WATER KNOWLEDGE NOTE

Drought-Proofing through Groundwater Recharge

Lessons from Chief Ministers' Initiatives in Four Indian States

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Indian agricultural communities are facing a crisis driven by, among other things, skewed terms of trade and farmers' inability to deal with increasingly adverse climatic conditions. Because agriculture continues to be the primary source of livelihood for most of India's population, governments at all levels are under pressure to find ways to help farmers. In western and peninsular India, where droughts are common, several state governments have vowed to make farming "drought-proof" through ambitious flagship programs. This case study reviews the experience of four such programs in Gujarat, Maharashtra, Telangana, and Rajasthan. Although the programs differ in approach, implementation style, and duration, all of them aim to shield farmers, particularly smallholders, from the misery imposed by droughts. Among these states, efforts in Gujarat appear to be the most mature; however, concerns regarding sustaining momentum, capacity building of communities, demand management, and establishing functional local governance remain. We use evidence gathered through field studies to draw lessons for designing effective drought-mitigation strategies through improved management of groundwater resources.

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WORLD BANK GROUP

Centrality of Groundwater and Managed Aquifer Recharge

In the three decades between 1970 and 2000, India added more irrigated areas through expansion of groundwater irrigation than it had through massive investments in gravity-flow surface irrigation systems in the 200 years before that (Debroy and Shah 2003; Shah 2009). The bulk of this addition came because of private investments in tubewells, pumps, and water distribution systems, supported by agricultural power subsidies in western and peninsular India. Today, India has more than 20 million groundwater-based minor irrigation systems: 8.8 million dugwells, 5.9 million shallow tubewells, 3.2 million medium tubewells, and 2.6 million deep tubewells.[2] These structures are used to pump out between 200 billion and 230 billion cubic meters of groundwater annually, making India the world's largest user of groundwater (World Bank 2012). Against their ultimate irrigation potential of 78.9 million hectares, these groundwater structures irrigate 63.3 million hectares annually (GoI 2017; Rajan and Verma 2017). In comparison, India's medium and major surface irrigation systems irrigate 20 million to 25 million hectares against their ultimate irrigation potential of about 40 million hectares.

Active and vibrant irrigation service markets in many parts of the country ensure that these 20 million groundwater structures not only service the well owners but also provide reliable and affordable irrigation service to non-well owners in their vicinity. One estimate, based on a large-scale national survey across the country (Shah 2009), suggests that in addition to irrigating the landholding of owners, each groundwater structure delivers irrigation to three to four water buyers. This number would be higher for larger and deeper groundwater structures, which are often jointly owned. Thus, although the dynamics of groundwater irrigation service markets vary across regions, they contribute in making groundwater irrigation available to 100 million to 120 million farm households, servicing more than 60 percent of the irrigated area in India (Shah 2007).

Groundwater irrigation is particularly appealing for smallholders because groundwater resources are widely distributed and the investment required to access it is relatively low. Groundwater not only helps smallholder farmers intensively cultivate and irrigate their small landholdings but also provides insurance against short- and long-term droughts—both of which affect surface water availability much more than groundwater availability. Shah and Verma (2017) define the three key roles that groundwater can play to safeguard against droughts: *stabilization*—to cope with mid-season dry spells; *buffering*—to cope with monsoon failure; and *carry-over storage*—to cope with consecutive years of drought.

When annual groundwater abstraction (for irrigation or otherwise) consistently approaches or exceeds recharge, wells fail to recover to predevelopment levels, even after a good monsoon. Over years, this overextraction results in depletion and lowering of groundwater levels—which makes groundwater irrigation more costly and less accessible, especially for poor farmers. This outcome seriously undermines groundwater's drought-resilience role, and many parts of India are already suffering the consequences.[3] Broadly, there are two approaches to reversing this trend: (a) enhance groundwater recharge to improve resource availability or (b) reduce groundwater abstraction by managing demand. The developing world provides several examples of the former and relatively fewer instances of the latter.

The "purposeful recharge (and storage) of water to aquifers for subsequent recovery or environmental benefit" is termed *managed aquifer recharge* (MAR) (Dillon et al. 2009). Sakthivadivel (2007; 2008) has argued that efforts for artificial groundwater recharge are as old as irrigated agriculture in arid and semiarid regions. In India, there is evidence from as early as 600 AD that constructing ponds or tanks[4] to capture rainfall runoff and augment groundwater recharge was considered the solemn duty of kings and rulers. Many of these structures still exist, and although they no longer command the centrality in irrigated agriculture as they once did, there have been efforts at reviving their groundwater recharge augmentation role.

This case study captures large-scale efforts by four state governments—in the Indian states of Gujarat, Maharashtra, Telangana, and Rajasthan—to promote groundwater recharge as the central strategy for helping rural communities deal with droughts (map 1). Although efforts in Gujarat have been accumulating over the past three decades, the programs in Maharashtra, Telangana, and Rajasthan are in their early years of implementation. Quantitative impact assessment is, therefore, difficult, but this case study attempts to understand the program design, implementation style, field processes, and response of communities to draw policy insights. The four states were purposefully chosen because they all have significant

MAP 1. Location of Study States in India

agrarian economies with large drought-prone areas and all four programs are being implemented throughout the state, often with ambitious objectives and desired outcomes. Another feature of each of these interventions is the extraordinary interest and political support they enjoy from their respective chief ministers.

Groundwater Management Efforts in Gujarat

Saurashtra Recharge Movement

Groundwater recharge started as a mass movement in Saurashtra, Gujarat, in the late 1980s in response to three successive years of drought (1986–88) (Shah 2000; Verma 2008). In their desperation to save crops, some farmers started diverting rainwater and water from nearby canals and streams into their wells. This practice was contrary to the prevailing wisdom at the time, which discouraged farmers from introducing silt-laden waters into their wells for fear of clogging the cracks and fissures and rendering the well defunct. Shamjibhai Antala, a local journalist and one of the pioneers of the movement, recounts, "Farmers were well aware, and even apprehensive about the 'silt issue' but the successive droughts and the impending threat of another crop failure left them with no choice" (Verma 2008).

This bold experiment bore fruit and the enterprising farmers were able to water their crops well into the winter season as scores of villages remained parched. Within a short time, thousands of farmers from the seven districts of Saurashtra were converting their wells into recharge structures. Over time, farmers, supported by local leaders and institutions, evolved different ways to deal with silt (by constructing a simple filter and settlement structure near the well) and expanded their portfolio of methods to enhance groundwater recharge. In addition to recharging dugwells, farmers desilted village water bodies and built check dams and sand dams on a large scale. Many community organizations contributed to the effort. The Swadhyaya Parivar—a popular quasi-religious movement—helped by propagating the message of groundwater recharge and offering volunteer labor for dugwell recharge. Sheth (2000) estimated that by the end of 1994, more than 230,000 dugwells were recharged in Saurashtra with the help of Swadhyaya volunteers. Several nongovernmental organizations (NGOs) and foundations contributed by providing financial and technical assistance for the construction of check dams and bori-bandhs (sand dams). Saurashtra Jaldhara Trust, an NGO based in Rajkot, made backhoes available free of cost to any village that wished to desilt recharge structures. Wealthy merchants and industrialists who had moved away from Saurashtra donated. The government of Gujarat pitched in through the Sardar Patel Sahbhagi Jal Sanchay Yojana (Sardar Patel Participatory Water Conservation Program; SPPWCP) by offering 60 percent subsidies for check dam construction. Gohil (2002) estimated that more than 130,000 check dams were constructed under this scheme across Saurashtra with overwhelming public participation.

Scientists have debated the impact of such large-scale decentralized water harvesting for groundwater recharge in Saurashtra and elsewhere. Although some have pointed to the local, village-level positive impacts, others have argued that such efforts are futile and "unscientific" (Kumar et al. 2008). In Saurashtra, studies have noted improvement in well productivity (Joshi 2002; Raval 2002), increased cropping intensity (Bhammar 2002), higher crop output (Joshi 2002; Bhammar 2002), and easier availability of wage labor (Raval 2002). On the other hand, Kumar et al. (2008) argued that unplanned and unchecked construction of water-harvesting structures has reduced flows to large dams and reservoirs downstream, thereby trading off public water supply services downstream for farmers upstream. Sakthivadivel (2008) emphasized the importance of capturing local runoff upstream to address problems of frequent drought in upper watersheds because blue water investments are mostly located downstream in a watershed or a basin, benefitting only that area with large-scale irrigation. Kumar et al. (2008) have also argued that cumulatively, the decentralized structures may not perform to their potential and therefore lead to higher evaporation losses, whereas Evenari, Shanan, and Tadmor (1982) and Shah (2002) have argued that smaller, decentralized storages will reduce evaporation losses vis-à-vis large reservoirs. Gohil (2002), Chemin (2002), and Jain (2012) have shown significant improvement in groundwater levels and vegetation cover in Saurashtra, crediting these to investments in decentralized water harvesting and groundwater recharge. Jain (2012) estimated the additional recharge from check dams and other water harvesting structures to be 480 million cubic meters per annum, contributing significantly to post-monsoon stabilization of groundwater levels in the region. Shah et al. (2009) and Gulati, Shah, and Shreedhar (2009) attributed a large part of the credit for unprecedented agricultural growth in Gujarat between 2000–01 and 2006–07 to the Saurashtra recharge movement.

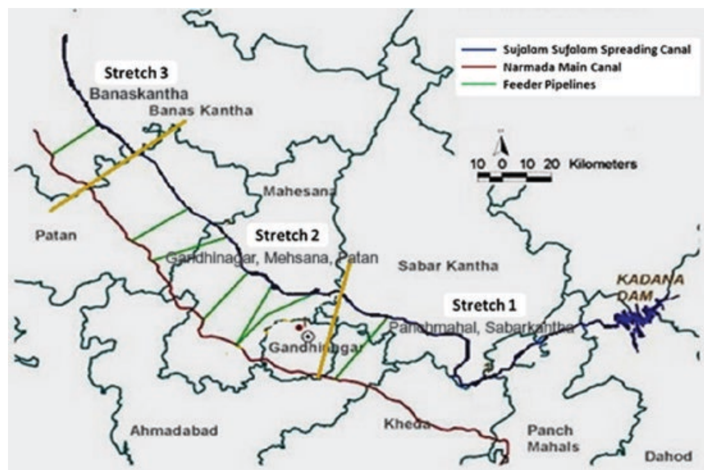
Sujalam Sufalam Yojana to Recharge Depleted Aquifers in North Gujarat

The Sujalam Sufalam Yojana was launched in 2004 with the objective of using the surplus water available in the Narmada and Mahi rivers to fill reservoirs and recharge aquifers in 10 water-scarce districts of north Gujarat. The scheme was designed with three key components: (a) pumping water from the Narmada Canal through pipelines to fill nine surface reservoirs in north Gujarat, (b) a 337-kilometer-long unlined "spreading canal" linking the Kadana Dam on the Mahi River to the Banas River, and (c) construction of 200,000 farm ponds along the spreading canal to enhance groundwater recharge (map 2).

Studies on the early impact of Sujalam Sufalam have reported: (a) a rise in groundwater levels (by 2 to 4 meters near recharge structures), (b) revival of dry dugwells (0.5 to 2.0 kilometers from the spreading canal), (c) expansion of irrigated area and an increase in cropping intensity, and (d) a reduction in energy use for pumping groundwater (ACT 2012; CGWB 2009; Prathapar et al. 2015).

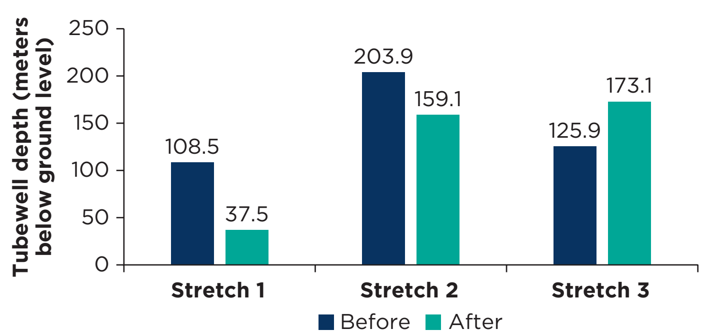
The study found that the impact of the recharge canal had not reached the last third of the canal (stretch 3) because water released in the canal was limited. However, the study found significant impacts in stretches 1 and 2. Based on surveys in 26 villages along the spreading canal, Rai et al. (2015) found a significant difference in the depths to which pumps were set,[5] with the shallowest pump depths in villages along the first third of the canal in stretch 1 (map 2 and figure 1). They also estimated an average 11.6 meter rise (from 95.7 to 84.1 meters below ground level) in water tables in treatment villages, leading to a near doubling of irrigated area (figure 2) and an incremental 31 percent increase in gross value of crop output (figure 3). The survey differentiated between "treatment" and "comparison" villages, classifying villages within 2.0 kilometers of the spreading canal as treatment and more distant villages as comparison. The gross value of output in agriculture increased by 125 percent in treatment villages to ₹124 crores,[6] whereas it grew by about 40 percent in comparison villages after the program (figure 3).

MAP 2. Sujalam Sufalam Spreading Canal



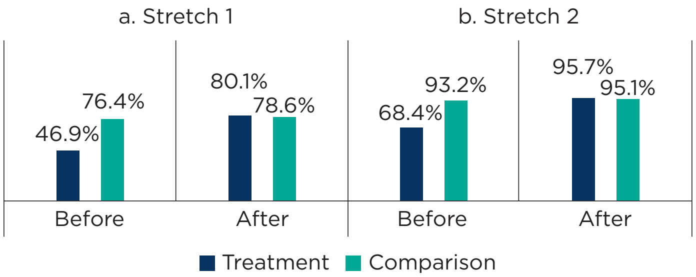
Source: Rai et al. 2015.

FIGURE 1. Depth of Submersible Pumps in Villages along the Sujalam Sufalam Spreading Canal



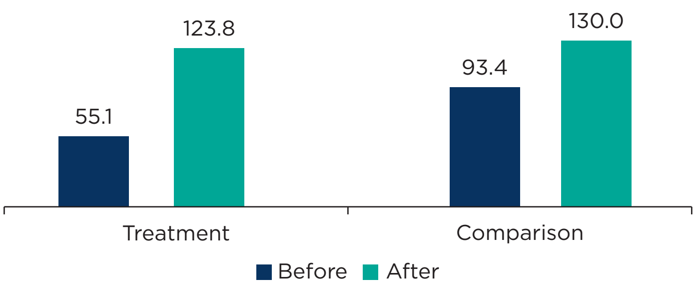
Source: Rai et al. 2015.

FIGURE 2. Irrigated Area as a Proportion of Cultivated Area in Treatment and Comparison Villages Before and After Sujalam Sufalam



Source: Rai et al. 2015.

FIGURE 3. Gross Value of Output from Agriculture (in ₹ Crores) in Treatment and Comparison Villages



Source: Rai et al. 2015.

Supporting Interventions

An important supporting intervention is the intelligent rationing of farm power. The provision of highly subsidized farm power over recent decades has routinely been blamed for overpumping of groundwater across India. In Gujarat, too, farmers had access to subsidized farm power and the electricity utilities were struggling to ration power supply to agriculture. Until 2005–06, the utilities supplied three-phase power for eight hours and switched the supply to single-phase for the remaining 16 hours to prevent farmers from operating their pumps. However, enterprising farmers found ways around such rationing efforts by employing locally manufactured "phase splitters" and operating pumps for 16 to 20 hours a day. Given the large numbers of farmers and their political influence, there was little that the utilities could do. Utilities accumulated large losses and had frequent pump and transformer burnout, disrupting power supply. Shah (2009) described this situation as "anarchy at the rural feeder" as the power supply worsened for all rural users. As a result, farmers were unhappy, rural consumers suffered, and utilities continued to accrue debts.

In 2005–06, the government of Gujarat implemented the Jyotigram Yojana and, in just 18 months, completely rewired the countryside and separated agricultural and nonagricultural feeders at a cost of US$250 million. Agriculture feeders now supplied eight hours of uninterrupted, high-quality, three-phase subsidized power according to a schedule while nonagricultural feeders were assured of around-the-clock power at commercial or near-commercial tariffs. These steps were implemented in conjunction with broader structural and organizational reforms in the electricity sector (Shah et al. 2012). Widely recognized as a huge success, the reforms substantially improved the quality of rural life in Gujarat and provided the government with an effective lever to improve groundwater governance (Shah et al. 2008; Shah and Verma 2008; see table 1).

TABLE 1. Farm Power and Groundwater Irrigation in India and Gujarat

	India		Gujarat	
Parameter	**2000**	**2013**	**2000**	**2013**
Number of agricultural connections (millions)	12.51	18.86	0.67	1.03
Annual agricultural power consumption (million kWh)	106,298	150,980	14,507	14,437
Annual farm power subsidy bill (₹ crores)	27,083	66,989	4,577	4,322
Annual gross well irrigated area (Mha)	33.775	42.438	2.920	4.51

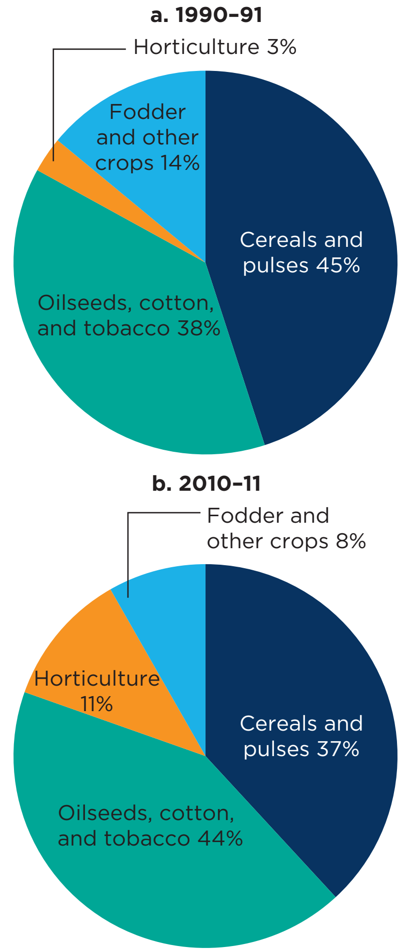
Sources: GoI 2001; GoI 2014; PFC 2015.
Note: Mha = million hectares; kWh = kilowatt-hours.

Gujarat is perhaps the only state in India where, at least in some areas, groundwater levels are improving (Jain 2012). Of course, this improvement should not be attributed to Jyotigram Yojana alone, but many have surmised that intelligent rationing of farm power supply has played a critical role (Gulati, Shah, and Shreedhar 2009; Shah et al. 2009; Shah et al. 2012). Table 1 shows that between 2000 and 2013, the national farm power subsidy bill more than doubled from ₹27,083 crores to ₹66,989 crores. Over the same period, Gujarat farm power subsidies declined from ₹4,577 crores to ₹4,322 crores despite more than 330,000 new farm connections and an increase in areas irrigated from wells from 2.9 to 4.5 million hectares. An increase in efficiency of pump utilization reduced waste of both power and extracted water, visibly shrinking water markets and increasing water prices.

Another supporting intervention is the promotion of efficient irritation technologies. Micro-irrigation technologies were first introduced in India in the 1970s. Several studies and field trials, both domestic and international, demonstrated the advantages of adopting efficient irrigation technologies, but state governments struggled to convince farmers to shift away from traditional methods of flood and furrow irrigation. Even inducements in the form of significant capital subsidies failed to rapidly expand the area under micro-irrigation, a technique largely viewed as suitable for "gentlemen farmers" who cultivate high-value commercial crops (Shah and Keller 2002).

In 2005, the government of Gujarat incorporated the Gujarat Green Revolution Company Ltd. (GGRC) as a special purpose vehicle to expand micro-irrigation acreage in Gujarat. Through a simple yet efficient subsidy disbursement process, GGRC has gained considerable ground in promoting micro-irrigation and became the nodal agency for all matters pertaining to government support for micro-irrigation adoption, claiming to bring more than 200,000 hectares of new area under micro-irrigation each year. Experts have debated the impact that greater use of efficient irrigation technologies has on net groundwater withdrawal at the basin level (Batchelor et al. 2014; Ward and Pulido-Velazquez 2008). However, micro-irrigation technologies have enhanced water use efficiency and improved farmers' incomes—catalyzing a steady shift toward horticulture crops that are less water-intensive and have a higher value (figure 4).

FIGURE 4. Change in Cropping Pattern in Gujarat



Source: Swain, Kalamkar, and Kapadia 2012.

A MAR Strategy for Gujarat

Building on earlier work, in 2008, the state government created a task force to develop an integrated MAR strategy for Gujarat. The task force was mandated to explore whether large-scale investments in MAR should become the major thrust of the state's water policy (Shah 2014). The team recognized that although community-led groundwater recharge efforts were beneficial, their planning and implementation was limited by scale (usually at the village level), skills, and resources. It also recognized that such efforts were more likely to succeed in hard-rock regions where investments in groundwater recharge led to immediate and proximate benefits. The task force report (GoG 2009) recommended a four-pronged strategy for managing groundwater in the state: (a) recharging with surface water, (b) recharging with rainwater, (c) incentivizing accelerated recharge by communities, and (d) introducing policies for groundwater demand management. It also outlined an implementation plan for the construction of 21,200 percolation tanks, 22,400 recharge wells, and 23,600 check dams, as well as modification of 42,000 existing wells through a budgetary allocation of US$700 million.

Although the strategy the task force recommended has not made its way directly into policy, efforts for artificial groundwater recharge continue to expand. For instance, just weeks before the expected onset of a 2018 monsoon, the Gujarat chief minister announced a monthlong campaign to create additional water storage at more than 8,000 sites across the state with the objective of capturing rainwater and catalyzing groundwater recharge. Through a campaign implemented on a mission mode by several government departments with the help of local communities, private players, and civil society organizations, the state set out to desilt 13,000 ponds, 200 large reservoirs, and 1,500 check dams and clean more than 3,400 kilometers of riverbeds to capture 11,000 million cubic feet (about 31.2 million cubic meters) of rainfall (Chhabra 2018). Named the Sujalam Sufalam Jal Sanchay Abhiyan, the government earmarked ₹345 crores (about US$50 million) for the campaign, and it is expected to become an annual exercise.

Drought-Proofing Programs in Maharashtra

The Marathwada and Vidarbha regions of Maharashtra are among the most drought-prone regions of India. The 1972–73 drought, which affected more than 20 million people (57 percent of Maharashtra's rural population at that time), led to large-scale crop failure and widespread farmer distress. The total loss to the economy was estimated in excess of ₹333 crores (about US$450 million[7]). Some media reports claimed that consecutive years of drought leading up to 2014–15 have been even worse (Anvesha et al. 2017). Maharashtra has also recorded an alarming number of farmer suicides in recent years, and there is a growing awareness that farmers are under severe stress from the worsening water situation, especially declining groundwater levels causing hydrological drought (Kakodkar 2015).

In response to the severity and impacts of drought in recent years, the government of Maharashtra in 2014 launched a five-year mission to make the state drought-proof by 2019. The state government intends to achieve this goal through a program improving village water security (Jalyukt Shivar [JYS]) and a parallel program rejuvenating water tanks (Galmukt Dharan and Galyukt Shivar [GDGS]). JYS harvests decentralized water to maximize irrigated crop land. GDGS removes silt from water tanks and spreads it on farmlands to improve productivity. Both programs have components to increase groundwater recharge. JYS aims to drought-proof 5,000 villages annually over five years, and GDGS has a target of desilting 31,459 reservoirs over four years (Solanki, Santhosh, and Chhetri 2018). JYS is implemented in villages, whereas GDGS is largely implemented through state government line departments.

JYS

Field studies in Maharashtra examining interim results of the program suggest variable results across villages but find that when implemented well, JYS makes a significant and positive impact on local water security. The impact is visible in expanded irrigated areas and improved cropping intensity, increased months in which irrigation water is available, and reduced reliance on tanker water supply to meet drinking water requirements. Of 12 villages that grew only monsoon crops before the intervention, eight were able to plant a second winter crop after the program began. Of 10 villages that relied on tanker water supply before the program, nine became tanker-free. And of the 19 villages that provided data on irrigated areas, 12 reported an increase after the drought-proofing intervention (Anvesha et al. 2017).

Anvesha et al. (2017) listed the following best practices to improve JYS interventions for consistent results:

- Villages become more involved and engaged in water planning, including such steps as an annual water budgeting exercise to allocate groundwater.
- Villages contribute a modest part of the financial resources required for recharge interventions.
- Villages account for their location in the larger watershed or river basin before planning water management.
- Villagers, technical experts, and engineers share knowledge and make collective and transparent decisions.
- Villagers receive training on water budgeting, efficient irrigation technologies, and water storage.

GDGS

Desiltation of tanks results in the restoration of tank storage capacity and augmentation of groundwater recharge. Under GDGS, silt extracted from the base of the tanks is spread on farm fields to replenish soil fertility and improve productivity. A study on tank desilting in Maharashtra from the research initiative of the International Water Management Institute (IWMI) and Tata Trust—the IWMI-Tata Water Policy Research Program (IWMI-Tata Program)—focused on three things: (a) understanding the processes followed in desilting tanks, (b) understanding farmers' perceptions about the program, and (c) quantifying the impact on village water security and rural livelihoods (Solanki, Santhosh, and Chhetri 2018). The study covered 30 villages in five districts: Aurangabad, Beed, Jalna, Latur, and Nashik.

The field study found significant benefits of tank desilting. Solanki, Santhosh, and Chhetri (2018) reported increased irrigated areas, improved drinking water availability, reduction in cost of cultivation, higher crop productivity, and perceived improvements in groundwater levels. However, the study also raised doubts concerning sustainability when the four-year program ends because of limited participation of villages in planning and carrying out the desilting work. In a few years, when the tanks and reservoirs need a new round of desilting to sustain the groundwater recharge and farm productivity benefits, it is unclear whether a follow-up program will be in place or whether villagers would be willing to do the work on their own.

Reviving Kakatiya Tanks in Telangana

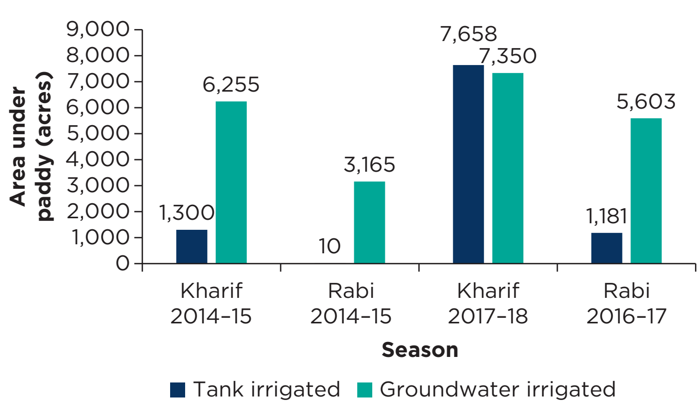
Peninsular India sits on hard-rock geological formations, primarily the Deccan Traps basalts and granitic basement complex of only moderate productivity. However, extensive areas are irrigated with groundwater. The expansion of groundwater irrigation occurred over the past 40 to 50 years as tank irrigation has taken a back seat in the region's minor irrigation landscape. Despite frequent well failure and rapid groundwater depletion, pump irrigation has provided "on-demand" irrigation to farmers and helped them grow multiple irrigated crops and use scarce land intensively to generate income. Tank-irrigated areas accounted for more than 15 percent of India's total irrigated area in the 1950s (Thenkabail et al. 2009). By 2011–12, the share of tank-irrigated areas dwindled to a mere 3 percent (MoSPI 2015). Tamil Nadu, where tank irrigation once dominated, has cut tank irrigation by one-third, from 940,000 hectares to 601,000 hectares (Palanisami and Ranganathan 2004). Availability of cheap pumping technology and subsidized or free farm power catalyzed a shift in farmers' irrigation preferences to pumping water from wells recharged from tanks instead of using flow irrigation even within the command areas of tanks and other surface reservoirs.

The Kakatiya was an important dynasty in Telangana's history and ruled between the 12th and 14th centuries from a capital in present-day Warangal. The Kakatiyas built thousands of small reservoirs to store rainwater for the dry season (Kothavade 2017). Often built in a cascade, the Kakatiya tanks were managed and maintained by communities of tank command farmers, tank-bed cultivators, and local fishing communities through a system of decentralized governance. Communities would work together in the summer to remove silt from bodies of water, and farmers applied the silt to cropland to maintain and improve productivity. Over time, the small reservoirs were neglected and fell into disrepair because of land-use changes in the catchment and the encroachment of tank beds. More than 46,500 of such decentralized storage reservoirs exist in Telangana, according to the fifth Minor Irrigation Census (GoI 2017).

Earlier governments recognized lack of access to irrigation as a key challenge in Telangana, where almost half of the gross cropped area of the state is rain-fed. But it took a state reorganization to launch a comprehensive project to revive tanks to improve irrigation access. In 2014, Telangana launched Mission Kakatiya to revive and harvest the benefits of tank irrigation by increasing the command area, water available for irrigation, and opportunities for agriculture. One of the major slogans of the movement for a separate Telangana state was "*mana ooru, mana cheruvu*" (our village, our tank), which later became the catchphrase for Mission Kakatiya. The five-year program intends to uphold the vision of the Kakatiyas by reviving and restoring minor irrigation tanks to use 7.5 billion cubic meters of water allocated for minor irrigation in the Godavari and Krishna river basins to irrigate 20 lakhs[8] acres. The tanks are filled by canals.

The main objective of Mission Kakatiya is to revive minor irrigation by desilting tanks to increase their water storage capacity and repairing sluices, weirs, and irrigation canals. The project has also impacted groundwater irrigation through increased recharge of groundwater from tank seepage. Field data show a positive change in tank-irrigated areas for all tank sizes, according to the IWMI-Tata Program, which led field studies in 2015, 2016, and 2017 that consistently reported increases in irrigated areas and cropping intensity. Figure 5 shows the change in rice paddy area before and after program implementation in study villages in the Nirmal and Warangal districts. Field

FIGURE 5. Change in Area under Tank- and Groundwater-Irrigated Paddy before and after the Program in Study Villages



surveys also suggest the silt application resulted in higher crop yields and lower costs of cultivation, and farmers reported increased availability of water in wells. A survey by the state groundwater department found groundwater levels increased in 22 of the 31 districts (*The Hindu* 2017). The IWMI-Tata Program field studies reported increases in noncrop incomes such as fishing, cattle herding, and fermented beverages known as toddies (Shah, Bharti, and Verma 2017). A NABCONS (2017) assessment showed a 62 percent increase in fish production in Telangana tanks.

Water Self-Reliance in Rajasthan

In Rajasthan, India's most arid state, droughts are frequent. The state is divided into four broad geographic regions: western desert plains, Aravalli Range and hilly regions, eastern plains, and southeastern Hadoti Plateau. To meet the needs of 5.5 percent of India's population and 18.7 percent of the country's livestock, Rajasthan has only 1.2 percent and 1.7 percent of the country's surface and groundwater resources, respectively. Rainfall is erratic and ranges from 150 millimeters in the western desert to 900 millimeters in the eastern plains. There is a high dependence on groundwater for both irrigation and drinking needs. India's Central Ground Water Board (CGWB) has reported an average groundwater development of 125 percent[9] in the state with overexploitation of groundwater in 47 percent of the blocks.

Table 2 shows the distribution of districts based on drought frequency, which vary from once every three years in the dry western district of Barmer to once every eight years in Bharatpur. Like the drought frequency, aquifer conditions vary across the state. Some areas have alluvial aquifers of significant thickness, and others have weathered and fractured hard-rock aquifers, implying that the state must tailor programs to match the climate and aquifer of each area. Evaporation losses, which range from 1,400 to 1,800 millimeters per year in most parts of the country, are highest in Rajasthan (3,000 millimeters per year) (Guerra, Watson, and Bhuiyan 1990).

To help rural communities cope with droughts, the government of Rajasthan aims to make villages self-reliant in meeting water needs. Launched in 2016, the Mukhyamantri Jal Swavlamban Abhiyan (MJSA; chief minister's Water Self-Reliance Campaign) is the state's flagship program to implement the so-called "four waters concept"[10] in drought-prone areas. MJSA was designed in four annual phases, with the first phase completed in July 2016 in all 295 blocks of 33 districts. The program includes constructing minor irrigation tanks; irrigation dams known as anicuts; check dams and field bunds to slow water runoff; and rooftop water harvesting structures, farm ponds, staggered trenches, and continuous contour trenches to capture runoff. To leverage similar programs administered by other line departments, MJSA also focuses on planting trees and seeds in barren wastelands, developing pastures, expanding horticulture, and promoting micro-irrigation. The program aims to create a movement on water conservation with participation of multiple departments and people working together. The program focuses on increasing irrigated and cultivable areas and aims to bring irrigation to at least 40 percent of existing rain-fed areas to increase production.

Conception, Structure, and Funding

Watershed development concepts are not new in Rajasthan. Several programs have been implemented, the most recent ones being the Integrated Watershed Management Program (IWMP), Hariyali Guidelines, and Pradhan Mantri Krishi Sinchai Yojana (Watershed Development Component). IWMP was initially criticized for being purely technical with little community participation, whereas Hariyali centered its work around public participation. MJSA intends to learn from this feedback by ensuring local participation in water planning and budgeting, aided by technology, to implement a ridge-to-valley approach.

TABLE 2. Distribution of Rajasthan's Districts Based on Drought Frequency

Frequency of drought (return period, years)				
3	4	5	6	8
Barmer, Jaisalmer, Jalore, Jodhpur, Sirohi	Ajmer, Bikaner, Bundi, Churu, Dungarpur, Hanumangarh, Nagaur, Sri Ganganagar,	Alwar, Banswara, Bhilwara, Dausa, Jaipur, Jhunjhunu, Karauli, Pali, Sawai Madhopur, Sikar,	Baran, Chittorgarh, Jhalawar, Kota, Pratapgarh, Rajsamand, Tonk, Udaipur	Bharatpur, Dholpur

Source: Government of Rajasthan (http://www.dmrelief.rajasthan.gov.in/images/droughtFrequency.gif)

Rajasthan River Basin and Water Resources Planning Authority (RRBWRPA) is the nodal agency to carry out the program. It sets technical guidelines to ensure consistency among structures built by various departments at district and block levels. Seven other line departments are involved in MJSA: the Forest, Water Resources, and Watershed departments are working on water harvesting; the Horticulture, Agriculture, and Public Health Engineering Departments focus on planning; and the Groundwater department provides technical support (figure 6).

The program relies on state government funds and department experts. RRBWRPA's primary role is to coordinate work among the departments and manage conflicts. The chief minister of Rajasthan holds regular meetings with the heads of all line departments involved for progress updates. At the district level, a team with representatives from all departments conducts pre-surveys, prepares detailed project reports, selects contractors, and monitors work and financial sanctions.

In the program's first phase, 3,529 villages were involved through 95,192 water conservation works, with a total expenditure of approximately ₹1,600 crores (about US$230 million). One-third of this expenditure came from the Watershed Department, and another third came from the MJSA United Fund. MNREGS (the Mahatma Gandhi National Rural Employment Guarantee Scheme) contributed 24 percent of funding, and the remainder came from various departmental funds, crowdsourcing, and corporate social responsibility[11] donations. Details of financial sanctions and expenditures incurred in three phases (ongoing) are listed in table 3.

FIGURE 6. Organizational Structure of the Mukhyamantri Jal Swavlamban Abhiyan Program

Source: Prepared by authors, based on information available at http://mjsa.water.rajasthan.gov.in/

Technology and Sustainability

The MJSA program boasts of using cutting-edge technology in all steps of implementation such as a mobile phone application for pre-survey and detailed project reports, satellite imagery and geotagging for planning and monitoring, and proposed drone surveys in the last phase. Each team conducting field surveys for site selection is required to track its transect walk through the village. The selected sites are uploaded with geotagging and checked by GIS (Geographic Information System) experts at block, district, and state levels to ensure saturation of the area with appropriate structures and benefits to all parts of the village. High-resolution satellite imagery is used to monitor progress of the structure after private contractors begin construction.

The program does not have a plan for long-term sustainability of the structures that are built, but it does require third-party contractors to maintain them for two years. Contractors selected for work submit a security deposit that is held for two monsoons and released only if the structures remain undamaged. When structures are built on private land, the farmer must contribute 5 to 10 percent (depending on caste/community) and take responsibility for maintenance.

TABLE 3. Expenditure Details of Rajasthan's Mukhyamantri Jal Swavlamban Abhiyan Program

Phase	Years	Financial sanction (₹ crores)	Works completed (cost; ₹ crores)	Donations (CSR/ individual; ₹ crores)
1	2015–16	1,710	1,602	38.6
2	2016–17	1,611	1,556	22.8
3	2017–18	1,292	6.84	6.3

Source: Authors compilation from various Government of Rajasthan documents available on: http://mjsa.water.rajasthan.gov.in/
Note: CSR = corporate social responsibility.

Impact and Field Impressions

An internal impact assessment was conducted at the district level to study the interim results after two monsoons. Piezometers installed across the state recorded that out of 21 non-desert districts, groundwater levels rose in 16 districts with an average increase of 1.42 meters. The program claims to have intercepted 188.39 million cubic meters of water through watershed development and created an additional 127.88 million cubic meters of storage capacity through tanks, anicuts, check dams, and other structures (GoR 2018). To assess the MJSA program's phase 1, it is reported that participating villages saw reduced water transportation (through water tankers) by 56 percent compared to nonparticipating villages. That finding implies participating villages had supplies available and did not need to transport water. About 64 percent of defunct hand pumps and 20 percent of tubewells were reported rejuvenated in 2017 compared to 2015, indicating farmers had access to improved irrigation in dry months. A total of 44,409 hectares of crop area increased in rabi and zaid seasons, and an additional 2,470-hectare increase was reported as a result of the improved water distribution system. The program also helped livestock farmers by ensuring water in surface structures for longer periods. About 28 lakhs trees were planted near small bodies of water to enhance green cover by 3,678 hectares, helping control soil erosion in various terrains.

The IWMI-Tata Program conducted fieldwork in three districts (Banswara, Sirohi, and Udaipur) to collect qualitative insights and validate the program's claimed impacts. Farmers from beneficiary villages reported either no change or a positive change in groundwater levels. They also reported a positive increase in rabi irrigated areas and two to three months of additional water availability in wells. In smaller structures, water continued to be present even at the end of March. However, in larger structures such as talabs and percolation tanks, higher evaporation losses resulted in faster drying up of structures. Farmers reported planting more wheat in 2017 and 2018 rabi compared to previous years. Farmers also tried new crops in the most recent rabi season such as green gram, pulses, and oilseeds. Transporting silt to farm fields has not been a focus of this program compared to similar programs in other states, and MJSA did not monitor the quality of silt or promote farmer awareness of its benefits. In most villages, farmers reported they were not involved in the planning process and did not contribute any labor to the program.

Although geotagging was implemented in phase 1 of the program, it was done after works were completed, which resulted in misplaced and missing tags. This study found several structures either wrongly mapped or nonexistent in the tribal villages of Banswara. Many structures listed as built under MJSA were found to be much older, with no recent restoration work. These findings highlight the importance of remote monitoring and the role of technology. In phase 2, geotagging was done from the first stage of implementation and progress was monitored remotely.

Discussion and Conclusions

Key Lessons from States

Gujarat offers a prime example of improved groundwater governance as the primary tool to build drought resilience. Through its continued emphasis on enhancing groundwater recharge, and by supporting interventions in energy and efficient irrigation technologies, Gujarat represents one of the more evolved strategies for MAR. The program's ultimate strength lies in the continuous engagement of the government and civil society in improving groundwater management. In his former role as chief minister of Gujarat, India's current (2019) Prime Minister Narendra Modi understood the importance and mass appeal of water, energy, and agriculture sector reforms and made them central to economic growth. The emphasis on these key sectors has continued and we find several other chief ministers also using groundwater recharge and populist farm power policies as key tools to demonstrate their commitment to help farmers.

Maharashtra, on the other hand, seems to have chosen a "big bang" approach,[12] setting itself an arguably unrealistic goal to make the state drought-free by 2019. Although it probably is a good way to motivate and energize the implementing agencies and communities, drought-proofing needs to be a continuous process and not a one-time intervention. Nevertheless, the intensity of effort has generated visible impacts in some villages in terms of improved water availability for drinking and agriculture. The government initiatives—JYS and GDGS—have attracted support from several nongovernmental organizations, civil society organizations, and village communities that are taking up additional independent efforts in support of their objectives. It is difficult to predict whether the momentum will continue beyond the four- to-five-year lifespan of these programs.

As Anvesha et al. (2017) and Solanki, Santhosh, and Chhetri (2018) have highlighted, there is high variability in the quality of implementation and impacts at the village level. It is still early, and there is room for mid-course corrections, greater involvement of communities in implementing the programs, and learning from

In Telangana as well as in Rajasthan, the chief ministers are betting on their flagship drought-proofing programs to win farmers' support in future elections. Telangana's Mission Kakatiya deserves credit for highlighting the role that traditional tanks can play in promoting groundwater recharge. However, as in Maharashtra, the sustainability of the program is a matter of concern. By implementing a supply-driven, top-down program, Telangana has missed an opportunity to invest in reviving sustainable village institutions and empowering local communities to maintain and manage tanks. The traditional neerghati—village tank manager—vanished with the decline in the importance of tanks, and it is unclear who will maintain the tank systems when Mission Kakatiya ends. By the time the last of the 45,000 tanks are desilted, the tanks in phase 1 of the program will need another round of desilting. Policy makers must urgently address the central question: Does the government need to plan a perpetual tank rehabilitation program to sustain benefits or will communities take responsibility for managing and maintaining tanks?

As the youngest of the initiatives covered in this case study, Rajasthan's village water security program, MJSA, underscores the importance of technology for transparent, timely implementation and monitoring of large-scale programs. MJSA also appears to have made a promising start in converging departmental efforts for holistic outcomes with a focus on small, low-cost, terrain-appropriate structures to capture surface runoff to recharge groundwater (unlike in Maharashtra and Telangana). Whereas most other programs focused on improving water availability, MJSA includes a component to improve water use efficiency. However, MJSA is like Maharashtra and Telangana in that no efforts have been made to help villages take ownership of community water assets and sustain the benefits following the termination of government programs.

Discussion

In this case study, we have reviewed interventions and their impacts in four Indian states, each of which has invested in improving groundwater recharge with the objective of helping rural communities cope with droughts. Although each state program has followed a unique trajectory, the origin of each is rooted in the agrarian distress caused by consecutive years of drought. The fact that each of these programs has a strong groundwater component shows that state governments are aware of the critical role groundwater can play in improving drought resilience. The strategies in the four states vary in terms of the maturity of program evolution, focus of specific interventions, funding strategies, community engagement and participation, mode of program delivery, and level of effectiveness. Table 4 compares the four states' programs.

Although none of the programs can claim to be complete, each has highlighted the importance of at least some key elements of what a successful and effective integrated drought-proofing program might look like. The MAR program in Gujarat seems to be the most evolved strategy with years of experience, but it is focused largely on the supply side and is designed for top-down implementation, with resource augmentation as its key objective. The supportive interventions of tightly managing the energy-irrigation nexus and promoting micro-irrigation technologies operate on the demand side at the macro level. The recharge movement in Saurashtra included much community participation, was led from the grassroots, and was supported by a government program—unlike similar groundwater recharge interventions elsewhere. There are no specific programs in Gujarat for catalyzing village-level institutions to manage groundwater but, as highlighted in 2018 through the pre-monsoon Sujalam Sufalam Jal Sanchay Abhiyan campaign, the government is keen to catalyze and channel collective action for groundwater augmentation.

In Maharashtra, the design of both JYS and GDGS calls for active community participation, but field studies suggest that villagers' responses have been mixed. Further, both these interventions focus largely on resource augmentation and treat drought-proofing as a one-off exercise, which is unlikely the case. Telangana's Mission Kakatiya highlights the important relationship between irrigation tanks and groundwater agro-ecosystems. It also illustrates the benefits of a campaign/mission mode and statewide implementation for quick results. However, this program also suffers from a lack of long-term strategy and misses the opportunity to revive traditional systems of community management and ownership of grassroots assets. Recently, the government of Telangana announced free power around the clock to farmers for pumping groundwater (Apparasu 2018), a move likely to ensure that any groundwater gains from Mission Kakatiya will be set back. However, in a surprise development, some farmer groups and leaders are lobbying the state government for a rollback to rationed supplies of

TABLE 4. Comparison of Drought-Proofing Programs in Four Indian States

Particulars	Province			
	Gujarat	Maharashtra	Telangana	Rajasthan
Flagship program	Integrated strategy for managed aquifer recharge (MAR)	Jal Yukt Shivar (JYS) and Galmukt Dharan and Galyukt Shivar (GDGS)	Mission Kakatiya	Mukhyamantri Jal Swavlamban Abhiyan (MJSA)
Intervention focus	Groundwater recharge structures	Watershed works and decentralized water harvesting under JYS; tank desilting under GDGS	Tank desilting	Water harvesting, continuous contour trenches, tree planting, pasture development, and micro-irrigation
Funding strategy	Separate budget from state revenues	Mix of government, donor, and corporate social responsibility funds	Separate budget from state revenues	Mostly departmental budgets
Centrality of groundwater as tool for drought-proofing	Most explicit focus on groundwater for drought resilience	Focus on creating and augmenting local water bodies for recharge	Focus on reviving traditional flow irrigation systems (irrigation tanks) but with emphasis on recharge	Focus on overall village water self-reliance; groundwater emphasis by default in an arid state
Extent of convergence with similar programs	MAR strategy developed after several independent programs such as Sujalam Sufalam Yojana	Little or no convergence	Program implemented independently in mission mode	Strong emphasis on convergence of different departmental programs and schemes
Groundwater demand management	Conceptually included but in practice, limited to promotion of micro-irrigation	Limited to awareness creation about water conservation	No focus on groundwater demand management	Limited to promotion of micro-irrigation
Community engagement and participation	Community role envisaged in groundwater recharge	In JYS, communities contribute labor and capital; in GDGS, communities manage silt lifting, transport, and application	Communities manage silt lifting, transport, and field application	Little community engagement and participation
Emphasis on training and capacity building of local institutions	Low	Medium	Low	Low
Focus on long-term sustainability	Low	Low	Low	Low
Key strengths	Strong political commitment; community participation; integrated planning	Strong awareness and high corporate social responsibility participation	Works implemented in mission mode on large scale	Strong convergence potential; low-cost small structures
Key weaknesses	Recharge interventions planned where surplus water is available, not based on where farmers need it most	Questionable if momentum will be sustained after program ends	Continuity of positive outcomes doubtful beyond life of the mission	Limited funding beyond usual departmental budgets

farm power supply (Dayashankar 2017), possibly because they understand how devastating free farm power can be for groundwater. Rajasthan's MJSA is perhaps the most nascent of the set, and its impact has yet to be fully felt. Unlike interventions in Maharashtra and Telangana, MJSA focuses on low-cost watershed-type interventions. This work will struggle to find community ownership except where strong village-level institutions already exist to absorb the costs and responsibility of maintenance.

The interventions in all four states focus too much on resource augmentation and too little on capacity building of communities. Only Gujarat includes elements of demand-side management (through supporting interventions) and intent to harvest social capital through supportive policies and programs. The Andhra Pradesh Farmer Managed Groundwater Systems (APFAMGS) program in the former Andhra Pradesh (now Andhra Pradesh and Telangana) implemented a large-scale capacity-building program for communities with the central premise that user awareness will translate into more-sustainable groundwater use decisions—both individually and as a group. Early studies of APFAMGS declared it to be a resounding success and ready for replication across the country (FAO 2010), yet recent assessments present a more tempered picture of the realities (Reddy and Reddy 2019; Verma et al. 2012). Although including capacity-building activities does not ensure improved results or better sustainability, field experience suggests that it can significantly improve the chances of communities taking ownership of local water governance.

There does not seem to be a straightforward and replicable template for designing an optimal "drought-proofing" program. At the same time, astute policy makers can draw useful lessons from the diversity of experience in the western corridor states of India. Engineering community participation is challenging, yet Gujarat shows the importance of tapping the potential of the farmers—latent or otherwise—through supportive policies and programs. Although too early to quantify the impacts, experiences in Maharashtra and Telangana highlight the way the rejuvenation of village water bodies and irrigation tanks can potentially improve local groundwater conditions. The experiences in Gujarat and Telangana highlight that efforts to better manage groundwater are incomplete if they fail to correct the perverse incentives from the energy-irrigation nexus. Finally, all programs illustrate that unless governments intend to support resource augmentation efforts perpetually, they will need to invest in reviving old or catalyzing new village-level institutions to be more effective in local water management.

NOTES

1. IWMI-Tata Water Policy Program, Anand, India.
2. Tubewells are classified as shallow, medium, or deep based on the depth from which they harvest groundwater. Shallow tubewells are up to 35 meters deep, medium tubewells are 35 to 70 meters, and deep tubewells are more than 70 meters.
3. Mapped information is available from Central Ground Water Board at http://cgwb.gov.in/.
4. Tanks are large or small reservoirs or ponds common to peninsular India and Sri Lanka, often constructed many centuries ago.
5. Typically, when groundwater levels decline in the region, farmers add "columns" to shift the submersible pump downward a few feet. When groundwater levels rise, farmers remove columns to lift the submersible pump closer to the ground to save energy and improve discharge. Reduction in tubewell depth here indicates the level at which the submersible pumps were located.
6. 1 crore = 10 million
7. US$1 = ₹7.4 in the average 1973 annual exchange rate, according to www.fxtop.com.
8. 1 lakh = 100,000
9. Refers to the total pumping relative to the total recharge annually in percentage terms.
10. The four waters concept concerns the harvesting of rainwater, surface water, groundwater, and in situ soil moisture.
11. Section 135 of the Companies Act (2013) requires that every company, private limited or public limited, that has a net worth of ₹500 crores, a turnover of ₹1,000 crores, or net profit of ₹5 crores must spend at least 2 percent of its average net profit from the immediately preceding three financial years on corporate social responsibility activities.
12. In the context of hardware or software migration, *big bang* refers to getting rid of the existing system and transferring all users to the new system simultaneously. Here the term means large-scale implementation with very ambitious timelines and expected outcomes.

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