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Local water resource management through stakeholder participation: case study, arid region, India

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Abstract

Access to clean water is important for socio-economic development worldwide. Bhuj, in an arid region in Gujarat State in India, has an ancient and unique water resource management system. The city's visionary king developed a catchment system of lakes so that, despite minimal rainfall and frequent droughts, sufficient water could be stored to sustain the city for around 300 years. However, over the years, with rapid urbanization and the introduction of a piped water supply, this ancient supply system was abandoned and was not maintained well. As a result, the city's water resources became polluted and defunct, which forced it to depend on distant water sources. This study shows how the city's water management strategies changed before independence (1947), and pre-earthquake (1947–2001) and post-earthquake (2001 to present). The paper mainly documents how the city's own water resources can be managed successfully by following the concepts of IUWM through effective stakeholder participation, to make the city water-secure.

Key words: ancient water supply system, local water resource management, stakeholder participation, water security

Highlights

- In the era of 'Smart City', city managers are focusing on creating centralized smart piped water infrastructure, focusing on importing water from distant water sources. Instead, to make city water secure, the focus should move towards integrated urban water resource management (IUWM). The paper highlights the case of an arid city – Bhuj, Gujarat, India, which has demonstrated excellent ways of water management and is moving towards water security with an active participation of local community including women from vulnerable groups. From the Bhuj experience, it is clearly understood that when institutions are supportive and stakeholders are mobilized, IUWM can be implemented for long term sustainability.

INTRODUCTION

Seven hundred million people could be displaced by intense water scarcity by 2030 (United Nations 2018). The World Bank believes that, if this continues, water wars are not far off (Prospect 2014). According to the National Institute for Transforming India (NITI Aayog 2018), 600 million Indians face high to extreme water stress and about 200,000 people die every year because of inadequate access to safe water. By 2030, India's water demand is projected to be twice the available supply,

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implying severe water scarcity for millions and an eventual 6% loss in the country's gross domestic product (GDP) (The Economic Times 2018).

Water security has been defined by UNESCO as the capacity of a population to safeguard access to adequate quantities of water of an acceptable quality for sustaining human and ecosystem health on a watershed basis, and to ensure efficient protection of life and property against water-related hazards such as floods, landslides, land subsidence, and droughts. Given population growth, deteriorating water quality, the growing impact of floods and droughts, and the other hydrological effects of global change, water security is a growing concern. It touches on all aspects of life and requires a holistic approach, which actively integrates social, cultural and economic perspectives, scientific and technical solutions, and attention to societal dynamics (UNESCO 2017). For the world to become 'water secure', the way in which water is managed needs to be changed immediately. Many experts recommend integrated urban water resource management (IUWM) as a better way to manage water resources in urban areas. The World Bank (2016) defines IUWM as:

> '*A flexible, participatory and iterative process, which integrates the elements of the urban water cycle (water supply, sanitation, storm water management, and solid waste management) with both the city's urban development and river basin management to maximize economic, social and environmental benefits in an equitable manner.*'

IUWM's principal components are conservation of natural water bodies in urban areas, recycling and reusing wastewater, storage and use of storm water, rainwater harvesting and groundwater recharge.

This paper documents Bhuj's water resource management journey. It also describes how the city has followed IUWM principles at consumer level to make the city water-secure.

Bhuj is in southern Gujarat, an arid region of India (see Figure 1). Bhuj Urban Local body (ULB) is known as Bhuj Nagar Palika (BNP). The Bhuj Area Development Authority (BHADA) was established after the disastrous earthquake of 26th January 2001, under section 22 of the Gujarat Town Planning and Urban Development Act 1976 on 9th May 2001 for rehabilitation and reconstruction of the city. BHADA has taken effective development steps to achieve the well-determined vision to provide infrastructure facilities, and new town planning of the earthquake-affected city, as well as

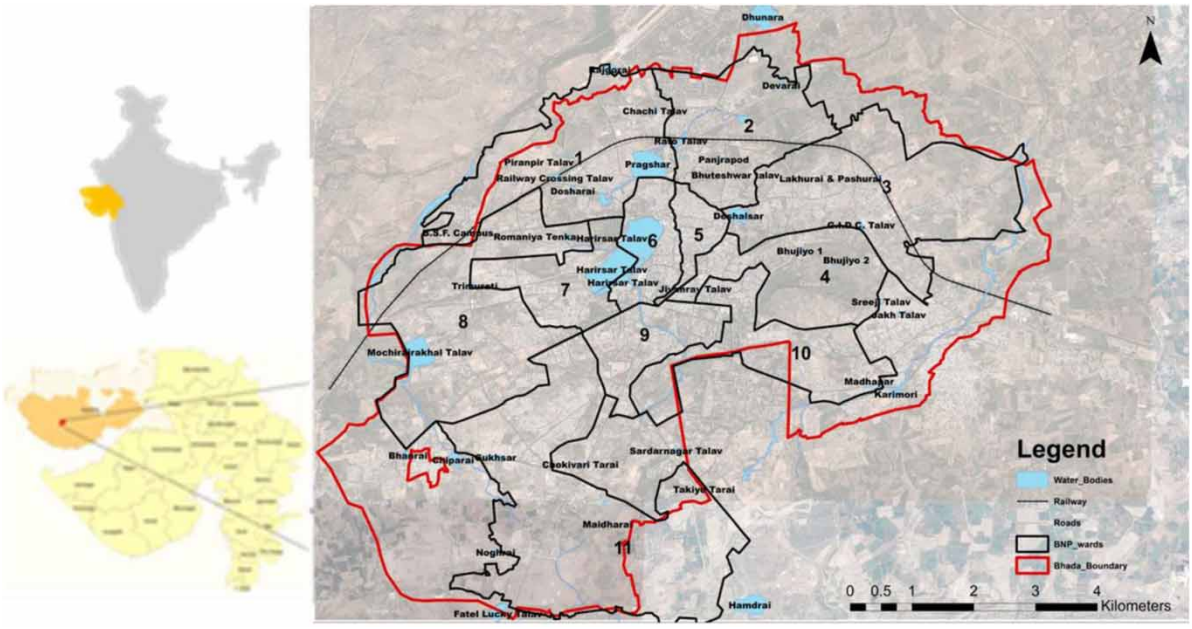

Figure 1 | Location of Bhuj city.

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rehabilitation for people at newly developed relocation sites. Figure 1 shows the area covered by BNP – the ULB – and the area within the BHADA boundary (BHADA 2001) The city has conserved its water catchments successfully, and managed water demand and supply security, by implementing rainwater harvesting and groundwater recharge projects in successful participation with stakeholders like the development authorities – BNP, BHADA – and participation from NGOs and the community.

The aim of the study was to identify the importance of stakeholder participation in water resources management and document the challenges faced by Bhuj in implementing its community-led water resource management projects.

MATERIALS AND METHODS

The information required for the study was gathered through primary and secondary surveys, including literature reviews, interviews with different stakeholders, and focused group discussion with the city's community groups. The city had different water management strategies before independence (1947), and pre-earthquake (1947–2001) and post-earthquake (since 2001). The detail of Bhuj city's ancient water system is explained below – '*Phase 1: Before independence (1947)*' – adapted from Raman (2014). The water management approach and the challenges faced during each phase have been documented, through focused group discussions with community groups and personal interviews with stakeholders involved. The stakeholders include NGOs, city officials, various community groups, historians, poets from the district (Kutch), officials from Kutch Museum, and descendants of the king's family.

After the earthquake in 2001, an NGO – ACT (Arid Communities and Technology) – began studying the traditional system with the aim of reviving it, to make Bhuj water-secure. ACT formed many community groups to implement community-managed water conservation projects in the city. To integrate different project groups, they formed an umbrella community group called 'Jal Strot Smvardhan Samiti' (JSSS), which means 'water resource conservation committee'. JSSS members were interviewed to document the challenges they faced in implementing the various water conservation projects. To understand the involvement and influence of government institutions on the disruption and revival of the traditional water system, representatives from departments dealing with forests, irrigation, revenue, and so on, as well as the ULB, a retired engineer from BHADA, and the city's mayors since about 2000, were interviewed.

WATER RESOURCE MANAGEMENT IN BHUJ

As Bhuj is in an arid region, it faces many issues related to water shortages. As shown in Figure 2, the city's water management strategies have changed over time.

1500-1800	1800-1960	1960-2000	2000-2011	2012-2020
• City depended on the water system developed by the king on the basis of understanding the local hydrogeology • Nearby lake catchments were linked • Enough water could be stored to meet demand	• Traditional water supply system community operated until the introduction of a government-managed, centralized system in the British era • Traditional system neglected	• Urban growth led to increased water demand • Piped supply system introduced in 1968 • Water brought from Kukma, 11 km from Bhuj	• Earthquake in 2001 • Water brought from Narmada, 700 km from Bhuj, in 2008 • Bharapar water scheme from 2011	• NGOs began researching the city's ancient water supply systems • Revival and protection of lake catchments with stakeholder involvement • RWH and groundwater recharge pilot projects.

Figure 2 | Phase-based summary of water resource management in Bhuj.

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Before India's independence (1947), the city depended on its own water resources, which became depleted between 1947 and 2001. Because of that, Bhuj faced many droughts and, to meet demand, many boreholes and wells were dug. Because rainfall and groundwater levels in Bhuj were lower, the yield from the wells was insufficient to meet demand.

Bhuj was devastated by a major earthquake in 2001 that caused major infrastructure damage, including the water supply system. This brought realization of the importance of protecting the city's own water resources and depending on distant sources. Many NGOs began reviving local resources and reusing the city's wastewater, as a result. ACT, for instance, started reviving the old water resource system and implementing water conservation pilot projects for rainwater harvesting and groundwater recharge. The phasing of Bhuj's water management system is explained below.

Phase 1: Before independence (1947): Bhuj has a long history of water resource management. The city's development began around Hamirsar Lake. The then king, Hamirji Rao, developed the water system on the basis of a good understanding of local hydrogeology. In 1510, Bhuj was declared capital of the Kutch region of Gujarat, which led to an increase in its population and, hence, water demand. To meet the demand-supply gap, the king linked three nearby lake catchments – Tapka, Lakki and Mirzapur-Mochirai – to that of Hamirsar Lake, as shown in Figure 3. In the late 18th century, a dam was constructed in the Dhunaraja catchment to meet further demand. Later, in the 19th century, Hamirsar and Pragsar lakes were linked – Pragsar Lake is North West of Hamirsar Lake.

To ensure efficient operation and maintenance, meticulous measures were taken to make special provision for regular cleaning of the water channels, through which water from the catchments were transferred to Hamirsar Lake. This was done by constructing the well known chaubees kuaan (twenty four wells). The wells are typically about 3 m deep and have 2 m $\times$ 2 m wide chambers constructed over the underground channel in the Mochirai Catchment through which regular cleaning and de-silting could be done. It is known as 'twenty four wells' because twenty four such chambers were built in a row one after the other. These chambers are so large (2 m $\times$ 2 m) that at least fifteen to twenty people can enter at the same time.

Figure 4 shows clearly that the importance of maintaining the system was such that meticulous efforts were taken in building these chambers and making sure that the channels were de-silted at regular intervals, especially before the rainy season. Apart from the regular channel maintenance, the lake was also de-silted regularly and was deepened whenever required. To ensure the water system's efficient operation, the king involved the community in cleaning the lake, catchment and streams regularly.

Hamirsar Lake's 7 km^2 catchment was expanded to 34.75 km^2 by these links, which enabled sufficient water to be stored to meet the city's needs. Because of the underlying understanding of the hydrogeology and the citizens' involvement in maintaining the water system, the city's water supply was sustained for more than 300 years, despite drought seasons.

Change from community to municipality managed system

In 1815 the British introduced a centralized system managed by civil engineers, who were largely unfamiliar with local water resource management systems, leading to its neglect. Instead of taking water from lakes, the population began to have to extract it from dug wells. As the traditional water system, the catchments and lakes, was fundamental to groundwater recharge, its neglect led to reduced groundwater levels and, eventually, Bhuj faced water shortages.

Phase 2: From independence to the earthquake: A piped water supply was introduced in 1960 and the focus shifted to household level water supply connections. The advent of the piped network and resulting increase in demand increased dependence on distant sources. Bhuj started importing water from nearby sources to meet its rising needs. From 2000 various sources came in, including Kukma, some 11 km from the city.

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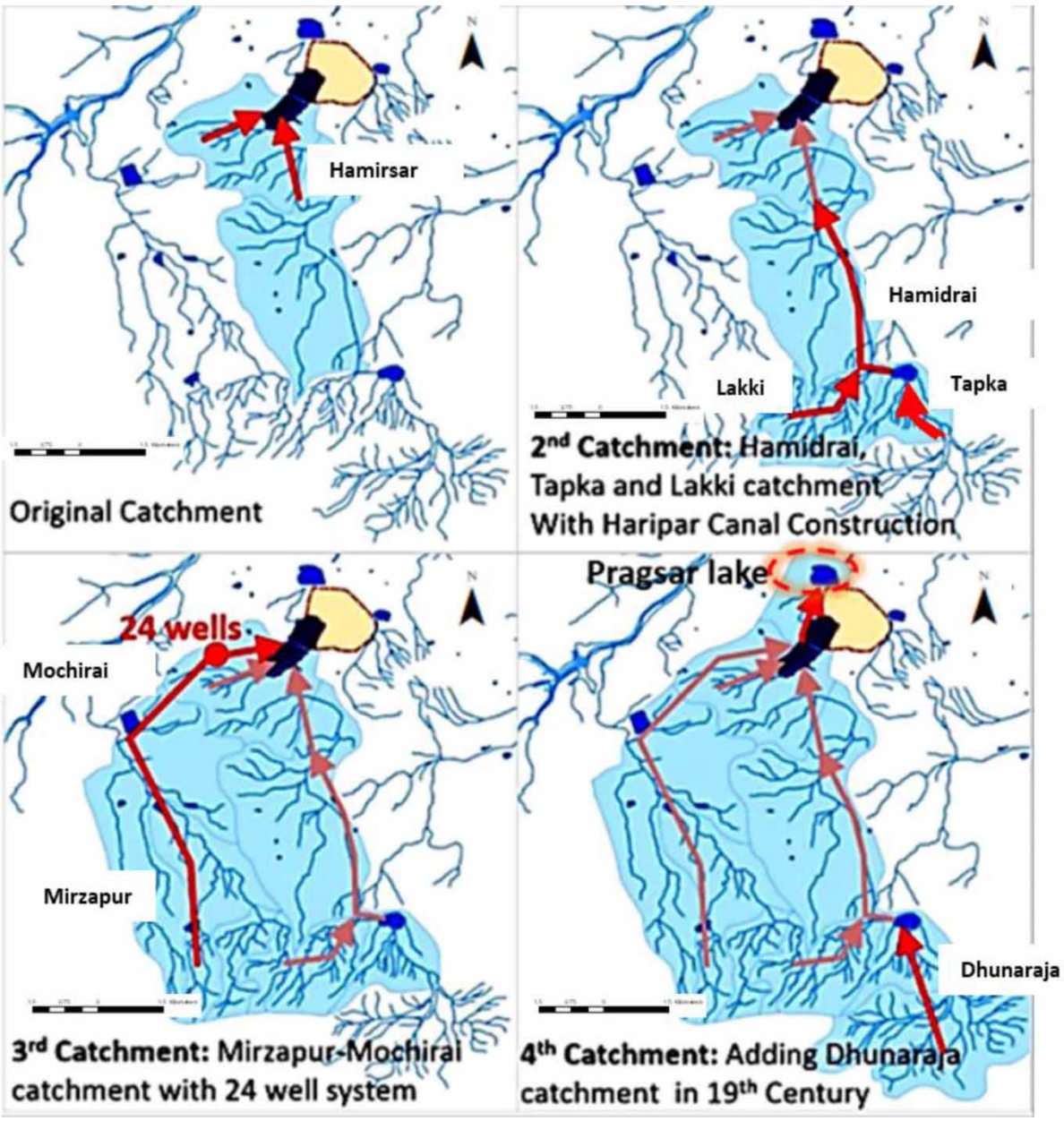

Figure 3 | Catchment linkages and development of ancient water system.

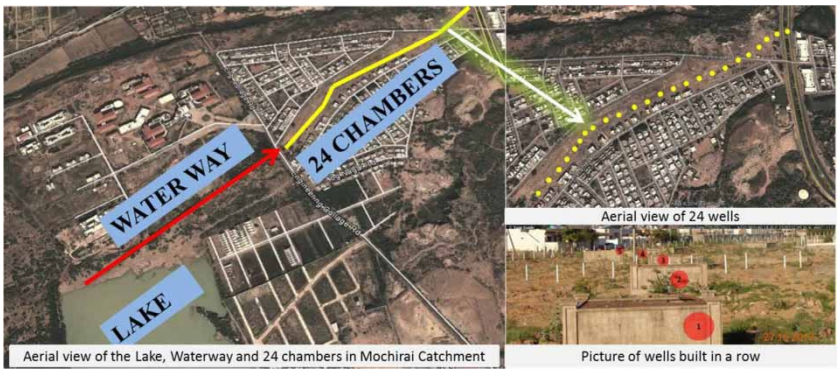

Figure 4 | Aerial view of the lake, waterway and 24 chambers in Mochirai catchment.

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Phase 3: Post-earthquake: Bhuj was affected by a severe earthquake in 2001 and its entire piped water system broke down. The distant (10 km) sources could not meet demand, so water was brought along a canal from the Narmada River, 700 km from the city, where water was the most pressing issue after earthquake, because the water system was inefficient, depending on distant water sources, and could not meet demand. As a result, ACT included water conservation as one of their agendas and implemented consumer-level water conservation pilot projects.

ACT began studying the local hydrogeology and the city's ancient water supply system. After the earthquake, people were hesitant about being in high-rise buildings and, as a result, Bhuj started expanding sideways. This development ignored the water catchment system completely and many natural streams were encroached upon (see Figure 5) so that the city's lakes and river dried up. ACT mapped the ancient system developed by the king, and identified the areas and lakes that had been encroached upon or polluted, or had vanished (Figure 5). If the streams are protected, not only will the lakes and other water bodies receive water, but groundwater recharge will occur. In other words, the streams need protection to make the city water-secure. Understanding the importance and value of the natural streams, ACT aimed to revive them and the lakes, where possible. A series of awareness-generating programs were conducted to encourage citizens, city engineers, ULB officers and others, and involve them in the process of documentation and conservation of the ancient water system (see Figure 6).

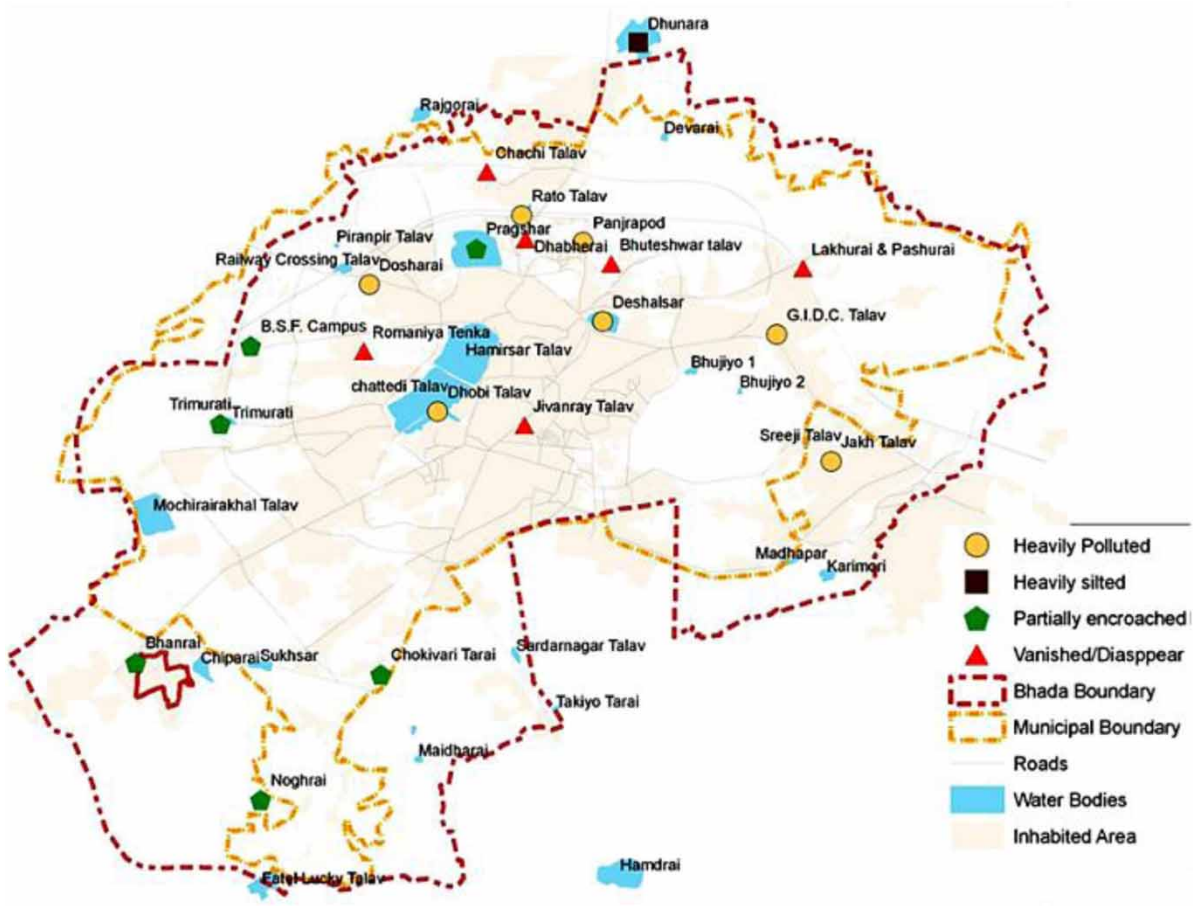

Figure 5 | Present status of lakes in Bhuj.

Initially, ACT faced many problems and challenges mobilizing people. While involving stakeholders, ACT realized that the people of Bhuj were strongly attached to Hamirsar Lake, in the city center (see Figure 1) and started conducting programs around the lake, which was really helpful in

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Figure 6 | Awareness generation programs conducted by ACT.

gaining people's attention. ACT has generated awareness amongst citizens through numerous activities described below and shown in the same sequence in Figure 6.

Activities included the following: (1) ACT prepared posters explaining the lakes' importance in the city, and ran 'Talav Parikrama' tours of Hamirsar Lake's periphery during which the Bhuj water system story was told and its importance explained by exhibiting posters; (2) drawing and essay competitions; (3) publishing newspaper articles and a monthly magazine called 'Hamirsar no Saad – Call of Hamirsar Lake' to generate water awareness amongst citizens; (4) running Jalpedi annual campaigns, in which 3D models of Bhuj's ancient water catchment system were used to help people understand it and make them aware that conserving it was important; (5) community lake cleaning – in both Hamirsar and Pragsar lakes, in the heart of the city; and (6) reconstructing Hamirsar Lake wall, which was destroyed by the earthquake, to define its boundary and prevent encroachment. The citizens of Bhuj crowd-funded reconstruction of the wall and this was a very popular, community-managed project.

After the successful awareness programs, ACT formed community groups for different water conservation projects and the umbrella group JSSS. Initially, JSSS was run mainly by ACT members, but gradually the community started joining and now only 2 or 3 committee members are from ACT, all others being community members (Bhuj citizens). Government bodies were also involved in the conservation programs. Over 12 years, JSSS has mapped the lakes and, where necessary, arranged for them to be protected by being demarcated on Bhuj city's development plan (DP). BHADA has agreed to demarcate them in the next DP and thus protect them from encroachment (CEPT 2016).

JSSS has also implemented projects – red boxes in Figure 7 – to revive the traditional water system. Tree planting was carried out around Hamirsar Lake by Bhuj's forest department. These projects were funded by BNP, and the work of cleaning the lakes and streams was done by city citizens under JSSS's community participation programs.

ACT has also implemented many consumer-level water conservation pilot projects. These include constructing consumer-level RWH (rainwater harvesting from the roofs of buildings) schemes on the city's public institutions, monitoring and recharging local groundwater, providing a continuous water supply in a slum area, that all make consumers depend less on supplies from BNP. All of these projects have been implemented successfully with stakeholder participation.

ACT approached public school principals in Bhuj to implement RWH projects. The importance of RWH was explained to them and how involving the children would be beneficial. They agreed and supported ACT/JSSS in constructing RWH schemes at their schools. To generate community

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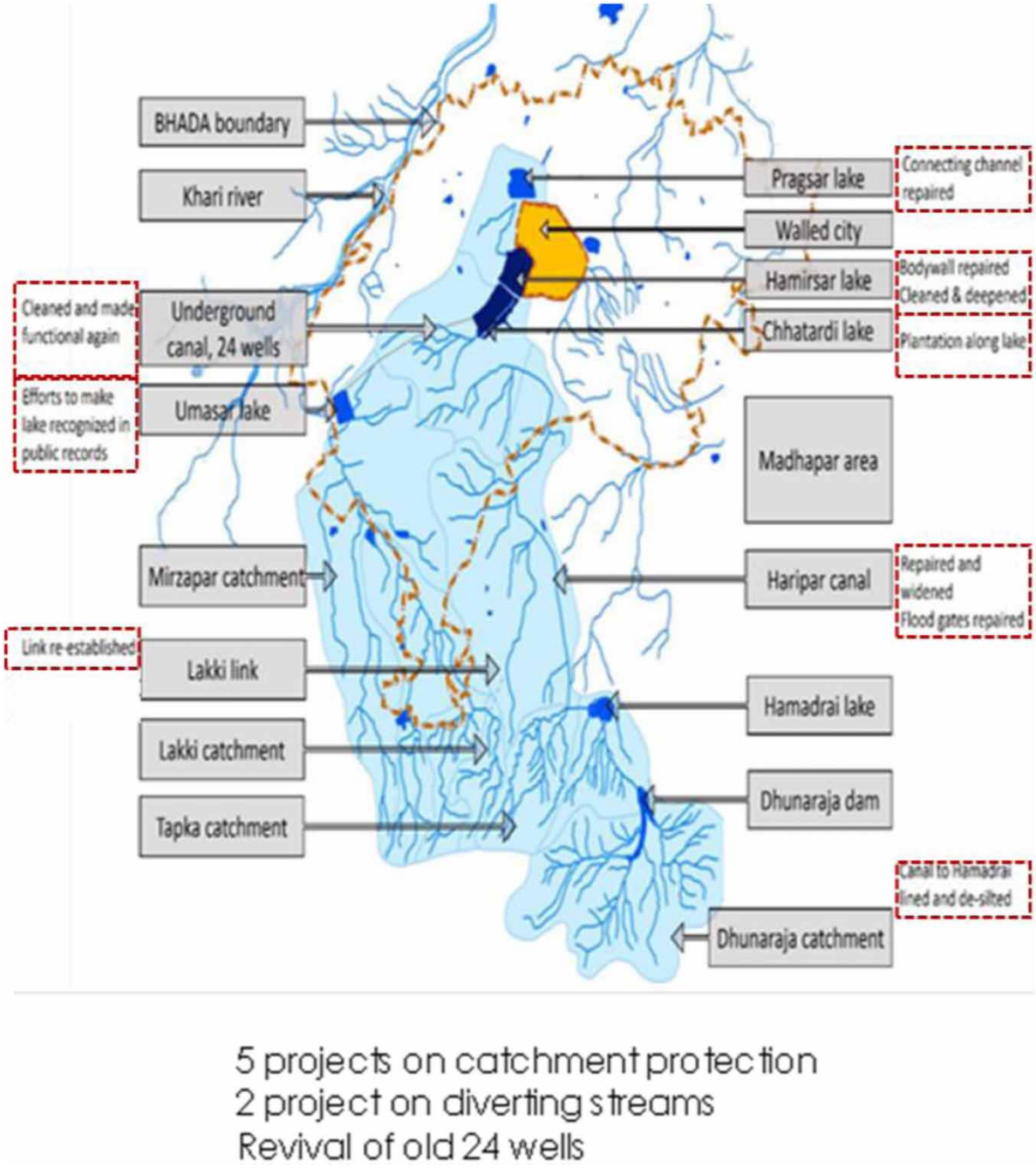

Figure 7 | Projects implemented to revive the traditional water system.

participation, ACT/JSSS first conducted awareness programs to convince students and their parents about the scheme. This took about two years, by the end of which the students and parents, and school staff members, were ready to construct, operate and maintain RWH systems. The model was first implemented at Shivnagar Primary School in 2010 through stakeholder participation. The schools involved have become self-sufficient in terms of drinking water, and the Shivnagar School model was so successful that two teachers adopted it at home and other schools have shown interest in implementing it (CEPT 2016). ACT has constructed RWH schemes in other schools and colleges with community participation (see Figure 8). The principals of these schools have reported that they can store enough rainwater to meet 3–4 months of demand from the schools.

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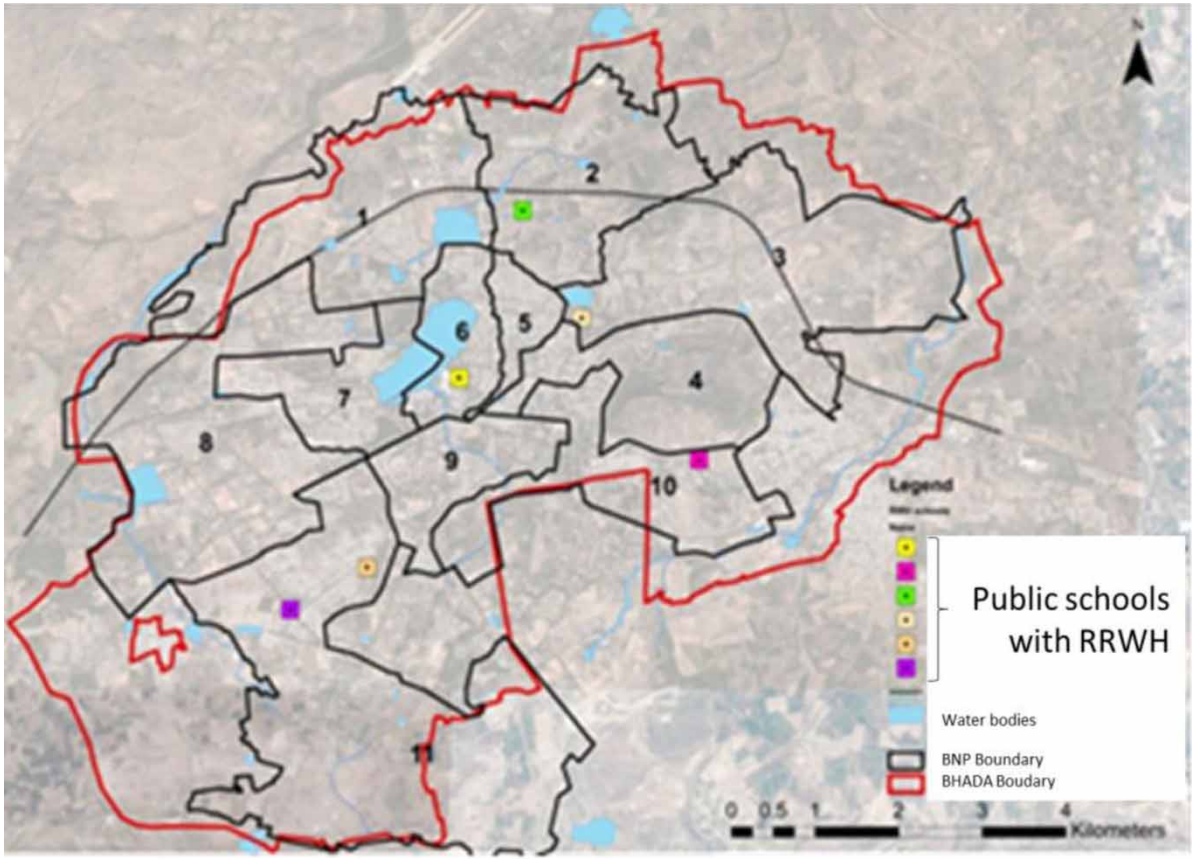

Figure 8 | Location of public schools with RWH structures.

ACT implemented another project providing a continuous water supply to one of the city's slum communities, a vulnerable group. While the slum was connected to the municipal supply, a technical issue meant that they were not supplied with enough water. The issue had not been resolved for a long period. ACT and other NGOs solved the problem innovatively by reviving a 200-year-old, traditional, dug well system near the slums (see left photo in Figure 9) and, with support from the community, stakeholders and councilors, connected every slum with a shared piped system (right-hand photo, Figure 9). The system, successful with and through community participation, is operated by the slum community who now receive a continuous supply.

Figure 9 | Continuous water supplied from a traditional dug well to the nearby slum.

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Other projects have comprised groundwater recharge using wells (Figure 10) to solve flooding problems (with the active participation of all residents). A residential area in Bhuj faced flooding issues every monsoon season, before recharge wells were constructed in the grounds of two local common plots. Three recharge wells of about 6 m depth were dug, increasing recharge capacity and solving the flooding problem. Of the total cost – 0.4M INR (about 5,500 USD) – 80% came as a grant from ACT and the remainder from contributions from the local residential association. The project was implemented in 2012, since when the local water table has risen about 13 m (40 feet). Because of its positive impact, the project was widely celebrated in the city and two similar projects have been carried out in areas facing similar issues.

Figure 10 | Groundwater recharge scheme constructed on common ground to deal with flood problems.

The majority of ACT projects have been successful because of institutional and stakeholder involvement. All have been at pilot scale so far but scaling up has started across the city.

Way forward and concluding remarks

With increasing urbanization and population growth, water resources and natural water conservation systems – such as, lakes and rivers – must be conserved for water security. Over time, water-scarce cities have come to depend on imports from afar. Sometimes, modern planners and developers overlook local hydrogeology and focus on implementing centralized water supply systems. Instead, city planning should begin with the water resources and water utilities, based on IUWM concepts. Projects on groundwater recharge, rainwater harvesting and wastewater recycling, as well as storing rainwater at household or another decentralized level, should be implemented. If a traditional water system exists and was effective, efforts should be made to revive it as much as possible. Continuous work and support from stakeholders and formal institutes can make the revival and conservation of traditional water systems practical.

In Bhuj, the projects implemented were sustainable because of active stakeholder participation. It is very important to conduct behavioral change activities and awareness generation programs in the right way for stakeholder participation to occur. In Bhuj, it was found that conducting different types of awareness programs for different types of stakeholder can generate interest and create long-lasting impacts. Stakeholder involvement is vital for sustaining projects related to water resource conservation. All types of stakeholder from many different backgrounds and income levels should be involved in such programs. From Bhuj's case, it is clear that implementing decentralized, community-managed water projects can help the city to become water-secure.

The technical and social aspects need to go together for successful implementation. The majority of projects in Bhuj were successful because institutional and stakeholder involvements were strong and

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the right technology was selected. The main reasons for the sustainable success of the projects were (1) appropriate technology selection, (2) successful stakeholder involvement, and (3) successful operation and management by local communities.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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