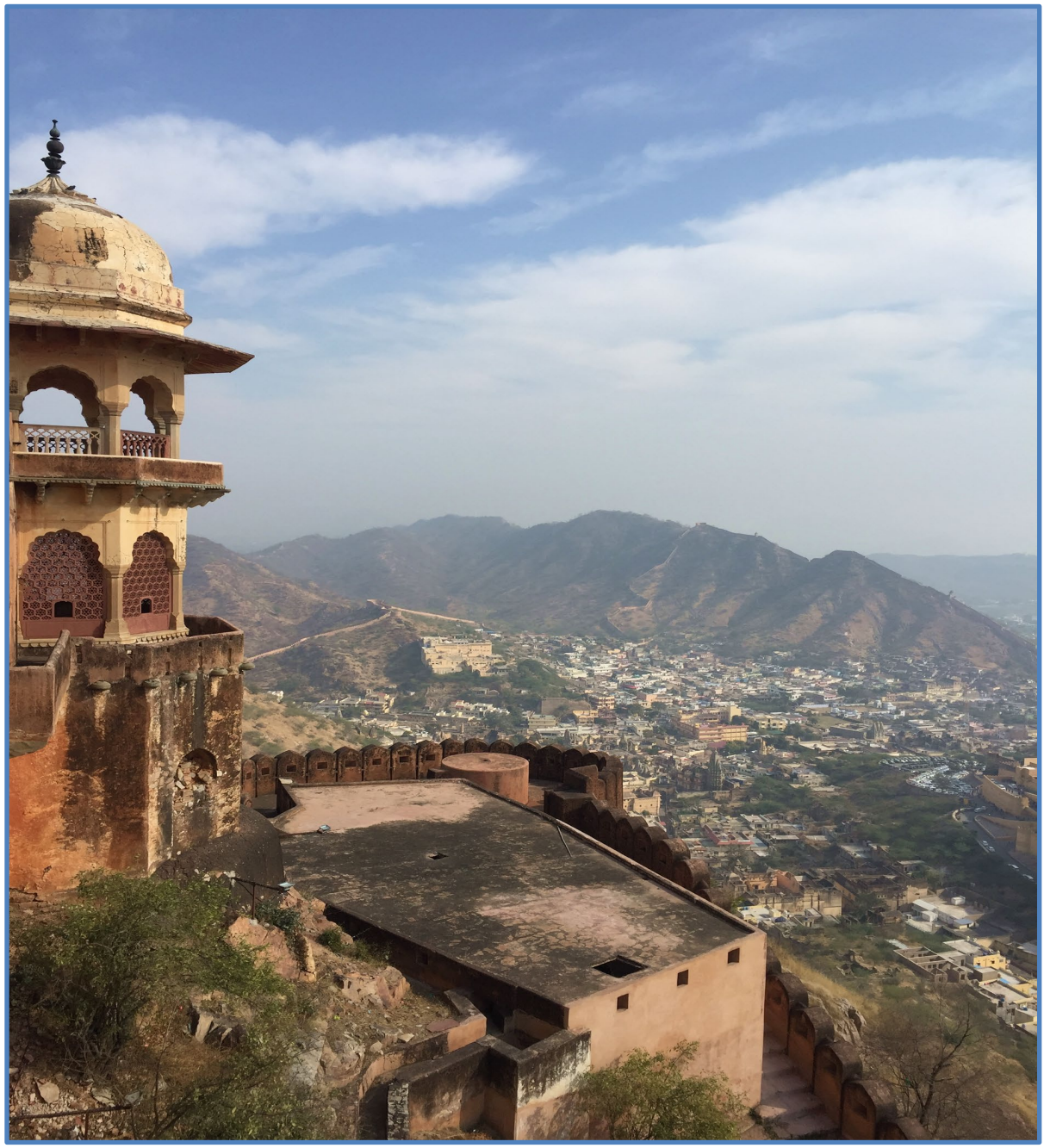
Sustainable Water Management Practices:
Addressing a Water Scarcity Crisis in Jaipur, Rajasthan, India



View from Jaigarh Fort - Jaipur, Rajasthan. February 2019. Photo by Author

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Abstract

Although urbanization often drives development and brings potential for prosperity, it also presents significant social, economic and environmental challenges that can exacerbate existing issues among populations experiencing growth. The expansion of urban and peri-urban communities, coupled with climate change, has led to the depletion (and often contamination) of existing water resources that pose grave challenges to the future of our planet's inhabitants. This report focuses on the crucial role of water supply to residents in the rapidly growing city of Jaipur, situated in the arid state of Rajasthan, India, which has a population of 3.1 million per India's 2011 census and an annual growth rate of 3%. Water scarcity has become an ongoing headline issue in Jaipur as household access to government-supplied piped water has been limited to approximately one hour a day between the hours of 6:00 and 7:00 a.m., giving residents just enough time to fill up any water storage containers for all daily needs. For people living in freshwater-rich regions with unlimited access to clean water, this can be a nearly unfathomable way of life.

To explore the myriad implications of this phenomenon at the community level, I conducted a 10-day long immersive fieldwork in Jaipur between January and February 2019. Through community member interviews and observational research in six key locations throughout the city of Jaipur and Amer, an adjoining historic settlement, I use both personal experiences and verified data to examine the challenges Jaipur faces to provide a clean, affordable, and consistent water supply to its expanding population. The analysis includes recommendations that seek to strengthen the economic, political and social factors that play a key role in ensuring the region's long-term sustainability.

While there is no silver bullet to resolve this crisis immediately, my experiences have led me to the conclusion that a more socially cohesive approach is needed at the core of the solution, in conjunction with additional water conservation techniques and updated financial infrastructure policies. The integration of these key factors will more fully support the basic standard of living and well-being of Jaipur's people, and maintain the city's legacy as a place of historical, architectural, economic, and social significance.

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Introduction

Jaipur City, founded in 1727 by Maharaja SawaiJaisingh, the Hindu Rajput ruler of the kingdom of Amber, is known as the 'Pink City' for its distinctly colored architecture within its walled, historic neighborhoods. As the capital of Rajasthan, Jaipur was one of the first planned cities in India and is also one of the fastest growing cities in the country, with a population of 3.1 million per India's 2011 census and an annual growth rate of 3%.[1] In addition to its economic and population growth, Jaipur is one of the most sought-after Indian tourist destinations, with nearly 3,000 visitors entering the city every day.[2]

While the initial planning of the city's historic settlement incorporated a sophisticated rainwater harvesting system, the city is now facing significant water shortages. Like many cities, Jaipur has had to grapple with climate change, unpredictable monsoon rains, institutional complexities within its water management system, and a population growth that is expected to reach more than five and a half million inhabitants by 2035.[3] The complexity of Jaipur's the water scarcity crisis had reached a peak emergency status in 2019 as the city's primary source, Bisalpur Dam, was predicted to run out of its average daily supply by August 2019.[4] Bisalpur Dam supplies approximately half of the city's drinking water, while tubewells and groundwater supply the other 50 percent. Water supply to residents has typically been distributed in time blocks, where residents are given a timeframe in which piped water is available to fill up household or business water storage containers. In recent years, water supply to residents has decreased steadily, with the most recent cutback in August 2018, when the piped water supply was reduced from 90 minutes per day to 45-70 minutes.[5]

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[1] Census of India, 2011. Retrieved from https://www.census2011.co.in/census/city/77-jaipur.html

[2] Jaipur Travel. History of Jaipur. Retrieved from https://www.jaipurtravel.com/history-of-jaipur.htm

[3] Macrotrends. Jaipur, India Population. Retrieved from https://www.macrotrends.net/cities/21280/jaipur/population

[4] DNA India. Bisalpur Dam records lowest water level in 6 years. August 2018. Retrieved from https://www.dnaindia.com/jaipur/report-bisalpur-dam-records-lowest-water-level-in-6-yrs-2648327

5 The Times of India. Jaipur residents to get less Bisalpur water from Wednesday. August 2018. Retrieved from https://timesofindia.indiatimes.com/city/jaipur/from-today-residents-to-get-less-bisalpur-water/articleshow/65585133.cms

In an incredible turn of events, excess rainfall in east Rajasthan between June and August 2019 refilled the dam, giving the districts of Jaipur, Tonk, and Amer the ability to fulfill irrigation and drinking water needs for the next two years. The excess rainfall came as a huge temporary relief to the city that was expected to enter a water shortage emergency crisis in the coming months.[6] While Bisalpur Dam has been temporarily filled, Jaipur still grapples with significant issues including its current water management system, groundwater quality, inconsistent rainfall and the likelihood of water shortages reoccurring in the future.

To explore the impacts of the city's current water management system and water shortages at the community level, I conducted a 10-day field analysis between January and February 2019 through community member interviews and observational research in six key locations throughout the city of Jaipur and Amer, a nearby locality. Community members' perceptions and personal experiences play a crucial factor when examining the health and well-being of a city, as they reveal a day-to-day quality of life that quantitative data cannot always reasonably capture. These community members do not represent an organization, corporation or government agency, so their perceptions and experiences are solely their own.

As urban planners, we are often challenged to analyze complex issues and recommend solutions that not only adhere to basic regulations and policies, but also help communities realize their full potential through local resources, capacity building, and collective action. While hard data was a vital component of my research, it was equally as essential to speak with Jaipur's residents about their perceptions of their current water supply, and therefore, more fully understand the existing sources of their fear, frustration, contentment, and motivation for change. As one of the defining issues of this era, water accessibility has proven to be not only essential for human and natural life, but also shapes economic growth, health, safety, and the social constructs of our communities. This report examines the city of Jaipur's challenge to provide a clean, affordable, and consistent water supply to its expanding population and proposes

[6] Weather.com. Excess Rains in Rajasthan: Brimming Bisalpur Dam Holds Enough Water for Two Years. August 2019. Retrieved from https://weather.com/en-IN/india/monsoon/news/2019-08-20-excess-rains-rajasthan-brimming-bisalpur-dam-holds-water-two-years

recommendations that will help strengthen the economic, political and social factors to ensure the long-term sustainability of the region.

Finally, I am deeply aware of the paradox that I am an outsider who seeks to provide recommendations for a city and culture that is not my own. While I performed the research with intentions of maintaining professional and personal integrity and transparent documentation, this report is meant to serve as a preliminary document for additional research, more tailored recommendations, and policies and actions that best serve the residents of Jaipur. I have immense gratitude for those who provided me with their time, knowledge, honesty, and hospitality throughout my research.

Climate and Rainfall

Rajasthan is the driest of the 27 states in India, with nearly two thirds of the region defined as arid (desert) or semi-arid.[7] The state comprises of 10% of India's total land mass but only contains 1.1% of India's surface water, making the ratio of land to water availability disproportional and creating a reliance on ground water. Due to its geography and absence of ample water sources such as rivers, lakes and canals, the state is primarily dependent on rainwater to fill its existing water sources; however, Rajasthan receives the lowest amount of annual rainfall in the country. As of 2017, up to 13,500 villages across the state did not have access to safe drinking water and relied solely water tankers to fulfill their needs. In addition, only 10% of Rajasthan's wells contain water that is considered safe for drinking. Reports have indicated that the ground water level in 190 out of the 236 existing blocks fall into 'dark zones' – ones that have been overused or are critically short of water.[8]

The official monsoon season for India lasts from June 1st through September 30th each year. Annual rainfall from 1971-2014 averaged about 575.7 mm, with over 90% of the total annual rainfall occurring during the monsoon season. In recent years, Rajasthan has been experiencing significant precipitation spikes which would initially appear to be

[7] Rajas. Water Resources of Rajasthan. February 2018. Retrieved from https://www.rajras.in/index.php/water-resources-rajasthan/

[8] Times of India. HC to government: Submit recommendations for Rajasthan water policy. January 2017. Retrieved from https://timesofindia.indiatimes.com/city/jaipur/hc-to-govt-submit-recommendations-for-raj-water-policy/articleshow/56674103.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst

the solution to its water scarcity crisis. During the 2019 pre-monsoon season from March 1st through May 31st, Rajasthan received a 73% increase in its normal rainfall. However, from June 1st through June 7th of its monsoon season, the state received 0.5 mm of rainfall compared to the average of 5.0 mm during that same time period - a 90% decrease in its typical rainfall.[9]

These short and intense rainstorms are not capable of recharging Rajasthan's lakes. Rainfall entering soil in a measured, consistent manner is necessary for the soil to absorb the water. If the water is not absorbed, it runs off, failing to recharge groundwater and often causes flooding. In recent years, the increased precipitation has flooded countless farms across the state, subsequently killing crops in their wake.[10] For lakes, this type of inconsistent recharge can make a significant difference in their ability to refill their water basins. Lakes depend on two types of approaches to recharge: the first is through rainfall, in which the basin of the lake acts as a catchment area. The second is through the groundwater table. When the groundwater table is low, and in some cases, polluted, lakes lose their second source of recharge and often become polluted from the small quantity of contaminated water that feeds into their basins.

The projected rising global temperature of 0.2 degrees Celsius every decade will also have a significant impact on the rate of evaporation.[11] Evaporation of water not only increases precipitation (contributing to intense rainfall) but also dries up water bodies. Because of this, any remaining water bodies in Jaipur and throughout the state will not only have lost one source of water to recharge its basin, but in addition, any remaining water they contain will be lost at a faster rate during the evaporation process.

Water Resources Management System: History to Present

During the 1980s and 1990s, Jaipur's population growth led to a large-scale groundwater extraction, reducing its water table significantly. During this time, the groundwater's nitrate concentration increased, deteriorating the existing water quality. In

[9] Weather.com. *Monsoon 2019: When Will Rains Start in Rajasthan?*.June 2019. Retrieved from https://weather.com/en-IN/india/monsoon/news/2019-06-07-monsoon-2019-when-will-rains-start-in-rajasthan

[10] India Spend. *Rajasthan is Getting More Rain. That's Not Good News*. May 2019. Retrieved from https://www.indiaspend.com/rajasthan-is-getting-more-rain-thats-not-good-news/

[11] Intergovernmental Panel on Climate Change. Masson-Delmotte, V.; Zhai, P.; Pörtner, H. O.; Roberts, D.; et al. (eds.). 2018. Retrieved from https://www.ipcc.ch/sr15/

addition to various initiatives and schemes (policies) created to resolve these issues, in 1999 the Government of Rajasthan authorized the Jaipur Bisalpur Water Supply Project, the city's current source of water.[12]

The dam supplies water to the city of Jaipur as well as its neighboring cities of Ajmer and Tonk. As of August 2018, records show that the dam's water level was at a recorded 309.19 RL meters, with just 8.61 thousand million cubic feet (TMC) of water remaining, about 22.2% of the dam's total water capacity. A staff engineer interviewed by DNA India reported that the dam's water level was noticeably decreasing in conjunction with waste accumulating in the dam, reducing the overall capacity of the reservoir. [4]

The distribution network of water to the city is bifurcated into two zones - the historic walled city and localities outside the walled city. Its pipelines are made primarily of cast iron, constructed prior to India's independence from Britain in 1947. As of July 2016, 466,868 consumer connections were accounted for; however, only 444,936 are metered connections and the remaining 21,932 are flat rate (FR) connections. Only 58.5% of the total number of meters are functional and replacements are rare due to a shortage of workers hired to replace or repair the meters. Table 1 below illustrates the total number of consumer connections and Table 2 illustrates the number of metered connections below. [12]

Table 1: Total Consumer Connection in all Divisions (As per MIS, end of F/Y 2015-2016) [12]

Total Consumers		N 1	N 2	N 3	N 4	S 1	S 2	S 3	S 4	Total
A	Domestic	31,034	48,178	22,328	52,139	38,739	74,227	52,670	56,378	37,5693
B	Non-Domestic	5,251	18,110	3,675	6,155	7,529	5,943	3,694	5,325	55,682
C	Industrial	531	397	147	1767	377	574	48	82	3,923
D	Flat-rate	1,836	514	6,492	9,127	1,156	926	977	151	21,179
	Total	38,652	67,199	32,642	69,188	47,801	81,670	57,389	61,936	456,477

Table 2: Total Consumer Metered Connections [12]

[12] Government of Rajasthan – Public Health Engineering Department. *Technical Sanction Proposals – Volume I: Reports, Estimates & Designs. Water Supply Improvement Works in Jaipur*. April 2017. [PDF document]

Total Meters Connections		N 1	N 2	N 3	N 4	S 1	S 2	S 3	S 4	Total
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C	Industrial	531	397	147	1,767	377	574	48	82	3,923
	Total	36,816	66,685	2,6150	6,0061	46,645	80,744	56,412	61,785	435,298

As of 2012, Jaipur's water consumption demand per day was 462 million liters (MLD); the available supply of piped water was 374 MLD, creating a 90 MLD deficit. These figures probably understate the severity of the problem, given the growth rate and decreasing water availability. Data shows that groundwater in most parts of Jaipur reportedly meets standard requirements except in older or more historic parts of the city where nitrate concentration exceeds 45 mg/liter, a level considered unsafe for consumption. Maintenance of the water distribution system and pumping operations is done through contracted third parties, although they are reportedly not hired based on quality of performance, increasing the risk of unmaintained pipes and substantial leakage. Water metering and installation of meter systems throughout Jaipur tends to be inconsistent and many meters that have already been installed are damaged or do not have readable meters. In addition, house service lines often become potential sources of pollution due to their poor quality. These issues have created a significant gap in city revenue from meter readings, increased pollution contamination for households, and does not hold contractors accountable for work performed to maintain the system's infrastructure. [12] Table 3 below illustrates the cost to the city government to operate and manage Bisalpur Dam's water:

Table 3: Operating and Management of Bisalpur water based on calculations from the PHED [12]

Expenditure	Rupees (Rs) in Lacs
Energy Charges	12485
Chemicals	427
Others: (O&M, Interest, Vehicles, Office Expense, Salaries, Medical, Pension Contribution, etc.)	8635.1
Total	21547.1
Say (Rs in Million)	**2154.71**
Average Water Production (Year 2015-16)	450 MLD
Cost Per KL	**Rs 13.12**

In addition to water quality and limited accessibility, water tariffs have been a contentious issue in Rajasthan, with the local government recently enforcing 10% increases on its residents in both 2017 and 2018. The previous rate of 1.76 rupees/per one thousand liters increased to 1.89 per one thousand liters. The 2018 increase affected nearly half a million residents in Jaipur who consume water up to 8,000 liters/month supplied from the public health and engineering department (PHED). In addition, charges from the PHED regarding new connections have increased by 35 rupees to 605 rupees, and residents who fall below the poverty line (BPL) will have an increased rate for new connections to 121 rupees. The PHED has also increased infrastructure, meter service, and renewal fee charges by 50%, which increased residents' overall water bills by 110 to 400 rupees per month. [12]

Overview of Field Research

My field research took place over the course of two weeks between January and February 2019 in the city of Jaipur, Rajasthan and communities around Amer within the Jaipur Municipal Corporation. I identified six sites as key locations to compare the age of water infrastructure and functioning water points, community members' perceptions of their water quality, the concentration of local wealth and resources, relationship with tourism, and population fluctuations. Translations and contextual knowledge during site visits and interviews were provided by local architecture students from the Aayojan Architectural School of Jaipur.

My first site visit began with **Purani Basti**, a historical neighborhood with some of the oldest water infrastructure within the walled city. The second site, **C-Scheme**, is an extension of the walled city with a high concentration of wealthier residents in Jaipur. The research then moved onto **Meeno Ka Mohalla and its adjacent Van Talab Lake**, followed by an analysis of **Man Sagar Lake**. Both of these locations have experienced significant socio-spatial expansions, given their close proximity to tourist destinations. Although numbers vary as to how many residents live within slums and colonies - informal settlements but not squatters - Jaipur Municipal Corporation reports that there are 211 slums within the city boundaries. Given the number of residents impacted by impoverished circumstances which often limits access to necessary resources, **Jawahar Nagar's nearby slum** and a **slum located adjacent to the Amrudo Ka Bagh Fairgrounds near C-Scheme** were included in the field research and analysis.

I performed my fieldwork through methods of observational research and interviews with community members, local businesses and temple caretakers using a semi-structured interview approach with a set of prepared general interview questions, that were subject to change depending on the interviewees' answers. Additional relevant questions arose during interviews as each of the conversations progressed. Questions and observations centered around average consumption rates, availability of usable water, both functioning and defunct water sources (to document either an increase or decrease in accessibility to water points), perception of water quality, estimated cost of water, and level of willingness to participate in a rainwater harvesting project.

On average, six to eight individuals per site, which included both men and women, were interviewed regarding their relationship with water. Only one site, Man Sagar Lake, consisted of interviews with one resident and one temple caretaker, with conclusions supplemented by external resources and observational research. Additional data for the analysis was also gathered through on-site interviews with water economist, Agam Mathur, as well as historian, Dr. Rina Hooja, both of whom possess a breadth of knowledge regarding the water management system and the demographic makeup of Jaipur.

While comprehensive and accurate quantitative data was challenging to obtain for each individual neighborhood and community, data was also extracted from verified sources such as literature reviews, government portals, and news sources to support the overall conclusions and recommendations. Progress has been made at the national and state levels to address the complexity of quality and quantity water challenges in India, although Jaipur has yet to build the local political and physical infrastructure to fully address its water challenges, which require long-term, not stopgap, solutions. Most evident during community member interviews, professional interviews and overall data compilation, was the lack of cohesion and alignment among relevant systems, policies and stakeholders. In order to more effectively streamline Jaipur's water management system, my six recommendations range from systematic-level approaches that incorporate a Smart Cities' model of a Smart Water Network (SWN) and leveraging partnerships through a green bank to attract private capital, to community-level

initiatives that focus on engagement, capacity building and rainwater harvesting initiatives.

Major Findings

Purani Basti

Purani Basti is considered part of the “walled city” or old city of Jaipur, with some of the city’s oldest water infrastructure and communal water points, including borewells and hand pumps. Purani Basti, like many areas in the old city, is rich in historical architecture with many low-income residents. Common in Purani Basti and throughout many historical communities in Rajasthan are temples that originally acted as both a religious gathering place and a daily source of water for local residents. Temples typically have three traditional elements on their grounds: the temple structure, a large tree for shade, and a well underneath the tree. Each of these are equally symbolic and functional to the site and the overall community, as noted by two temple caretakers.[13]

Figure 2 - local temple, Purani Basti

Figure 1 – local resident and borewell, Purani Basti

[13] Personal communications, 2019

Most evident throughout Purani Basti were the number of dried communal wells associated with temples, and wells constructed near residential housing. Due to the depleting water table, many residents explained that their water points had dried up and they often relied on free government water tankers, fee-based private water tankers, borewells, and hand pumps to meet their water needs, increasing either their effort and/or income spent on water. Residents described in detail that 50 years ago, the wells were flowing with water throughout Jaipur but were no longer a reliable source. Several residents also expressed frustration regarding the increased amount of pollution that was affecting the groundwater quality of their borewells. When asked about rainwater storage, five community members were enthusiastic about the idea of having this as a supplemental amenity but stated the government would have to pay for the installation since it was not something that they could afford.[13]

"50 years ago, there was water flowing from the wells here. Now, most have dried up and we rely mostly on piped water and tankers for our water supply."

- Purani Basti resident

Four interviewees stated that while they assumed the water provided to households through the government municipal lines had been filtered to an extent, they were concerned about residual elements and pollutants in the water. Two interviewees also noted that because of the aging pipes, there was not only water leakage/loss but also a water quality issues associated with this.[13]

"I'm worried about the water quality from our pipes, and that it may not be suitable for drinking."

-Purani Basti resident

C-Scheme

C-Scheme is considered to be one of the wealthier communities of Jaipur, originally constructed in the mid-late 1940s. During the site visit, four of the six interviewees noted that they had decreased their water usage, including bathing their children and household cleaning, because of the decreased water availability from the municipal water lines. Because of this, there was a significant increase in spending to pay for the water delivered by private water tankers, although this number varied by several hundred rupees depending on the household. Three of

"We talk about the water shortage every night at dinner."

-C-Scheme resident

the five interviewees were mothers and while they did not manage the household finances, and therefore did not know the approximate cost of their water usage, they emphasized that it was a daily discussion amongst family members regarding the decreased availability of water in Jaipur and the future of their city's water source.[13]

While free government water tankers are available to many areas throughout Jaipur, C-Scheme's residents can afford the cost of quality, filtered water and therefore often have nearly unlimited access to private water tankers, unlike low-income or slum communities in the city. These households use some of the largest water storage containers available for their households, a stark contrast from the type of water storage used by slum residents, usually consisting of handheld buckets or smaller storage containers. While all household interviewees noted their awareness of the water scarcity issue in Jaipur, two interviewees stated that they had not changed their water usage habits and did not intend to do so in the future. When asked about rainwater storage device, four of the six households stated they would be receptive to having one installed if water availability continued to decrease.[13]

Meeno Ka Mohalla/Van Talab Lake

Meeno Ka Mohalla, located in Amer, is a short distance to many of the tourist destinations and palaces that draw visitors to Jaipur and Amer. According to a local elder resident, the community is approximately 50 years old but in the past 10-15 years, the community has experienced significant socio-spatial expansion. As the community's population has increased and tourists often pass through the area, the water table has decreased. In conjunction with this, the nearby Van Talab Lake's has experienced a significant amount of pollution due to the sewage and stormwater runoff that is funneled into it through pipelines from the community. This has led to an increased demand for clean water from sources outside of the village, most notable a number of water tankers frequently visiting the area.[13]

In the center of the village and in most localities near Jaipur city, there are two working hand pumps and approximately two borewells, although the residents expressed their concern that the water from the hand pumps was often filled with too much sodium to drink without boiling the water first and generally used for smaller cleaning activities. On average, borewells reach a depth of 150 - 180 meters where more pure, drinkable water is available. Hand pumps reach a depth of approximately 60 meters where the water is extracted, meaning that the water is often not drinkable at the level because of the polluted water table. In Jaipur, even extracting water through borewells has become problematic because of the increased pollution and low water table, leading to less available clean drinking water from these sources.[13]

"The high demand for clean water allowed us to create this business. There is actually competition between us, the other business here, and others that are opening up in localities nearby, as demand for water increases."

-Meeno Ka Mohalla water filtration dispenser business owner

During the two days spent in Meeno Ka Mohalla, I counted six water tankers entering the village, demonstrating the high demand from local residents for drinking water. The increased water demand has also led to the creation of two local water filtration businesses in the center of town that provide large filter water dispensers and water bottles to residents and tourists.

Figure 3 - Water tanker in Meeno Ka Mohalla

On average, the eight community members who participated in the water consumption discussions stated they paid approximately 300-350 rupees 2x/month for additional water from the water tankers in case the piped water supply was not enough for the month. Most of the residents also agreed they did not feel as though the water from the municipal government lines inside their household was purely filtered water appropriate for drinking, although they often drank it since that was their primary water source. Many households also referenced a decrease in frequency of water availability, stating that piped water decreased from twice/day to once/day between 2017/2018 and 2018/2019 with no direct communication between the

government and community regarding the decrease in frequency. This decrease led a change in their daily consumption and water use including bathing, cleaning and drinking habits.[13]

"The government never spoke to us about raising the water rates last year. Maybe they wrote about it, but they never told us."

- Meeno Ka Mohalla resident

Man Sagar Lake

Mansagar Lake is 300-acre man-made body of water created in the 18th century by Maharaja Jai Singh II to support the nearby dam. It is the largest body of water in Jaipur and is surrounded by an urban area, vegetation and wildlife. It is an attraction admired by both visitors and locals. Many tourists are drawn to the lake because of the Jal Mahal ("water palace"), an architectural monument in the center of the lake with a backdrop of Jaipur's hills behind it (see *Figure 5*) When the lake is full, several floors of the palace sit below the water while the top floor is exposed.[14]

Figure 4 - Polluted water flowing into Van Talab Lake

While the lake is natural habitat and aquatic ecosystem for fish, birds, insects, microorganisms and vegetation, and a haven for more than 150 different species of local and migratory birds [14], it has become severely contaminated by siltation, settled deposits and an inflow of wastewater. The site visit revealed that the west side of the lake is the most polluted while the northeast and southeast portions of the lake are separated by the dam, bifurcating the cleaner water from the polluted water on the west end. A running and walking path was recently constructed around the lake's perimeter for tourists and nearby residents to enjoy the site of the water palace and surrounding grounds.

[14] Rainwaterharvesting.org. Man Sagar Lake. Retrieved from http://www.rainwaterharvesting.org/mansagar_lake/mansagar_lake.htm

Figure 5 - Man Sagar Lake and water palace

When I interviewed a local temple caretaker and a local resident, both men spoke of an increasing frustration with the water's pollution; however, the issue of its waste is complex. Precipitation, especially outside of monsoon season, is not consistent enough to fill up the lake and therefore, sewage water is funneled into the lake to fill it and helps to attract visitors to what would otherwise be a nearly empty lake. A filtration system then moves the sewage from the east to the west end of the lake, turning it into graywater and helps prevent an undesirable smell that would inevitably drive away visitors.[13]

"I cannot even use the temple's borewell to water the vegetation and plants nearby. It can only be used for cleaning the floors because it is so polluted."

- Temple caretaker

There have been attempts by the state government of Rajasthan to resolve the lake's polluted condition, including a public-private partnership in 2008[14]; however, the lake's water quality is still heavily impacted by the waste. The pollution has spread to the surrounding land, its ground water quality and the lake's vegetation, with vegetation especially on the west end of the lake noticeably dying or growing in minimal amounts. The temple caretaker also referenced a nearby borewell once used for drinking but due to the lake's pollution, the water has not been clean enough for even bathing or to water the ground's vegetation and is solely used for washing floors and cleaning the temple.[13]

Jawahar Nagar Slum and Amrudo Ka Bagh Fairgrounds Slum

The combination of land shortage and poverty has become a major issue in growing urban environments across the globe, including nearly every city in India, where slums accommodate many of the city's workers such as drivers and cleaners. In a recent government effort to provide all residents with access to water, both the **J**awahar Nagar and Amrudo Ka Bagh Fairgrounds slums receive free piped water through the municipal water lines.[13]

Figure 6 - Amrudo Ka Bagh Fairgrounds slum

While slums often have many similarities such as the ingrained social cohesion deriving from the close proximity of people, Jawahar Nagar and Amrudo Ka Bagh have some distinct differences. Jawahar Nagar's nearby slum is situated on elevated ground next to the city's hills, which becomes problematic during the summer. Based on accounts from the eight individuals who were interviewed in this community, the elevated plane of the slum requires more energy to transport the piped water up to the houses. The city's frequent electrical blackouts during the hotter months have prevented the government from piping water to the slum regularly, leaving residents without household access to water.[13]

While there is often a daily listing in local newspapers of communities impacted by the blackout, many slum residents cannot read and therefore remain unaware until they turn on their faucets in the morning. The residents are then forced to go find water, often in a nearby public garden and carry the water back to their houses via whatever containers can be transported on foot and are large enough to fulfill the needs of the family for the day. During these summer months, the amount of piped water available doesn't often fulfill the needs of the residents and many families purchase an additional 200 liters of water from tankers, in addition to the approximately 1200 liters split between family members in one household from the piped water lines. Jawahar Nagar's nearby slum also has a significant amount of sewage that gets dumped into a channel next to grounds, causing health issues for the children who play near the pile.[13]

"The quality of water is very low here. Sometimes I don't even want to bath in it because I fear it has too many pollutants."

- Jawahar Nagar resident

The slum adjacent to Amrudo Ka Bagh Fairgrounds is situated next to land used frequently for large exhibitions. In addition to recent sanitation policies, residents explained that the nearby exhibitions have been an incentive for the government to keep their community clean. Individual toilet stalls have been constructed on the outskirts of the slum and are maintained by the government. However, four of the residents felt like the piped water quality was still often too low for even bathing and felt obligated to run the faucet for several minutes to clear out sediments and other pollutants before using it for bathing and drinking. Like most slums and low-income communities, it does not have proper sewage channels and often has sewage running through the center or sides of their roads in small ditches.[13]

Overall, both communities pointed to health issues as a result of waste and nearby sewage and felt that the quality of the piped water was low. However, each community member was receptive to the concept of rainwater harvesting as a supplement to piped water, provided the government funded and managed the installation.[13]

Challenges, Opportunities and Recommendations

Cohesive Consortium Approach

Sustainable water management requires a holistic approach that addresses the complexity of a city's water sources, infrastructure and consumption rates that are inevitably intertwined with its political and social structures. Most evident during community member interviews, professional interviews and various forms of research, was the lack of cohesion and alignment among the systems, policies and stakeholders who play a role in water management or consumption across the city. In order to tackle the complexities of the water scarcity crisis, it is vital to pool resources, expertise, capacity and decision-making roles into a streamlined, cohesive approach that can increase the level of impact, influence and systematic efficiency.

In Jaipur, forming a consortium with representatives from the local government, relevant non-profit actors, community leaders and private investors (where applicable), to develop and implement initiatives would help foster more effective change. This consortium would theoretically act as a partner with Jaipur's government, helping to design and implement policies, community initiatives and drive new partnerships for a more effective water resource management system. An innovative system with pooled resources could include a Smart Cities' model of a Smart Water Network (SWN), which is elaborated upon more in the annex section of this report.

Community Engagement

After forming a consortium and identifying roles and responsibilities of the stakeholders, one of the primary objectives should focus on public education and community engagement regarding the water scarcity crisis and potential solutions, both at the community level and government levels. Empowering communities significantly helps to build community buy-in that will ultimately sustain any future initiatives or new changes to the current water allocation system. By strengthening the capacity of local communities to work together to map their vulnerabilities and strengths and identify priorities and mobilize community leaders and groups, the more resilient the region will become to current and future shocks and stressors in their water system.

Public-Private Partnerships

Following the creation of the consortium, an immediate need exists to address the financial challenges Jaipur faces. Many cities across the globe lack of funding when it comes to large capital infrastructure projects, often urgent in nature either due to poor quality, low capacity or both. Several local professionals consulted during the field research commented that Jaipur has reached its capacity on loan money it is legally permitted to borrow, leaving the government, and subsequently, the residents, without a safety net to help finance water infrastructure repairs, replacements, or rainwater harvesting system installations.[15]

[15] Marin, Phillippe. The World Bank. Public-Private partnerships for Urban Water Utilities: A Review of Experiences in Developing Countries. n.d. Retrieved from https://www.oecd.org/env/outreach/44576275.pdf

Of the potential avenues the city could consider, the first is a public-private partnership (PPP or P3). While these have traditionally been justifiably controversial for a variety of reasons, newer, successful models of PPPs have changed the "large concession" structure into a hybrid where public financing, such as leases, are combined with an efficient private operation. Variations of this model have proven to be successful in countries such as Senegal, Cote d'Ivoire and Colombia, where the emphasis was on an increase in service quality and efficiency gains. A comprehensive study performed by the World Bank on PPPs uncovered that the most significant financial contribution from a private investor is not the actual funding amount but the capacity to improve the financial viability of the water and sanitation services overall, creating a "virtuous cycle", and thereby, a long-term solution. It is crucial to note that the efficiency gains are contingent upon the PPP design and regulatory framework (i.e. an opportunity for influence from the consortium), which should be tailored to the needs of Jaipur. [15] Ultimately, the goal to create a reliable water management system in Jaipur rests on the shoulders of society and the government to ensure, not on the private sector.

Green Banking Strategy

Leveraging public funds to attract private capital can take many forms, including more unique models such as green banks. While initial models of green banks proposed attracting financing for clean energy projects, a green bank could play a key role in Jaipur to address its water infrastructure by facilitating partnerships that would garner capital. Green banks generally possess a set core characteristics, which include:

- a mandate focusing mainly on mobilizing low-carbon, climate resilient investment (LCR), using interventions to mitigate risks and enable transactions
- innovative transaction structures and market expertise
- independent authority and a degree of latitude to design and implement interventions
- a focus on cost-effectiveness and performance[16]

Green banks can be found in countries all over the world, including two recently financed partnerships in India focusing on solar energy. Although based in the United

[16] Green Bank Network. What is a Green Bank? n.d. Retrieved from https://greenbanknetwork.org/what-is-a-green-bank-2/

States, Rhode Island's green bank approach to improve the state's water quality is a model to consider for Rajasthan, with the structure and policies tailored to the local context. The purpose of Rhode Island's Clean Water State Revolving Fund is to provide financial incentives that aid organizations seeking to reduce water pollutants. Municipalities and quasi-public agencies have access to below-market interest rate loans, for projects that implement activities related to the reduction of water pollutants.[16]

Increasing Block-Tariff

An alternative to a PPP or an option that can be implemented concurrently with private investment is an increasing block tariff (IBT) system. IBT's, also known as "lifeline" or "social tariffs", aim to provide the first water block of cubic meters to households at a lower price, usually below the cost of provision. While slum residents receive free water, there are many low-income communities in Jaipur that would benefit from a more equitable water-rate system. Because many of the wealthier residents tend to store and consume a larger than average volume of water in Jaipur, these households would face higher prices per cubic meter, thus aiming to balance the city's water-pricing and potentially create a net revenue. A challenge for this scenario is that volumetric tariffs would only work if all household connected are metered, meaning that infrastructural improvements would need to take place prior to a new water-pricing system that required meters.[17]

Rainwater Harvesting

Although rainwater harvesting is not a new concept in India, there were few, if any households during the site visits that were practicing this method of water catchment. Various factors that contribute to this include a lack of funds and capable structures that would support these systems, a lack of training and knowledge of how to construct them, and an overall reliance on piped water and water tankers as primary water sources. While water tankers have been sufficient supplemental sources of water, they have been a reactive solution and are costly to both the government and residents.[18]

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[17] Massachusetts Institute for Technology. Establishing Pricing Policy. n.d. Retrieved from http://web.mit.edu/urbanupgrading/waterandsanitation/funding/estab-price-policy.html

[18] Bhattacharyya, Ananya. City Lab. What India Can Teach the Rest of the World About Rainwater Harvesting. December 2015. Retrieved from https://www.citylab.com/environment/2015/12/rainwater-conservation-india-kerala-water-roof/420591/

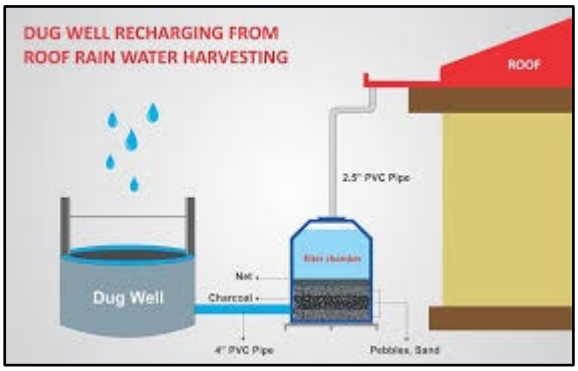

Figure 7 - Sample rainwater harvesting system. Source: Mazhapolima Rain Bounty 2008 – 2016 album

The state of Kerala in southwestern India is similar to Jaipur in that it also faces severe water shortages during dryer months of the year. Starting in the mid-2000s, NGOs and the Kerala government sought to popularize rain water harvesting on roofs as means to resolve this crisis, allowing communities to use dry or discarded wells for conservation and groundwater discharge. The scheme, Mazhapolima, uses roof-water harvesting to recharge wells, with trained NGOs that installed the roof rainwater harvesting systems. Subsidies are given to low-economic households and in areas where groundwater has been severely exploited or has a high saline. Most households are required to pay a standard installation of $75-$100, depending on where or not a sand filter is installed.[18]

The catchment and filter process begins at the rooftop where the rainwater or precipitation flows into a gutter connected to polyvinyl chloride pipe. The water passes through a filter consisting of charcoal, pebbles, sand and other local materials, and then moves onto the dug well (see *Figure 7*). This type of well has performed successfully in regions with laterite or sandy soil and where the wells are not sealed by concrete at the bottom. As the water table lowers, the water retained in the wells from the rooftop ultimately gets pushed into the ground, thus recharging the well and groundwater table. When multiple wells are recharged in an area, the groundwater table increases both in quantity and quality, with many communities having witnessed a disappearance by the third year in pollution and salinity because the freshwater has pushed down the older water. This is also an alternative for rural communities surrounding Jaipur city that spend a significant amount of government money on water tankers, as funds could be redirected towards constructing rainwater harvesting systems on residential roofs.[18]

Conclusion

Many cities around the world are experiencing a depletion (and often contamination) of their water supply systems that pose grave challenges to the future of our planet's inhabitants. With climate change and population growth impacting urban environments on nearly every continent, urban planners are challenged to create new systems or

modify current ones that can adapt to unanticipated changes, shifting densities, and available resources. My research used both hard data in conjunction with community members' personal experiences and perceptions to propose the above recommendations. These recommendations seek to create a more participatory, inclusive water resource management system, address financial sustainability, harness the power of communities to capture their own rainwater, and address varying levels of economic affordability.

While a trip of this length could never fully uncover all of the complexities and intimate details of Jaipur's water challenges, both the community members' accounts and my own research helped identify some of the most pressing issues the city was facing and opportunities to foster both systematic and community-level change. As urban planners, we are often challenged to analyze complex issues and recommend solutions that not only meet basic needs and adhere to regulations and policy but also help communities realize their full potential through local resources, capacity building, and collective action.

Moving forward, I strongly believe that Jaipur has the potential to transition from a reactive city to a city prepared to respond to shocks and stressors, and maintains its legacy as a place of historical, architectural, economic, and social significance for generations to come.

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Annexes

Assumptions and Limitations

Assumptions

It is assumed that the community member participants provided honest and truthful responses to the interview questions, to the best of their knowledge. It is also assumed that participants had an interest in participating in this topic, and did not participate with any other motives. These assumptions are likely true, as this study did not provide any compensation or motive for participation.

Methodological Limitations

Sample Size:
The community members that participated in the interviews and discussions were chosen upon entering each community, based on who was available to speak during the time I was there. The primary research collected through interviews totaled 40 community residents, business owners and temple caretakers. While sample sizes are less relevant for qualitative research, this did impact the conclusions drawn.

Lack of Available Data:
The most recent national census for India was conducted in 2011 and current, exact demographic data for Jaipur was unavailable. While this did not limit the actual interview process, the numbers and descriptions noted for demographics are estimates.

Measures Used in Data Collection:
While the majority of participants engaged in full interviews consisting of nine questions, a small number of participants were only asked between three and five questions that pertained to them (such as the temple caretaker and business owners). This contributed to a more in-depth analysis for some conclusions while others had less reliable data available to draw concrete conclusions.

Additionally, some of the community members could not provide exact data on their consumption or cost rates, either because they did not know, did not pay a water bill, or estimated the cost during the interview. I did not collection personal identification data such as name and age but ensured that each individual participating was an adult who participated in decisions around water usage within a household.

Fluency in Local Language:
The dominant use of Hindi spoken in Jaipur required the use of student translators for most of the interviews. Although the translators were considered trustworthy and unbiased (as they were informed to translate verbatim and not mix their own opinions prior to the study's beginning), some information could have been excluded or inadvertently lost during the translation process.

Time and Geography:
The community-level research was conducted over a period of ten days, with varying amounts of time in each location. While six sites were identified as places that would demonstrate a significant range of access to drinking water, there are many neighborhoods and communities that were left out simply because of time available.

Baseline Community Member Interview Questions

1. **Water Sources:** What are your household's sources of water? (government piped water, water tankers, borewell, handpumps, etc.)

2. **Household Consumption:** How much water does your household consume in one month from the government piped water?
    a. Do you consume water from private or public water tankers?
    b. If so, how much?
3. **Water Costs:** If you do pay for water, how much does that cost your family per month? (government piped water).
    a. Do you pay for extra water from private water tankers?
4. **Water Quality:** Are you satisfied with the quality of your water?
    a. Why or why not?
5. **Rainwater Harvesting Initiatives:** Would you participate in a rainwater harvesting program to have more clean water available?

Relevant Government Schemes and Programming

Government of India

The Indian government established the **National Water Mission (NWM)** under its *National Action Plan on Climate Change* and received formal approval of its Mission Document in 2011. The Mission focuses on water conservation, decreasing wastewater, and equitable water distribution across States, given the inconsistent access to water resources and adequately functioning water management systems throughout the country. Its goals include the establishment and maintenance of water databases, the promotion of citizen and state activism around water conservation, prioritizing vulnerable and overexploited areas, increasing overall water efficiency by 20%, and the facilitation of basin-level integrated water resources management. This Mission was intended to be financed from 2013 through March 2017; however, the Mission is still active as of 2019 based on publications and events posted on NWM's website.[19]

Government of Rajasthan

Rajasthan has developed numerous policies and publications regarding the preservation and conservation of water. As of July 2019, the Rajasthan government has been working towards creating a comprehensive water law, Rajasthan Water Bill 2019, that will focus on conservation, protection and regulation, including sanctions for wasting water. In May 2019, the Ministry of Water Resources (MoWR) released a "Water Conservation Efforts by Rajasthan State", detailing the existing state of water resources and efforts made to conserve the remaining assets. While water harvesting and artificial ground water recharge initiatives have been underway throughout the state, Jaipur is not mentioned specifically in this publication, nor is it mentioned in the state's Water Resources "Vision 2045", that details the sustainable development and preservation of water[20].

[19] Government of India. National Water Mission. Retrieved from http://nwm.gov.in/?q=schemes
[20] Times of India. Rajasthan budget focus on jobs and water conservation. July 2019. Retrieved from: https://timesofindia.indiatimes.com/city/jaipur/state-budget-focus-on-jobs-and-water-conservation/articleshow/70080087.cms

One of the state's programs, Mukhya Mantri Jal Swavalambi Yojana (MJSY), which had been renamed Rajv Gandhi Jal Sanchaya Yojana (RGJSY), launched in 2015 and focused on water conservation in rural areas. The program became defunct after three phases of implementation because of political changes after an election, as well as a lack of funds allocated towards to program. It will depend on funding from the Indian government in order to implement it. [21]

Also launched in 2015 by the Government of India, the Atal Mission for Rejuvenation and Urban Transformation (AMRUT), has proven to be a more sustainable initiative, focusing on capacity building, reform implementation, water supply, sewerage and septage management, stormwater drainage, urban transport and development of green spaces and parks. Within its water component, AMRUT addresses:

- Water supply systems including augmentation of existing water supply, water treatment plants and universal metering.
- Rehabilitation of old water supply systems, including treatment plants.
- Rejuvenation of water bodies specifically for drinking water supply and recharging of ground water.
- Special water supply arrangement for difficult areas, hill and coastal cities, including those having water quality problems (e.g. arsenic, fluoride)

While AMRUT has not implemented projects in Rajasthan, its success has indicates that the program's potential would have the capacity to effectively address some of the water supply system challenges that Jaipur faces.

Government of Jaipur

In 2018, Jaipur formed an autonomous body to management the city's water supply system and sewage. The Jaipur Water Supple and Sewerage Board (JWSSB) was created to finance, design, construct, oversee and modify the schemes for the city's water supply, as well as implement meter reading, billing and revenue services.[22] While progress has been made at the national and state levels to address the complexity of quality and quantity water challenges, at the local level there is very little public information on the progress of the Board to date, or recent efforts on behalf of the city to develop long-term solutions that address its more pressing water issues.

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21 Times of India. Ambitious water scheme in Rajasthan stares at fund crisis. July 2019. Retrieved from: https://timesofindia.indiatimes.com/city/jaipur/ambitious-water-scheme-in-raj-stares-at-fund-crisis/articleshow/70182599.cms

[22] Times of India. Autonomous board to monitor water supply and sewerage management in Jaipur's urban areas. August 2018. Retrieved from https://timesofindia.indiatimes.com/city/jaipur/autonomous-board-to-monitor-water-supply-and-sewerage-management-in-citys-urban-areas/articleshow/65345435.cms

100 Smart Cities

Recognizing that its resources have been increasingly constrained by a number of factors, in 2015 the Indian cabinet approved the equivalent of $7.5 billion U.S. dollars to develop 100 Smart Cities and an additional $7.5 billion for urban rejuvenation in another 300 cities. A 'Smart City' is a model for an urban environment that relies on information and communications technology (ICT) to "enhance its livability, workability, and sustainability"; it links multiple systems to enhance the safety, security, and efficiency of municipal services (especially when resources are scarce) including energy, transportation, infrastructure, healthcare, public safety and water services. A Smart Water Network (SWN) within the Smart City model would allow Jaipur to anticipate and respond to its water network issues, including leak detection, water quality issues, conserving energy, and tracking residential consumption[23]. In September 2018, Jaipur hosted a Smart Cites Expo with the goal of exploring the adoption of Smart City proposals. The Times of India reported that the Jaipur Smart Mission Ltd. (JSML) sought to install air and water quality systems in 2017; however, the city primarily remains focused on the city's other major sectors including heritage, tourism, mobility, and civic infrastructure.[24]

[23] Amir, A., & Kumar, B. P. *The Role of Water in India's Smart Cities*. June 2016. Retrieved from https://www.waterworld.com/international/article/16202026/the-role-of-water-in-indias-smart-cities

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Map of Site Visits

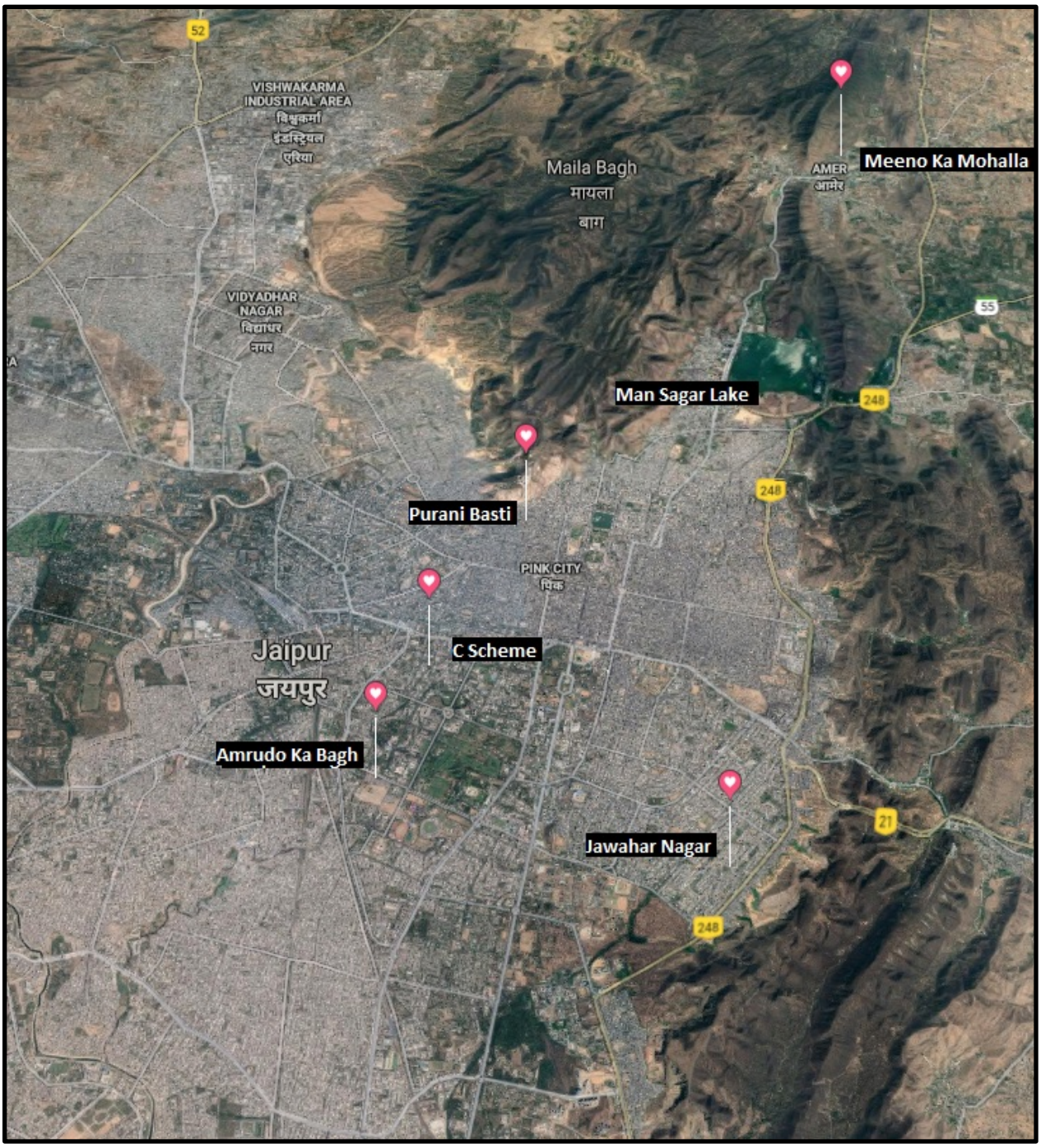

Figure 8 - Site visits during field research in Jaipur. Source: Google Earth

Additional Field Research Photos

Figure 9- Sunrise over the hills of Amer

Figure 10 - Street in Walled City

Figure 11 - Man drinking from borewell in Walled City

Figure 12 - Residents of Walled City

Figure 13 - Meeno Ka Mohalla water filtration business

Figure 14 - Young boy outside of home in Meeno Ka Mohalla

Figure 15 - A mother with her two children cleaning out the pollutants and debris of a street drain in Meeno Ka Mohalla

Figure 16 - School children in Meeno Ka Mohalla*, very excited at the prospect of visitors!*

Figure 17 - Street art of an elephant in Amer

Figure 18 - A man and a goat independently pose for a photo in Meeno Ka Mohalla

Figure 19 - Male and female bathrooms installed by the government for Amrudo Ka Bagh slum residents on community's perimeter

Figure 20 - Water storage containers in the Amrudo Ka Bagh slum

Figure 21 - Resident outside of home in Amrudo Ka Bagh slum

*Figure 22 - Report author, Kira Baltutis, with resident children in **J**awahar Nagar slum*

Figure 23 - Inside the temple near Man Sagar

Figure 24 - Trash engulfing perimeter of Man Sagar Lake

Figure 25 - Street in Jawahar Nagar slum

Figure 26: Report author, Kira Baltutis, with Aayojan Jaipur university students who provided English translations, contextual knowledge, and much needed masala chai tea breaks and friendship throughout the field research