as one of major potential contribution towards a sustainable water policy. Water knowledge, trust, and attitudes call for a more effective way of communicating the current issues in the city, whether it is the drinking water quality per neighborhood, or the technical challenges of managing water resources at a large scale.

Water Forest

- Critical Issues. Level of consensus: **Apparent Consensus**
    - Of the actors who commented on the critical issue facing the water forest, all mentioned the urban sprawl and encroachment or irregular settlements.
- What the city should do. Level of consensus: **Apparent Consensus**
    - This axis represents one of the low conflict axis because most of the proposed solutions are around conservation and enforcement of policies to prevent urbanization in the water forest and other natural recharge areas of the city.

Bodies of Water

- Critical Issues. Level of consensus: **N/A**
    - Bodies of water were not mentioned during this question. However, it did appear in the solutions proposals in the following question.

- What the city should do. Level of consensus: **Potential Consensus**
    - Similar responses were collected among the actors who commented on this axis. Some solutions call for the conservation and regeneration of bodies of water, some of which currently exist as sewer and stormwater drainage, however solutions of large scale will create large conflict among stakeholders. Solutions that propose the conservation and management of existing bodies of water have a lower conflict potential. Further communication needs to happen among stakeholders within this axis to reach a consensus.

Rainwater Harvesting

- Critical Issues. Level of consensus: **N/A**
    - This axis was not mentioned as part of the critical issues question. Many people commented on its potential to help preventing flashfloods, but also about the water quality and its use.
- What the city should do. Level of consensus: **Potential Consensus**
    - Most of the proposed solutions call for building codes to include rainwater catchment and reuse, commercial and industrial buildings to do the same and incentivize neighbors in order to reuse that water. Some actors see this axis with a potential to mitigate flashfloods, but not to solve the water access problem, even if every roof in the city harvests rainwater. Some actors raised the concern of water quality in terms of public health since rainwater is heavily toxic thanks to air pollution. We believe further communication among actors needs to take place before developing policies around rainwater harvesting.

Anticipated Impact

Our client will use this work to better understand their collaborators' perspectives and stances on critical water issues. This understanding will yield stronger relationships, build coalitions, and will help in finding a common ground if a conflict should arise.

Isla Urbana will be able to advise the Secretary of Environment in Mexico City on how to effectively put resources in areas of low conflict and where experienced stakeholders have expressed the need for those resources on a holistic path to sustainability. It is anticipated that the advice will then inform the Secretary about political feasibility of proposed solutions, or at least political feasibility to some degree.

Additionally, this work will be shared with all interviewees in order to facilitate the benefits of shared information. We believe that stronger research, coalitions, and compromise can arise from understanding gaps between their own perspectives and those from their fellow water sustainability colleagues.

Appendix 1: Axis Profiles

Note: In addition to the interviewees highlighted within each axis for their specific expertise, interviewees with a generalist background in the water sector also contributed across axes, including:

- Arnoldo Matus Kramer, Chief Resiliency Officer, CDMX Resilience Agency
- Laura Martínez Pepín Lehalleur, Directora del Programa Agua, Fundación Gonzalo Río Arronte
- Eduardo Vázquez, Executive Director, Agua Capital
- Hilda Hesselbach, Water Security Science Lead for Mexico and Northern Central America, The Nature Conservancy
- Carole Farell-Baril, Environmental Impact Analyst, The Nature Conservancy
- Elías Cattan, Founding Architect, Taller 13
- Tony Peregrina, Director, Cuatro al Cubo
- Arturo Farías, Founding Partner, Keystones Ventures

1. Hydraulic Infrastructure

Management, repair, and development of infrastructure for both potable and wastewater, including extraction, treatment, distribution, and reuse

Background

This axis encompasses the potable water distribution system, the combined stormwater and sewage drainage system, potable water and wastewater treatment plants, pumping stations, wells, and other components of the built environment that allow for management and control of water and wastewater. This broad range of water infrastructure applications are represented because all of them either exist and require maintenance, including treatment plants, fractured sewers, and leaking water pipes, or they are subject of ongoing debate, such as building a new drainage tunnel to combat increasingly intense and consistent flooding.

No modern city can survive without a robust, reliable, efficient, and adjustable water management plan. In order to manage water up to such standards, the infrastructure needs to be in good state and with the challenges of a city like Mexico City it especially needs to be diverse. It is estimated that 40% of potable water is lost through leaks in the distribution system. The combined sewage and stormwater system can no longer handle the intense storms that hit the city leading to flash floods that harm mobility and put the public at risk through the contact of raw sewage. Treatment plants requiring maintenance cannot operate to achieve the water quality they were designed for. The limited maintenance efforts being taken by the authorities are outpaced by the continued degradation of the system and if no action is taken, the system will inevitably continue to deteriorate.

Interviewees with expertise in axis

- Antonio Capella, Researcher, UNAM Institute of Engineering
- Héctor Reyes, Director of Potable Water and Water Treatment, SACMEX
- Rafael Carmona, Researcher, UNAM Institute of Engineering
- Darío Munguia, Deputy Director of Debris Removal, SACMEX
- Ramon Domínguez, Researcher, UNAM Institute of Engineering
- Armando Alonso, Engineer

Consensus on importance of axis

The most prevalent conflicting opinions are between hydraulic engineers and the rest of the actors. While engineering experts allocated 11 out of 30 points (37%) to infrastructure on average, the remaining actors surveyed allocated a lower average of 5 out of 30 points (15%). It can be inferred from these conflicting averages that there are two distinct perspectives: one that feels heavily engineered infrastructure is the main solution to the problem, while the other view considers infrastructure to be part of a holistic solution. It was identified that all actors are in favor of increased maintenance and repair to the existing infrastructure, but most of them believe large technical solutions, such as building larger infrastructure, will not suffice in the long run and will not solve the most critical issues. Repairing the distribution grid and renovating water treatment plants are the more common interests among the actors.

In terms of stormwater and flood control infrastructure there is little overlapping conversation. The current approach to drain all the stormwater without control after a rain event has little to no contest. By traditional engineering practices the protocol is to design and build for extreme events, but when events are larger than expected then a new larger project gets underway. The consensus among actors is that there is a need for diverse projects, not larger infrastructure. The proposals are to add control to the system by retaining stormwater or wastewater at some points of the city while other parts drain. Other proposals ask for stormwater infiltration ponds in highly permeable areas where the city would benefit from aquifer recharge.

Proposed solutions

- Employ trenchless pipe repair technologies.
- Maintain and renovate water treatment plants to maximize the use of water reused for irrigation, industry cooling processes, and aquifer recharge.
- Clean and regularize the existing dams in the west of the city so they can retain stormwater; this space could also be used for recreational water activities if sufficient treatment is applied.
- Monitor potable water throughout the system more consistently and accurately to find inconsistencies; prioritize locations with inconsistencies for maintenance and pipe replacement.
- Utilize the existing infrastructure more efficiently and, where possible, blend it with green infrastructure such as in the case of Parque La Quebradora.

Implementation challenges

- Large infrastructure is needed to contain runoff water and rainwater.
- Replacing pipes and fixing leaks causes a lot of traffic congestion and people don’t see the benefits directly.
- Recharge wells need to inject high quality water to comply with Norma 127 to protect the confined aquifers from contamination.
- SACMEX has a relatively small operational and maintenance personal capacity for a population the size of Mexico City.

2. Information & Data

Measurement, documentation, and accessibility of data and information throughout the water sector

Background

Decisions for technical solutions need to be informed by processed data and high-quality, accessible information. Data includes water quality data; both for potable and surface, spatial distribution of water usage and availability, consumption, intensity of rain, soil-type distribution throughout the watershed. Information includes research/academic conclusions, political entities jurisdiction boundaries, and public policies among others. This axis stands central to all other axis because it provides certainty for decision makers and it is believed that by having consolidated data and information available, more initiatives can be designed and implemented.

Currently, important information remains private, difficult to find, or difficult to understand. There is a lack of consistency regarding how or where data can be found and it is often left uninterpreted. This lack of accessibility causes systemic inefficiency while inhibiting collaboration between civil society, academia, government, and business.

Interviewees with expertise in axis

- Adrián Pedrozo-Acuña, Researcher, UNAM Institute of Engineering

Consensus on importance of axis

The average resource distribution allocated by the actors is 4.2 out of 30 points (14.2%). It is the second most important axis according to the actors only after Hydraulic Infrastructure. Out of the 32 interviewed actors, 15 of them commented on the importance of good quality and organized data and they agree on the current challenges they face.

Proposed solutions

- Form a commission in charge of compiling data from academic research, government entities, and civil society; this commission should create a data collection plan to understand the different areas of the city.
- Create a metering plan to accurately measure water consumption throughout the city, which will inform people of their water use and provide a better estimate of how much and where water is lost through leaks.
- Implement smart water technology for real-time control systems monitoring dams, rainfall, and river flows to prevent floods.

Implementation challenges

- Unorganized and unprocessed data can lead to inaccurate interpretations of the current, big picture state of affairs and actual impact of a particular intervention. This severely handicaps design and planning.
- Without high quality data, the problem is not understood and analysis depends on rough estimates (i.e. water consumption is inaccurately measured).
- City residents need to understand where their water comes from, its quality, how much they consume, and where it goes after it is used.
- Accurate maps of Mexico City's underground water infrastructure are unavailable, thus leaks are difficult to locate and permanently fix.

3. Infiltration & Aquifer Recharge

A balancing act – Pursuing hydrological equilibrium in the Valley of Mexico's aquifers through infiltration

Background

Mexico City relies on groundwater to meet over 70% of its demand (Salinas et al. 2016) but the aquifers beneath the city are being exploited at an unsustainable rate. Urbanization and the abundance of impermeable surfaces, deforestation and exploitation of natural areas, upstream waste, and downstream overconsumption threaten long-term water security and continuing the current trajectory will have severe consequences, including water scarcity, increased dependence on importation, and continued subsidence. Both demand- and supply-side solutions are needed to restore the balance between recharge and extraction, and efforts to increase infiltration are an important component of maintaining the water supply.

Interviewees with expertise in axis

- Víctor Rico Espínola, Director of Urban Design, Oficina de Resiliencia Urbana
- Elena Tudela, Co-Founder, Oficina de Resiliencia Urbana
- Gustavo Madrid Vázquez, Director, eeT estudio
- Loreta Castro Reguera Mancera, Design Director, Taller Capital
- Eduardo Vázquez, Executive Director, Agua Capital
- José Antonio Lino Mina, Director, Centro DÍA (Desarrollo e Investigación Ambiental)

Consensus on importance of axis

On average, stakeholders allocated 3.1 of their 30 points (10.4%) to infiltration. While most actors believe that infiltration is at least somewhat important (only 4 of 32 actors gave it fewer than 2 points), there are divergent opinions about the validity of natural vs. man-made infiltration and whether efforts should be focused exclusively on conservation of the water forest and other natural infiltration systems. However, there is general agreement that deep injection wells are not worth the cost and complexity.

Proposed solutions

Actors from across the water sector shared ideas for improving aquifer recharge, from data collection to green infrastructure:

- Conduct study to better understand geological features of the area that impact infiltration/recharge; develop map of areas best suited for infiltration projects.
- Build infiltration parks, gardens, and medians wherever possible; increase collaboration between urban planners and the water community for these efforts.
- Utilize permeable construction materials in new public works and retrofit where possible; mandate the use of permeable materials in new private development.
- Enforce existing policies and create new incentives to safeguard protected lands and prevent urban sprawl.
- Separate stormwater and sewage drainage systems so rainwater can be infiltrated without requiring treatment.

Implementation challenges

There are various limitations and constraints to implementing these infiltration solutions at sufficient scale to achieve hydrological equilibrium:

- Public opinion on the value of investing in solutions like infiltration gardens is mixed. Much of the watershed land area is already developed and densely populated so it will be difficult to restore infiltration capacity and expensive to retrofit developed areas with impermeable materials.
- Preventing urbanization is often in direct conflict with economic development so schemes to incentivize the conservation of undeveloped land are often complex and costly.

4. Governance & Policy

Laws, initiatives, watershed commissions, management, and enforcement

Background

Historically, Mexico City's water supply and risk mitigation policies focused on reducing flooding and meeting immediate water demand. Unsustainable water management practices, e.g. lifting the moratorium on groundwater pumping in 1976, have been permitted for political gain. (Tellman et al. 2018) These policies contributed to the current crisis of aquifer overexploitation, inequitable distribution, and environmental degradation. Current public support and overall recognition of the severity of the water crisis creates a policy window for sustainable water management policies.

Interviewees with expertise in axis

- Marina Robles, Secretary of Environment, Government of Mexico City
- Amalia Salgado, Professor, UNAM Department of Political and Social Sciences

Consensus on importance of axis

Actors tend to understand that governance is a key component of water management but their confidence in formal governing bodies varies. On average, stakeholders allocated 3.6 of their 30 points (12%) to Governance and Policy. The majority of respondents who discussed governance agreed that civic engagement has increased over time and fosters greater accountability within government. Many also expressed concern over the government's capacity to successfully manage water.

Proposed solutions

- Support cross-boundary watershed commissions and interstate collaboration.
- Meaningfully engage civil society and enhance participatory governance mechanisms
- Expand Water Funds and other innovative financial tools.
- Improve enforcement of current water-related policies by strengthening financial resources and investing in human capital.

Implementation challenges

- Combating political corruption and inefficiencies within governing bodies.
- Difficulty in enforcing current policies, e.g. preventing irregular settlements.
- Degree of political willingness to address water issues and level of multi-stakeholder interactions.

5. Water Forest

Protecting the source – Conservation and management of ecosystems and resources within the Water Forest

Background

Approximately 250,000 hectares of fragmented forest and grassland are located on the southern outskirts of Mexico City. These lands, nicknamed Mexico's Water Forest, contribute about two thirds of the city's water supply through precipitation recycling, water purification, infiltration and groundwater recharge. Because of its obvious importance to the people of Mexico City, about 80% of this land is under some sort of legal protection. However, despite this legal status, it is estimated that 2,400 hectares of this land are lost each year with a total of 35% loss of the forest in the last 40 years. At this rate, the forests of Mexico City will be gone within 50 years.

Interviewees with expertise in axis

- Jurgen Hoth, Director of Water Forest Program, Conservation International

Consensus on importance of axis

Many actors identified the water forest as an important component for Mexico City's water security. On average, stakeholders allocated 3.8 of their 30 points (12.7%) to water forest. When respondents were asked about their dream for Mexico City, the majority included a healthy water forest.

Proposed solutions

- Restoration of the water forest: Although forests are being replanted, many are planted too densely. This density prevents the growth of grasses, mosses and lichens that would typically act as the forest's "sponge" to absorb water and reintegrate it into the ecosystem. Thus, these densely-planted forests must be correctly thinned, and more resources should be allocated toward grassland protection and restoration.
- In some instances, grassland has been destroyed to make way for forest restoration. This has been counterproductive in the short-term. Grassland restoration, although not quite as effective as old growth water forest, is highly effective in absorbing and filtering water to recharge the city's rivers and aquifers.
- Utilize payment for Ecosystem Services (FMCN Model).
- In general actors called for a shift in Mexico City's resource management paradigm so the city may stop fighting nature as it has for the last 400 years and instead work with it to create water systems that follow natural watershed patterns.

Implementation challenges

- Lack of adequate enforcement of laws that protect these areas is exacerbated by the fact that the large swath of land containing the water forest is spread across three different governing bodies: the Federal District (Mexico City), the state of Mexico, and the state of Morelos. It is likely that the absence of an integrated restoration and monitoring plan is at least partially attributable to this situation of shared jurisdiction. Multiple actors cited this lack of enforcement as a key challenge in water forest viability.
- Lack of cooperation between stakeholders, illegal timber harvesting, and the unauthorized granting of land permits by federal delegates in these protected areas were identified as specific challenges.

- Actors also identified the poor relationship between the engineers and environmentalists who work with water forest lands as a barrier to proper water forest management.
- Numerous participants cited poverty and lack of affordable housing in Mexico City as a major threat to the water forest. Many lower-income residents are forced to live on less-valued land located on the periphery of the city; often in legally-protected areas of the water forest. With these settlements comes illegal timber harvest, pollution with agrochemicals, human waste, and destruction of water forests and grasslands that were previously playing a vital role in the city's water supply.

6. Bodies of Water

Restoring rivers and protecting cultural heritage – Conservation and management of all bodies of water in the watershed, both natural and man-made

Background

Mexico City is home to more than 40 rivers. (Inzunza & Taller, 2016) Although rivers optimally provide stormwater capture, flooding mitigation, and gradual reintroduction of water into the aquifer, almost all rivers in Mexico City have been routed through tubes and filled with pollution and sewage.

Xochimilco, located southeast of Mexico City, is a unique area of over 2,400 hectares of protected wetlands and pre-Columbian farms called *chinampas*. (Chavira, 2017) It is also home to the endemic, highly-endangered axolotl. Due to the intense exploitation of nearby wells by a city desperate for water, the springs that once fed the area have been depleted and must be refilled with treated-wastewater which is said to be contaminated with heavy metals. (Chavira, 2017) At the current rate of destruction, it's estimated the Xochimilco's waterways along with a proud piece of Mexico's heritage will be completely destroyed within 15 years. (Chavira, 2017)

Interviewees with expertise in axis

- Luis Zambrano, Researcher, UNAM Institute of Biology
- Marisa Mazari Hiriart, Researcher, UNAM Institute of Ecology
- Eduardo Valencia, Project Developer, Ectagono
- Erica Valencia, General Director, Ectagono

Consensus on importance of axis

Many actors said that Mexico City's bodies of water were an important factor when considering the water crisis. On average, stakeholders allocated 3.2 of their 30 points (10.7%) to bodies of water. Participants agreed that public awareness and concern regarding the protection and restoration of bodies of water has been increasing in recent years and is now includes involvement by groups of citizens outside the environmental community.

Proposed solutions

Respondents active in Xochimilco waterway protection and restoration are working to raise awareness in Mexico City about the area and its value to get community members at all levels involved in conservation efforts.

- Continue current restoration of La Compañía River, Topilejo protected lands project, and monthly river cleanings.

- Further restoration of Rio la Piedad and Rio de Magdalena were cited as two expensive, yet highly impactful projects that should be prioritized in the coming years. Additionally, restoration of Canal la Vida and Canal Nacional were identified as important, yet smaller impact projects that would be less costly to achieve.

Implementation challenges

- The city has implemented some misinformed water management measures in the past such as the creation of canals via river water diversion. These projects did not incorporate the proper reservoir upstream of the canal or consider the sediment load carried by the river (Raju, 2009).

7. Rainwater Harvesting

Rain as a resource – The role of rainwater harvesting in improving equitable water access and mitigating flooding

Background

Mexico City receives over 700 mm of rain each year mostly between May and October. (Climate Change Knowledge Portal, n.d.) Given the city's sprawling land area, this represents a substantial resource that is not capitalized on currently. Rainwater frequently floods the streets, combining with sewage as it overwhelms existing drainage infrastructure. At the same time, the city is overexploiting its groundwater resources, and residents in many underserved areas depend on costly water trucks to fill their cisterns because they lack reliable in-home water access. These issues have historically been addressed in isolation, but rainwater harvesting (RWH) for household, industrial, commercial, and agricultural use offers an opportunity to couple them, improving water access while minimizing flooding and reducing strain on the city's aquifer.

Interviewees with expertise in axis

- Enrique Lomnitz, General Director, Isla Urbana
- Delfín Montañana, Coordinator of *La Carpa Azul*, Isla Urbana
- Laurent Herbiet, Founder, Sistemas Pluviales
- Sebastián Serrano Silva, Marketing and Communication Manager, Soluciones Hidropluviales

Consensus on importance of axis

While many actors believe that rainwater harvesting is a key component for addressing Mexico City's water crisis, there is not consensus among all who participated in this study on its overall level of importance. On average, stakeholders allocated 2.9 of their 30 points (9.6%) to rainwater harvesting. In general, there is consensus that rainwater harvesting is best paired with other infrastructure solutions as it could not be deployed at sufficient scale to solve water access issues or flooding alone due to its seasonal limitations.

Implementation challenges

Despite its potential, rainwater harvesting faces a few challenges in scaling effectively:

- Mexico City's six-month rainy season means that RWH only addresses water access issues during half of the year. Thus, RWH must be paired with other solutions that provide water for underserved communities during other times.

- Captured rainwater must be either stored or transported elsewhere, meaning that RWH at scale will require additional infrastructure investments.
- There is a shortage of expertise in designing and installing RWH systems, which limits the speed of implementing the practice at greater scale.

Proposed solutions

Actors from across the water sector shared ideas for increasing uptake of rainwater harvesting, from incentivizing existing technologies to overhauling the city's drainage infrastructure:

- Incentivize rooftop RWH on existing structures through subsidies.
- Mandate rooftop RWH and reuse systems for all new development.
- Capture and store rainwater in public spaces to create closed-loop systems (e.g. Parque Iman).
- Seek support from authorities to better integrate RWH with existing infrastructure.
- Develop resale schemes for captured rainwater, either to the grid or a 3rd party.
- Separate stormwater and sewage drainage systems so rainwater can be more easily treated and reused at large scale.

8. Culture & Education

Understanding the city's relationship with water

Background

Water culture can be defined as the attitudes, values, and behaviors a society has in relation to water. Despite a lacustrine past, Mexico City currently hides much of its water from sight by confining its rivers to pipes and pumping water out of its basin. The city's thirst for water breaks records: inhabitants consume water at one of the highest rates in the world - 300 liters/day on average (Watts, 2015 and Hernandez, 2018).

Interviewees with expertise in axis

- Claudia Campero, Water Campaigner, Food and Water Watch

Consensus on importance of axis

Actors were divided on culture and education's role in addressing Mexico City's water crisis, particularly its initial urgency. On average, stakeholders allocated 2.7 of their 30 points (9.2%) to Culture and Education. Only 3 stakeholders did not allocate any points to this axis. Respondents tended to believe that Mexico City's residents lack water culture and that those experiencing water stress typically conserve water and better understand its value.

Proposed solutions

- Increase progressive water-pricing to reflect its true value and minimize waste.
- Reenvision Mexico City's relationship with water by enhancing water visibility in public spaces (e.g. Parque La Quebradora, Río La Piedad).
- Incorporate environmental education in schools, neighborhoods, and within governmental agencies.
- Utilize diverse, targeted campaigns to increase water crisis awareness.

Implementation challenges

- Improving water culture and changing consumer behavior is time-intensive.
- Previous CONAGUA campaigns to create water culture had a limited impact and are considered ineffective by multiple actors. (Ortega-Gaucin et al., 2016) Future campaigns would need to address past criticisms.
- Jointly sharing responsibility for water usage reduction among industry, residents, agriculture, etc.

Appendix 2: Coding Framework

1. Hydraulic Infrastructure
    a. Extraction
        i. Planning
        ii. Operations and maintenance
        iii. Subsidence
        iv. Demand exceeding supply
    b. Treatment
        i. Quality
        ii. Planning
        iii. Operations and maintenance
    c. Distribution
        i. Leaks
        ii. Quantity
        iii. Reliability
        iv. Planning
        v. Operations and maintenance
        vi. Inequality
    d. Reuse
        i. Residential
        ii. Agriculture
        iii. Industrial/commercial
        iv. Planning
        v. Operations and maintenance
        vi. Inequality
    e. Drainage
        i. Inequality
        ii. Planning
        iii. Operations and maintenance
    f. Planning
    g. Operations and maintenance
    h. Storage
    i. Technology
2. Information & Data

    a. Measurement
    b. Documentation
        i. Data quality
    c. Accessibility
        i. Cross-sectoral
        ii. Public
    d. Academic Research
3. Infiltration & Aquifer Recharge
    a. Deep-well injection
        i. Mapping
    b. Urban design using natural elements
    c. Aquifer imbalance
        i. Subsidence
    d. Sponge Cities
4. Water Forest
    a. Conservation
        i. Ecological resources
        ii. Urbanization
        iii. Policy
    b. Restoration
5. Culture & Education
    a. Water culture
        i. Behaviors
        ii. Attitudes
        iii. Knowledge
        iv. Management
        v. Trust
    b. Usage
    c. Civic engagement
6. Bodies of Water
    a. Conservation
        i. Human-made
        ii. Natural
        iii. Regeneration
    b. Management
        i. Human-made
        ii. Natural
7. Rainwater Harvesting
    a. Residential
    b. Agriculture
    c. Industrial/commercial
    d. Retention
    e. City planning
8. Governance & Policy
    a. Laws
    b. Initiatives

   c. Management
      i. Accountability
      ii. Transparency
      iii. Institutional capacity
   d. Enforcement
   e. Watershed commissions
   f. Imports
   g. Price/cost
      i. Subsidies
   h. Scarcity
9. Other
   a. Climate change

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