The case of Mexico DF: A sinking city

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Introduction

Mexico City is sinking. In the last hundred years it has sunk more than 10 meters (Sample, 2004). This poses a grave problem for the megacity and its 21.1 million inhabitants, most of whom are bereft of vital infrastructure such as water. Unplanned urban growth is largely the cause of this, and this problem is only aggravated by the issue of land subsidence, which has caused millions of dollars worth of damage to infrastructure such as buildings, water pipes and sewer lines, subway tunnels and roads (CNN, n.d.). This further contributes to the ever-present concern of water management and supply. Despite a relative abundance of water sources both underneath and in areas surrounding Mexico City, large swaths of the city suffer from water shortages. In fact, the abundance of freshwater is even problematic, as evidenced by perpetual threat of flooding. Furthermore, this problem is not endemic to Mexico City itself, but is recorded to be affecting the entirety of the Mexico City Metropolitan Area (MCMA)

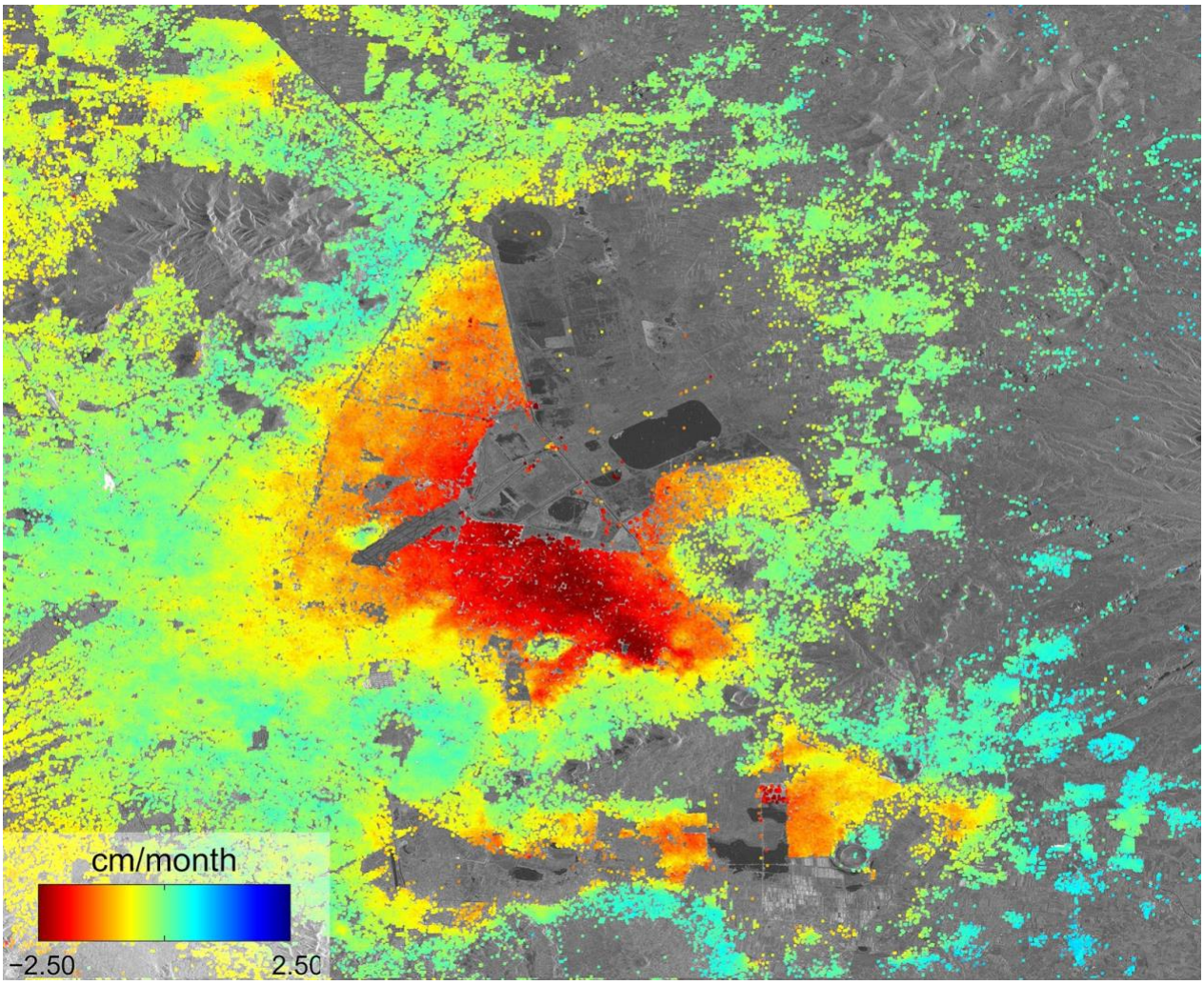

Figure 1: Mexico City Subsidence between October and December 2014 (European Space Agency, 2014)

Mexico City's problem is complicated regardless of the angle from which it is approached. Its consequences extend to the economic, health, political and environmental domains. Increasing inequity, combined with poor water quality, has put the life of millions of people at risk. Insufficient enforcement of urban planning and informal real estate market created a chaotic and nearly anarchic spatial growth process, making the provision of efficient and equitable water supply a serious challenge to management and investment (Tortajada, 2008, Jordan et al, 2011). This makes the issue of subsidence, and managing subsidence, a truly wicked problem.

Framing the problem

An important note to consider on the matter of subsidence in Mexico City is that it is not a recent occurrence. In fact, formal records show that this has been occurring as early as the mid 19th Century, while informal records suggest the city was sinking as early as the Spanish Conquest. A large part of this has to do with Mexico City having been built atop Lake Texacoco, which was filled in to make room for the expansion of the city. In recent years

however, the increasing size and density of the urban population has exacerbated the levels of subsidence.

For the past five decades, the MCMA has required freshwater inputs from other river basins in order to satisfy its water demands. The two main water sources are the groundwater aquifers in the Mexico Basin and water transferred from the interbasin of the Cutzamala and Lerma rivers (Rodriguez, 2010). Registered and non-registered wells are over-extracting water to satisfy nearly half of the water demand (Rodriguez, 2010). This poses an increasing threat to the future of water availability throughout the metropolitan area. The governance of this resource has mainly focused on the supply rather than demand side of things. Unless the current system takes a radical turn, future solutions will require higher investment costs to transport water from further and more expensive sources.

Health Aspect

One in four people do not have access to piped fresh water and have to rely on foul water distributed weekly (Marshall, 2005). According to a report conducted in 2007, 2% of the water samples collected did not satisfy residential chlorine standards, and 12% contains pathogenic microorganisms (SACM, 2008). Additionally, much of the water being extracted is contaminated by insufficiently-filtered wastewater (Sosa-Rodriguez, 2012). 91% of wastewater is discharged without any treatment (Sosa-Rodriguez, 2012). Much of the untreated wastewater is sent to the contiguous state of Hidalgo where it is used to irrigate produce fields because, farmers argue, it is a much cheaper alternative to fertilizers (Hollander, 2014; Jarman, 2015). The issue is aggravated by infrastructure damages caused by the land subsidence. As the city sinks, some of the pipes that used to flow downhill and drive wastewater far away into the Great Drainage Canal now require uphill pumping. As if the energetic and economic costs were not enough, these pumps' failures have often resulted in entire suburbs being flooded with wastewater damaging the health and livelihoods of everyone affected (Tortajada & Castelán, 2003; Hollander, 2014).

Environmental Aspects

Multiple studies of the MCMA's geological conditions have indicated that geomorphology plays an crucial role in the land subsidence. Long-term studies using remote sensing techniques such as INSAR have shown that aquifer extraction is not the sole cause for land subsidence of Mexico City (Cabral-Cano et al, 2008). Furthermore, multiple variable analysis methods such as DRASTIC-sg indicate that there is no clear correlation between the rate of water extraction and the rate of subsidence (Hernández-Espriú et al, 2014). Rather, the sinking of Mexico City is multifaceted. Crucial to understanding the phenomenon is the geomorphology and hydrology of the Valley of Mexico. The valley is the main drainage basin into which the water from the surrounding mountains flow, and Mexico City is located at the lowest point of this basin (Ortiz-Zamora & Samaniego, 2010). Furthermore, numerous studies have shown Mexico City's soil base to be overwhelmingly lacustrine (Ortiz-Zamora & Samaniego, 2010). Lacustrine soils are composed of clay and sediment, making them highly porous and ideal for the rapid infiltration of water. However, this type of soil is also highly unstable and relies on pore pressure and water infiltration in order to maintain structure (Ovando-Shelley et al, 2008). Decreased infiltration and increased overhead weight from uncontrolled urban growth has resulted in the depressurization of lacustrine soils. This makes them more susceptible to compression therefore increases the incidence of subsidence. Long-term studies have also found the rate of subsidence to be greater in urban areas than in rural areas, which suggests a that subsidence has a strong link with dense urban growth (Siles et al, 2015). This relationship is clearly demonstrated in Figure 1, where the incidence of land subsidence is far greater in the dense downtown core of the MCMA than in the surrounding territories, and non-existent in Park Texacoco where no urban development is occurring.

Social Aspects

The urban area of Mexico City spreads across multiple state boundaries with no central agency taking real responsibility for water resource management. The absence of a coordinated, metropolitan approach to housing and urban development has resulted in policies that exacerbated the urban challenges that they set out to solve. The impacts of this problem disproportionately affect the poorest and most marginalized residents of the sprawling metropolis. The Federal District is running out of areas to expand to, and as a result a number of illegal settlements have begun to form in conservation zones. Such settlements reduce the amount of permeable surface through which water can infiltrate, reducing the total area available for groundwater recharge and increases the risk of flooding. Furthermore, water is extremely undervalued. The culture of non-payment (Barkin, 2011) and the undercharged water tariff price (Rucker, P., 2010) have created fiscal challenges to the implementation of capital-intensive projects. The supply of water services and sanitation is often characterized by insecurity and exclusion. This has brought rise to a water system that is heavily reliant on both the informal and formal sector. Of metropolitan Mexico City's 2.5 million water connections in 2000, 67% were domestic, but it is estimated that this only accounted for 64% of actual connections, the rest being illegal (Tortajada, 2006). Many marginalized communities and informal settlements do not have formal access to drinking water and are thereby forced to buy their drinking water from informal water vendors.

Governance Framework

The Mexico City Metropolitan Area's (MCMA) main water concern is not so much water scarcity as it is the lack of a unified structure of management. To date, there has been no global, international, or regional agreement on a systematic approach toward managing land subsidence. While non-profit organizations provide valuable oversight and conduct experiment on sustainable water measures, their efforts are largely limited by the lack of information and poor local governance coordination. For example, Mexico City's Natural Resources Commission (CORENA), Greenpeace Mexico, Guardians of the Trees, Mexican Environmental Law Center, and indigenous peoples in Texcalyaca and Xalatlaco petitions to protest the Greater Water Forest against urban sprawl (WWF, 2012). However, these international efforts only provide minor, patchworks solutions to relieve these issues.

At the federal level CONAGUA is a powerful semi-autonomous body within the Ministry of Environment and Natural Resources (SEMARNAT, 2008). It was founded in December 1992 as part of the National Water Law, which established CONAGUA as the central federal authority, and promoted greater involvement of the private sector, as well as addressing issues surrounding ecological balance and health (Saade-Hazin, 1997). It is the highest institution for water resource management within Mexico, and it administers the rights for water use and wastewater discharge as well as planning, irrigation and developing drainage systems (CONAGUA, 2010). Within CONAGUA, several subcommittees have been created, such as the Technical Groundwater Committees (COTAS), to oversee issues of subsidence, but has not made a concerted effort on its own to deal with the problem.

What we are seeing is never ending delegation of tasks from agency to committee to subcommittee to private sector to community, as well as the absence of policies or long-term strategies to address these matters. As Saade Hazin (1997) points out, at the municipal level there has been a lack of continuity and accountability in policies and programs due to the three-year administration periods with no legal possibility of re-election where many of the problems are left for the next administration (Sosa Rodriguez, 2012).

Many water governance gaps faced by the sprawling city are not specific to the water sector particularly, but relate to broader governance challenges of the country. Due to a high level of corruption there are a number of gaps which relate to issues of accountability, regulation, funding, policy, limited transparency, informality, and the capacity of administration. The gaps are exacerbated as a result of the institutional fragmentation of the government, legal, and regulatory framework currently in place. Further co-ordinated efforts are needed to bridge these multi-level gaps across all levels of government.

Moving Forward

Any real solution to this wicked problem needs to be cohesive, and take into account issues of water, urban, and ground management. It is difficult to rank these in order of severity, as they are all of equal concern and contribute the greater issue of land subsidence. To date, federal water management agencies have focused on short-term solutions that respond only to immediate problems, such as trucks delivering water to neighborhoods experiencing shortages (Porse, 2013; Marshall, 2005). These solutions are not effective in the long run, as they are not backed up with measures necessary to eradicate the issue (Porse, 2013).

Long term solutions are extremely capital intensive, require an immense degree of centralized planning, and must be implemented on a regional scale to be effective (Tortajada & Castelán, 2003). As a result, most projects that would help alleviate land subsidence do not move past

the proposal stage. In fact, budgetary and policy constraints are often cited as reasons why long-term strategies are not put in motion (Porse, 2013). One proposed plan is to allocate around $40 million for the construction of a mile-deep aquifer as well as for the treatment of wastewater (Growing Blue, 2013). Likewise, the Emisor Oriente, a sewerage project intended to address drainage issues, will cost approximately $1.18 Billion (Wallis, 2013).

The construction of the Emisor Oriente tunnel is part of the Hydric Sustainability of the Valley of Mexico program, which was launched in 2007 and is the most promising program to date (SERMANAT, 2008). The success of the program should lead to considerable strides in this area, as it has set out to increase wastewater drainage capacity, reduce the risk of flooding, decrease aquifer overexploitation, which should aid in managing the issue of land subsidence. The treated water could be used to recharge the aquifer without risking its contamination. It could also be used to supply part of the demand for water for uses that do not require much purity, such as cooking, flushing toilets, showers etc. This would help bring aquifer extraction rates down to sustainable levels. Fulfilling the program's objectives would be a leap closer towards a solution, but already the construction of the tunnel has experienced delays as it was expected to be completed by 2012, but is now projected for 2016 (Wallis, 2013).

One of the most critical management strategies for this problem will be increased coordination and cooperation at a metropolitan level. Disaster risk in Mexico City is primarily handled using reactive rather than preventative measures (Barkin, 2011). The focus of water management is its immediate provision rather than putting more attention towards long-term strategies. The consolidation of an institutional framework aimed at overcoming medium and long term challenges is instrumental. Such framework should specify each actor's role in the management of the resource and foster collaboration between actors. In order to have all actors working towards the same goal a common strategic direction should be determined to help guide the assessment of challenges and progress towards resilience.

To date, most of the policies that are implemented by the issue's governing agencies have been designed to address water supply and distribution, rather than land subsidence and aquifer over extraction. Subsidence has been aggravated by the continued growth of Mexico, which not only increases the immediate effects of subsidence, but also necessitates that resources be diverted towards solving other problems related with massive urban centers. Urban growth is problematic as there is some oversight concerning what can be built, where it is built, and how it is built. While halting urban growth is unfeasible, enacting policies that encourage development in areas where the incidence of subsidence is lesser, are not. Rehabilitating existing buildings would also help reduce the amount of new constructions, which could be incentivized by offering subsidies to real estate development companies. Imposing a height restriction on buildings could also help reduce the amount of weight exerted upon the compressible soil, and would also contribute to pre-existing earthquake prevention as low rise buildings are less prone to toppling. Such policies would require changes to Mexico City's building codes, which would need to be coordinated with the Ministry of Public Works.

Equally important is informing the public as to the underlying causes of land subsidence. While many people in Mexico City are aware of the issue, they are not aware of what they can do themselves or how they can encourage the government to implement effective solutions to address the problem. In its book *Shaping the Future of Water for Agriculture,* the World Bank (2005) emphasizes that resolution to these problems requires more user

involvement and calls for a public education and information program that does not exist at present. One way of addressing this is to directly engage the public in the decision making process by establishing a community oversight group focused on land subsidence, ensuring that sufficient funds and government efforts are targeted to deal with this pressing matter. Increasing public awareness can also encourage the effective payment of water bills and the conservation and reutilization of water, which will decrease water demand from the aquifer as well as contribute to the financing of the capital intensive projects.

Taking everything into consideration, if there was one major recommendation that we had to make, it would be a more efficient management organization. CONAGUA would be an example of such an organization, but it only tackles issues of water management. A proper oversight committee would require a broad but cohesive approach, be capable of coordinating an effective strategy that addresses the urban, social, hydrologic, and geologic issues that constitute this wicked problem and have the budget and will to do so. This body would need to be able to coordinate with existing stakeholders such as CONAGUA, the Ministry of Public Works, and various NGOs and Private companies.

Proposed actions and stakeholders involvement

	Government	**Private companies**	**Public**	**NGOs and international agents**
	Enforce progressive water tariff to encourage water is used and distributed in a efficient and equal manner	Pay higher progressive water tariff based on usage	Pay progressive water tariff based on usage	Cooperate and monitor tariff collection and finance
Conserve and reuse water resources **reduce water demand** **extract groundwater at a sustainable level**	Increase education about water issues, encourage public discussion and involvement on aquifer overexploitation	Increase awareness on water resources usage	Increase awareness on water resources Develop cultures and custom of conserving and reusing water.	Research, expose, and organize data about government, private, and public
	Construct water purification plants public and incentivise private water purification plants	Construct water purification plants	Increase personal reuse of water	Continue and expand current investment in rainwater harvesting project in the local community
	Improve the maintenance of current water infrastructure to reduce water loss		_	Facilitate academic research and innovations

	through lack of maintenance pipeline			Promote public discussion
Sewage and health	Invest in the treatment of wastewater and use it to recharge the aquifer to avoid its contamination, and to irrigate crops that currently use the untreated water. Finalize the construction of the Emisor Oriente tunnel to increase the city's drainage capacity.	Utilize treated wastewater for uses that do not require much water purity.	Pay water bills in a timely manner. Adopt the use of treated wastewater and use power as consumers to demand their crops be irrigated with treated wastewater.	Oversee that health standards are met and exert pressure to demand more widespread piped water access.
Limit urban sprawl **Curb land subsidence**	Impose urban zoning Limit construction level base on geology and risk of subsidence Slowly shift national economical focus to discourage migration into Mexico Valley	Use lightweight material for construction, and build according to the zoning and risk of substance		Continue research on lightweight material's impact on land subsidence Monitor illegal settlement and urban sprawls on conservation land
	Enforce protection on green area to increase natural water infiltration and reduce water evaporation		Increase awareness on forest ecological service	
	Allow and promote general public, private, NGOs, International agents involvement	Active cooperation	Active cooperation	Active Cooperation
Effective Governance	Release projects information, management strategies, and data to in a truthful and timely matter	Release water usage information	Form inclusive Oversight Community to ensure government and private accountability	Monitor and check the reliability of information available
	Form special committee on land	–	–	

subsidence for holistic management approach		
Special committee on land subsidence cooperate and coordinate different level of government from both water and urban management		cooperate with local community, regional governance and global academic, continue to collect expose and organize data available for governance transparency

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