Groundwater Management in India

A multi-state field study of availability, utilisation and locally appropriate solutions for sustainable, equitable and efficient use of groundwater

Gujarat State Report

January 2023

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INSTITUTE FOR CONTEMPORARY STUDIES

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1 Executive summary

1.1 Groundwater scenario in India

Over the last few decades our dependence on ground water has increased tremendously. It has become a major source of water for domestic and agricultural use in India. According to an estimate the ground water resource meets 80% of our water demand. Agriculture is a major consumer of the ground water; it supplies nearly 60% of water demand of the agriculture sector. Worryingly, since the 1990s the area under canal and tank irrigation has observed absolute decrease in India, whereas, ground water fed agricultural area has increased in these years. The convenience and efficient last mile connectivity of ground water resources encouraged many farmers in this country to switch from canal/tank irrigation to the tube well/bore well.

A committee constituted by the government of India to review water governance in the country led by Dr. Mihir Shah in his report in 2016 observed that the public finance on water resources after independence largely focused on surface water.[1] Huge amount was invested on creating surface water infrastructure. The ground water resource remains neglected despite it is replacing surface water from agriculture to domestic use in the last some decades. Individuals invested hugely in ground water infrastructure especially after the green revolution as it was easier and efficient in terms of available for the end use. The technological advancement and availability & affordability of power also helped individual investors (largely farmers) to create groundwater structures. Currently there are around 30 million groundwater structures in this country.

For the purpose of ground water extraction, enough knowledge and data is available. The problem is with lack of data on aquifer management. Being a large country, the geological and hydrological characteristics of the landmass varies from region to region. It further creates complexity to understand sub-surface characteristics pertinent to water seepage, storage and water movement. The CGWB has categorized 14 different aquifer settings in India. Major aquifers include Alluvial, Laterite, Sand stone, shale aquifer, Lime stone aquifer, Basalt aquifers and Crystalline aquifers. According to a classification of geohydrologist Dr. Kulkarni, Crystalline and Alluvial aquifers comprise 59% of the total aquifer area in the country. The mountain and volcanic system of aquifers accounts for 16% of the total area each. These complex aquifer systems require detailed mapping and study for better management of ground water.

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1 https://www.indiawaterportal.org/sites/default/files/iwp2/report_on_restructuring_cwc_cgwb.pdf

1.2 Groundwater policy gaps

The increasing unsustainable extraction of groundwater is a serious issue that has now turned into a water crisis in many parts of the country. In the states like Punjab, Rajasthan, Haryana, Delhi, Madhya Pradesh, parts of Uttar Pradesh and Tamil Nadu have started withdrawing more water from sub surface than available for usage. This gap in demand and supply is continuously increasing as there is no aquifer management system in the place. The numbers of critical and over exploited units are on rise. This invited crisis due to mismanagement of natural wealth has serious social, economic and ecological consequences. There are many reasons behind this problem and these problems have been discussed a number of times.

Ground water extraction is largely unregulated. The only law that loosely governs this precious resource in India is the Indian Easement Act, 1882. This law gives all rights to land owners to extract the ground water. In other words it excludes land less people from access and use of groundwater. This law does not control or regulate water extraction and its usage by the land owner. To strengthen the regulatory mechanisms, the central government has so far issued four versions of model law to be adopted by state governments. The first model bill was released in 1992 and the latest bill was released in 2017.

Yet not all states have converted the model Bill into state legislation. Andhra Pradesh, Assam, Goa, Bihar, Delhi, Himachal Pradesh, Jammu and Kashmir, Karnataka, Kerala, Lakshadweep, Puducherry and West Bengal have adopted the older version of model bill, but in most cases the attempt is half hearted.[2] Moreover experts believe that the model Bill must also move from command and control mode to participatory mode to ensure full participation of people.

The unavailability of data and knowledge on aquifer systems is another big problem in developing better management plans for the ground water. The CGWB collects data from selected wells four times a year to monitor ground water development. The sample size for this yearly exercise is so low that nothing can be argued conclusively based on collected information. There is a long pending demand of mapping aquifers in this country for better management plan. The CGWB has been attempting to map aquifers for all districts in the country. This data and mapping of aquifers would definitely improve our ability to manage groundwater better.

The absence of an integrated approach of ground water recharge and extraction is completely missing in India. There have been some attempts through government and non-government agencies to integrate both of these aspects, but this idea is still not part of national or state level management plans. The absence of regulations and public finance for the management of ground water further discourages any national or state level plans for ground water resource management.

In the past the CGWB attempted to design a national level master plan for artificial recharge of aquifers in 2002 and 2013. The board has now revised this master plan in 2021. According to this master plan, nearly 1.41 crore artificial recharge structures are needed across the country. The type of structures recommended for states and districts varies depending on their geological and hydrological features. The plan is expected to be financed by ongoing projects such as MGNREGA and Watershed Management. The implementation of the master plans requires investment of Rs. 1.33 lakh crore.[3]

Involvement of people in planning and execution of activities related to artificial recharge and ground water extraction has not been seriously promoted at the policy level. However, we have numerous small examples across the country to show that if people are involved aquifers can be managed sustainably and benefits can be shared equitably.

1.3 The multi-state study

There have been some attempts in various states commissioned by nongovernmental organizations to empower farmers with knowledge and capacity to help them to make the right agricultural decisions and choices. Many of these serious attempts helped in yielding good results as well. On the other hand there are numerous examples where projects related to artificial recharge were carried out successfully both by the government and non-government agencies. Some states also tried to regulate groundwater resources. All these actions by different organizations generated huge knowledge and experiences to vet success and failure of each type of programs. These small scale and localized solutions for ground water management are effective in terms of striking a balance between water supply and demand.

Learning from these models can help improving ground water regulations in different states. Therefore this study was commissioned by Rajiv Gandhi Institute for Contemporary Studies (RGICS) in 2021 in ten different states namely Punjab, Rajasthan, Gujarat, Uttar Pradesh, West Bengal, Assam, Madhya Pradesh, Maharashtra, Telangana and Tamil Nadu. Main objectives of the study were as follows:

- To develop an overview of the hydro-geological characterises of different states/regions and the extent of ground water extraction.
- To document and assess the regulatory framework in different states for the management of ground water resources.
- To assess the ability of localized solutions for management of ground water resources to strike a balance between demand and supply of groundwater.
- To draw policy lessons from successful localized solutions for ground water resource management

Groundwater experts and NGOs specialized in groundwater management in different states helped us to implement this project. This is a qualitative research project which involved methods like field work, stakeholder consultation and secondary data analysis. This state report gives an overview of the context and main natural features- geographical, geological, hydrological and hydrogeological- which impacts that status of groundwater in the state. Then it deals with the human interventions – in terms of demand and utilisation, the major policies, laws and regulations, programs, schemes and institutions pertinent to groundwater in the study state.

The main incremental contribution is in the section on lessons from locally appropriate solutions for sustainable groundwater management.We have given summaries of case studies from different location in the study state documenting such locally appropriate solutions.

Finally we summarise the main lessons from the study in a section titled the eightfold path.

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[2] https://scroll.in/article/929433/as-the-water-crisis-deepens-can-india-afford-to-leave-groundwater-unregulated

[3] http://cgwb.gov.in/Whatisnew/2021-06-30-Final-Approved%20Master%20Plan%202020-00002.pdf

2 Gujarat state report

2.1 Context and key features

The State of Gujarat located in western part of India has an area of 196,024 Sq Km with the longest coastline of 1600 km. There are 18,225 villages and 348 towns with a population of 60,439,692 (2011 census). The droughts are frequent in major part of Gujarat. The annual rainfall shows steep reduction from 2000 mm in extreme south (Dangs and Valsad districts) to 300 mm in Kutch district.

The diverse physiographic, climatic, topographic and geological conditions have given rise to diversified groundwater situations in different parts of the state. Occurrence and movement of groundwater is controlled by rock formations of varied composition and structure and range in age from Archean to Recent. Similarly, the landform varies from the hilly tract to the uplands of Kachchh and Saurashtra, the alluvial plains extend from Banaskantha in the north to Valsad in the south, the low-lying coastal tract surrounding the Kachchh and Saurashtra uplands and the marshy to saline tracts of the Rann of Kachchh and little Rann of Kachchh. The topography and rainfall virtually control the runoff and groundwater recharge.

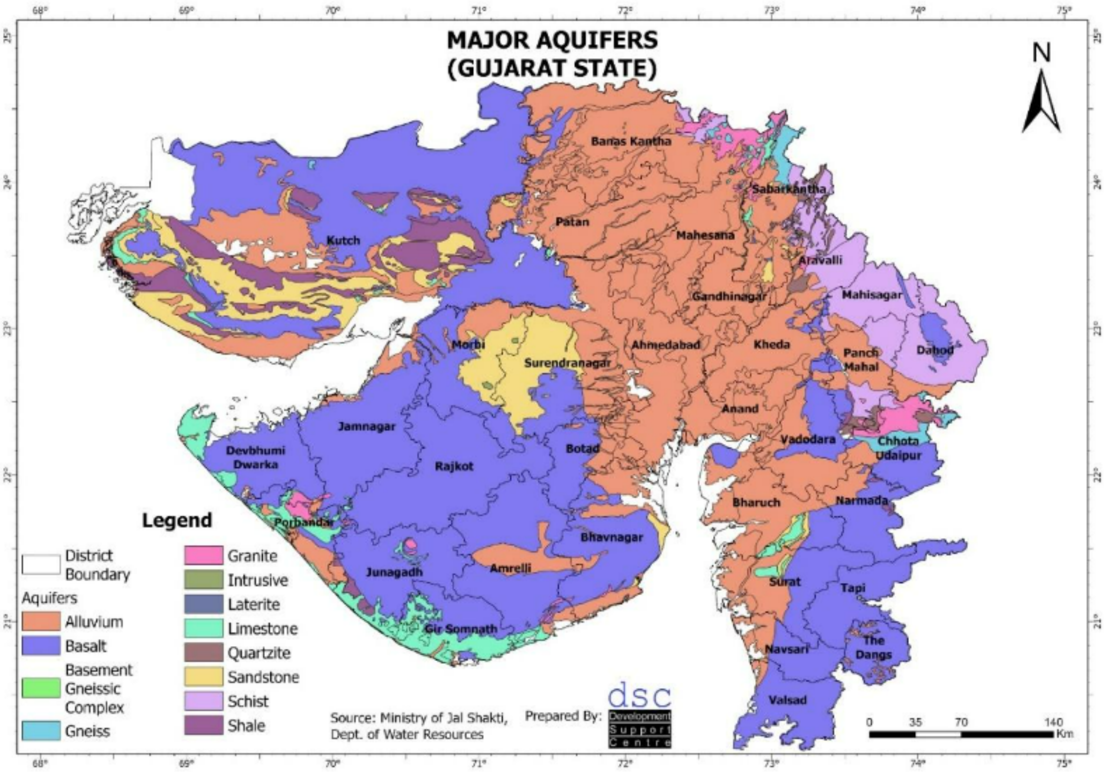
Gujarat is covered by number of large and small river basins, which are characterized by represent varied and complex hydrogeological, agro-climatic and hydrological features. Large rivers like Narmada, Mahi, Tapi, and Sabarmati flow through the state and form their own basins. Other minor rivers have been grouped together to form river basins. In all, eight river basins have been identified by the All-India Soil Survey & Land Use Department as listed below:

1. Sabarmati river basin.
2. Mahi river basin.
3. Narmada river basin.
4. Tapti river basin.
5. Luni and other drainage in the Great Rann of Kachchh
6. Draining in to Gulf of Kachchh
7. Southern Kathiawar
8. Sharavati to Tapti

Gujarat has three distinct physiographic areas, viz., and Mainland Gujarat, Saurashtra and Kutch regions.

2.1.1 Case Study 1 - Rain Water Harvesting Model

The Mainland Gujarat consists of the entire stretch of the Gujarat from north to south including the central and eastern part of Gujarat. Looking in the mainland Gujarat region, it consists of high relief areas in its eastern, north-eastern and south-eastern parts which is covered by the Archeans (Hard Rocks) and Deccan Traps with a steep topographic gradient. This results into high runoff and it provides a little scope for groundwater recharge. The groundwater potential in this terrain is limited.



The Mainland Gujarat consists of the alluvium aquifer which is extending from Banaskantha in north to Surat and Valsad districts in south. This aquifer is one of the largest and most potential groundwater reservoirs for the state. This aquifer is thick, extensive, hydraulically connected and have moderate to high yield. The Archeans rocks are mainly the metamorphic rocks like Schist, Gneiss, Quartzite and Basement Gneissic Complex. The rocks of Archean and Proterozoic age covers parts of Vadodara, Kheda, Panchmahals, Sabarkantha, Mahesana and Banaskantha districts.

These rocks do not form a good aquifer due to their poor porosity and permeability. Mainly dug wells, dug-cum-bore wells are feasible in these rocks where the rocks are sufficiently mantled or fractured or jointed. As per CGWB report, the wells tapping in these aquifers have a maximum depth of 30 to 40 mbgl and beyond which the occurrence of groundwater is not common.

The alluvium aquifer present in Mainland Gujarat is mainly composed of gravel, sand silt or clay deposited by river channels or on floodplains and is of Quaternary age. The alluvial and aeolian deposits extend as one continuous plain from north to south and also as the valley fills in the hard rock terrain. As per the CGWB reports, the Quaternary sediments in the Cambey basin as an estimated thickness of around 500m. However, in the districts of Mahesana, Banaskantha and Sabarkantha, the thickness reduces to less than 50 m near the hilly terrain. In general, in North Gujarat the average thickness of alluvium is ranging from 40m to 500m.

In southern Gujarat the alluvium mostly overlies the basalts and the tertiary sediments. The thickness ranges from few meters near the rock outcrops to more than 75m in the lower reaches. These Quaternary sediments vary in its character and composition. In Cambey basin, the sediments are composed of clay, silt and sand. The proportion of gravels, pebbles and boulders increases towards the hilly tract. Groundwater in the alluvium is under unconfined conditions at shallow depths. In deeper zones, it occurs under semi-confined and confined conditions. As per the CGWB reports, the majority of mainland Gujarat districts has multiple aquifers in the alluvial plains and has a depth up to 500m.

2.1.2 Saurashtra

Majority of Kachchh and Saurashtra region is occupied by a variety of hard and fissured formations which include basalts and consolidated sedimentary formations with semi-consolidated sediments along the low-lying coasts. The compact and fissured nature of rocks forms a discontinuous aquifers and friable semi-consolidated sandstone forms an aquifer. These types of rocks results into moderate groundwater yield potential. The highly potential aquifers are found in the coastal and deltaic areas but salinity intrusion is a major problem in these areas. The coastal and deltaic areas form a narrow linear strip which is underlain by Tertiary sediments and alluvium. Due to higher groundwater exploitation in these areas, it has disturbed the hydro chemical balance leading to excess seawater ingress.

The quality of groundwater in both hard rock and alluvial terrain is largely suitable but the groundwater in coastal and Rann areas is not because of the mineralization is higher and salinity is common. The different conditions of groundwater occurrence in the state have led to a divergent groundwater situation in the areas occupied by different geological formations.

In Saurashtra region the consolidated sedimentary formations are of Mesozoic age i.e., particularly of Jurassic and Cretaceous formations like Dhrangadhra and Wadhwan sandstones. The Dhrangadhra sandstone comprises of about 400 m thick, fine to coarse grained sandstones which are inter-bedded occasionally with shales. The groundwater yield in this sandstone is of limited to moderate discharge. There is presence of sills of 30 to 50 m thickness intruded in the Dhrangadhra sandstone formations. This formation of sandstone is of semi-confined conditions. Majority of Saurashtra region is covered by Deccan traps. The characteristics of this Deccan traps is similar to what is found in Kachchh region as mentioned above.

The Saurashtra Coastal has the presence of Tertiary and Quaternary age formations. The Gaj beds of Miocene age are present along the Saurashtra coast. They consist of limestone, clay and grit with thin sand layers. The quality of Gaj beds is slightly inferior due to presence of clay bands and inherent salinity because the Gaj beds were deposited during the marine conditions. The Dwarka beds consists of clay and limestone is about 150 m thick. The groundwater in Dwarka beds is of poor water quality. The Quaternary formation in Saurashtra includes miliolitic limestone. The miliolitic limestone are high cavernous nature and is locally a very productive aquifer.

2.1.3 Kachchh

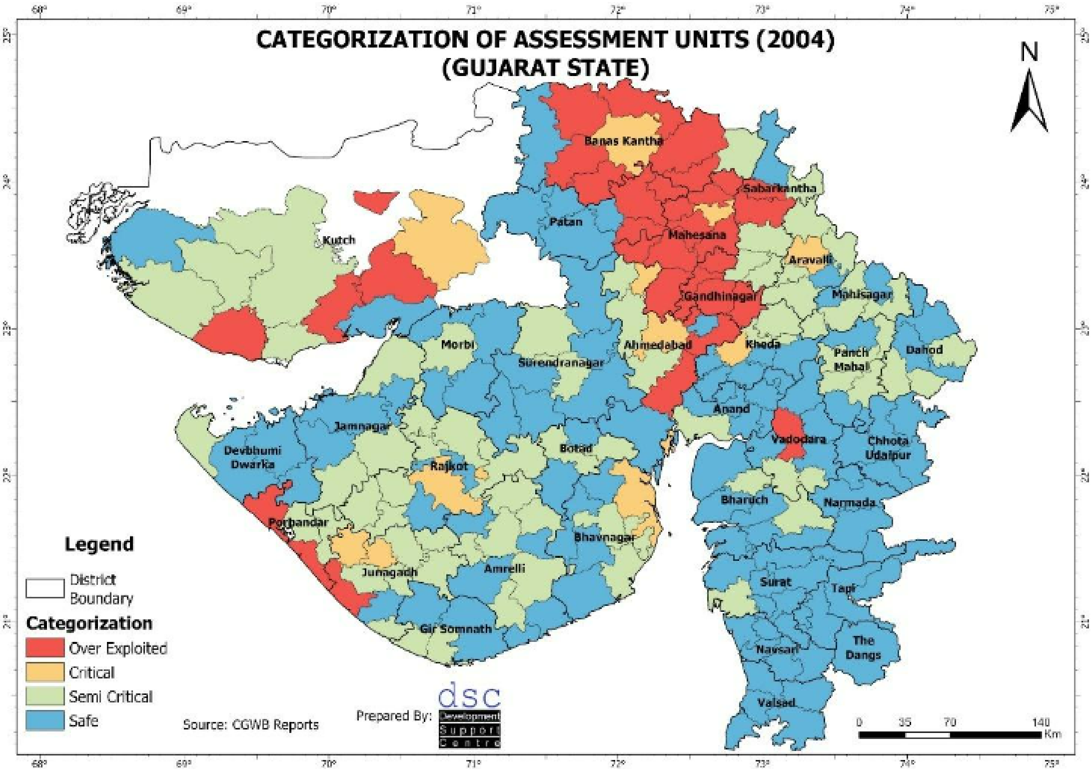
In Kachchh region the consolidated sedimentary formations are of Mesozoic age i.e., particularly of Jurassic and Cretaceous formations like Pachchham, Chari, Katrol and Bhuj series. The aquifers of Bhuj series are important as it consist of friable, soft, medium and coarse-grained sandstone occurring at depths of 300 m. The salinity distribution in Bhuj series is generally low in non-irrigated areas but it gradually increases in intensive irrigation and discharge areas. In Kachchh along with consolidated sedimentary formation there is also the presence of Basalts which are Deccan Traps. The basaltic lava flows of Deccan Traps flows in horizontal to near horizontal disposition over a very wide area.

From the groundwater potential point of view the jointed and fractured basalts hold and transmit water in good quantities. The thickness of traps in Kachchh region ranges from 100 to 150 m. The quality of groundwater in these traps is generally potable. There is presence of Tertiary formations in Kachchh region too. The sandstone in Manchhar series forms a good aquifer in Kachchh region. As per CGWB reports, the Tertiary rocks in general do not form a good aquifer for better groundwater development because of its quality of groundwater.

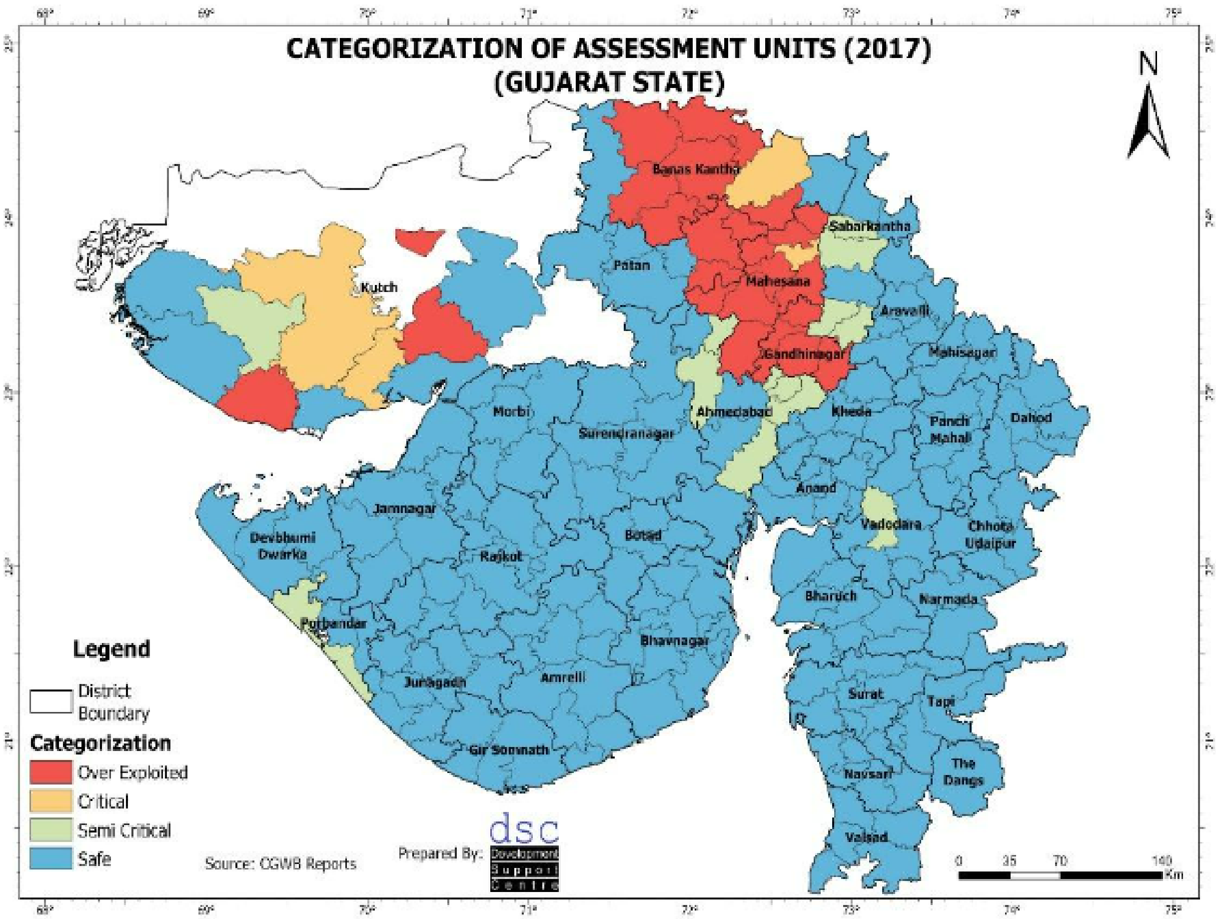
2.2 Groundwater availability and utilization

On the basis of groundwater extraction assessment units are categorized into following four categories:

I) Safe
II) Semi Critical
III) Critical
IV) Over Exploited

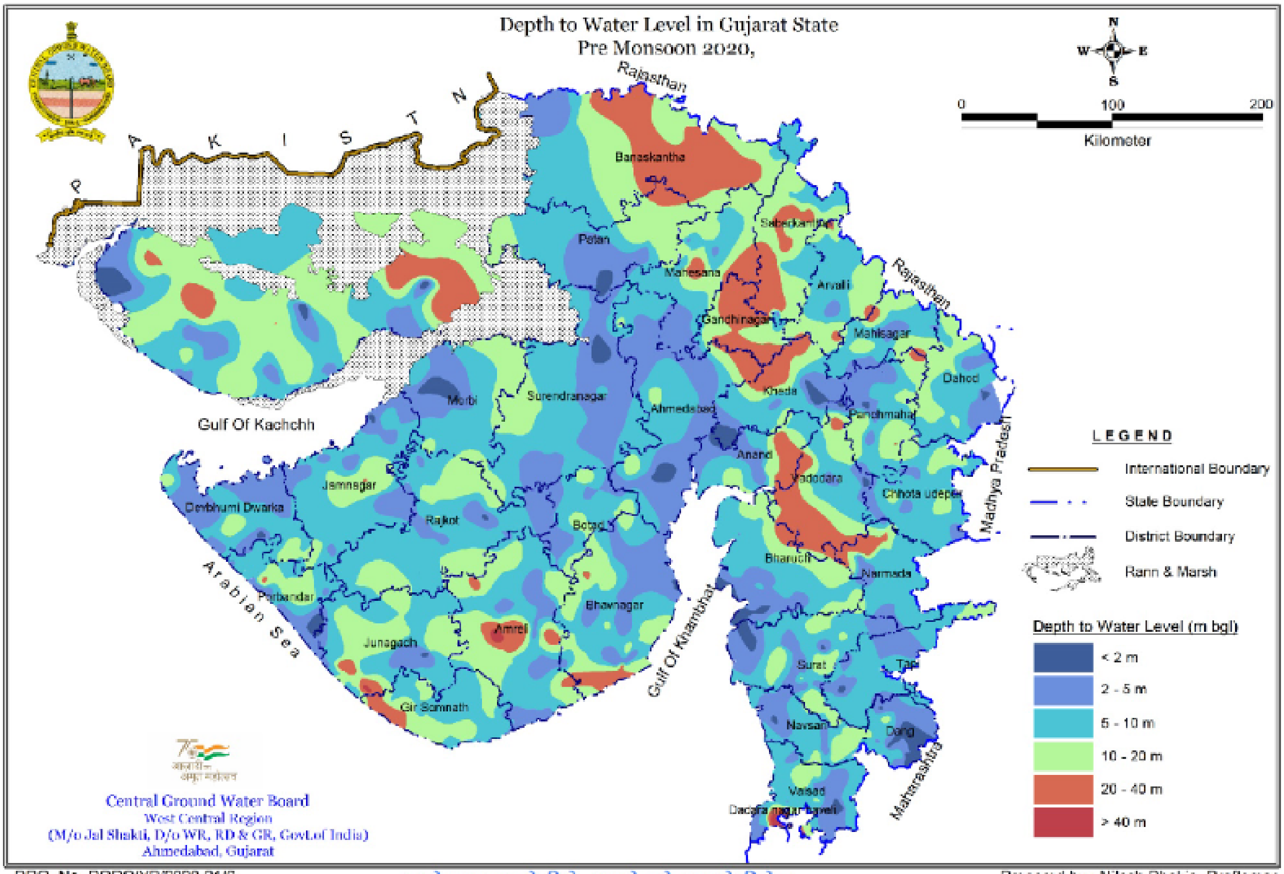


If the groundwater extraction is less than 70% it is categorized as Safe. If the groundwater extraction is between 70% and 90% it is categorized as Semi Critical. If the groundwater extraction is between 90% and 100% it is categorized as Critical and if the groundwater extraction is more than 100% it is categorized as over exploited.



According to the data published by the Central Ground Water Board, the seasonal water level fluctuation shows rise in 87% of the total wells monitored in the Gujarat state area during the Pre and Post Monsoon of 2020. Fall in water level is observed mainly in Kachchh, Saurashtra and central part of Gujarat as isolated patches. In the state, the maximum rise of 25.05 m is recorded at Goraj in Junagadh district whereas the maximum decline of 12.93 m is observed at Samkhiari in Kachchh district. In North Gujarat region, 87% of the total well analysed shows rise in water level. Maximum rise observed 21.90 m at Bavaliya in Mahisagar district. Out of the total well analysed, maximum rise (39%) is observed in the category of 0-2 m. Few isolated patches of fall observed in Banaskantha, Mahisagar, Mahesana and Dahod districts.

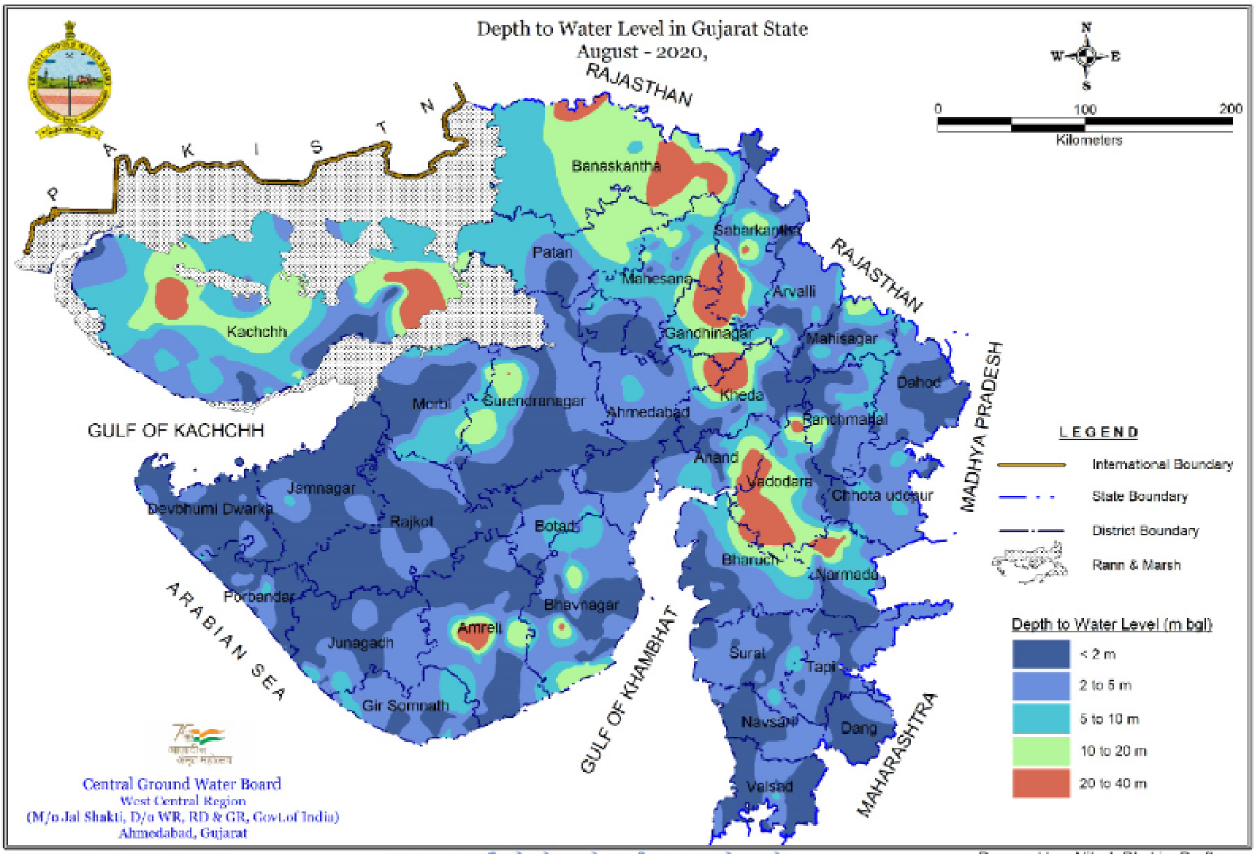
Further the CWGB data reveals that in South Gujarat, about 85% of the well in the area have recorded the rise and maximum in range of 0-2 m. The maximum rise observed 12.70 m at Bari Pada in The Dangs district. The fall is in 15% of total well and maximum categorised in the range of 0-2 m. Over all 88% of total well analysed shows the rise in water level in the entire Saurashtra. Fall is mainly in the range of 0–2 m and is found in isolated patches and cover 10% of the total area of region. The maximum rise observed 25.05 m. at Goraj in Junagadh district. In Kachchh 93% of the total well analysed recorded rise in water level. The fall is mostly in the range of 0–2 m recorded in about 5% of the total well. Rise is observed in all parts of the region and mostly in the range of more than 4 m.



DRG. No. RODC/YB/2020-21/6

जागो अब जल के लिये, बचाओ उसे कल के लिये ।

Prepared by : Nilesh Dhokia, Draftsman



DRG. No. RODC/YB/2020-21/7

स्वस्थ रहना है तो योग करो, पानी का सदुपयोग करो.

Prepared by : Nilesh Dhokia, Draftsman

Systematic and regular monitoring of groundwater levels brings out the changes taking place in the groundwater regime. The maps so generated are of immense help for regional groundwater flow modelling which serves as a groundwater management tool to provide the necessary advance information to the user agencies to prepare contingency plans in case of unfavorable groundwater recharge situation. The data also has immense utility in deciding the legal issues arising out of conflicting interests of groundwater users. The monitoring of groundwater levels has been carried out at groundwater monitoring wells four times in a year simultaneously throughout the State during the following periods.[4]

a) May - 20th to 30th (pre-monsoon)
b) August - 20th to 30th (peak monsoon)
c) November - 1st to 10th (post-monsoon)
d) January - 1st to 10th (recession stage)

Water level data of the groundwater monitoring wells collected during the year 2020 - 2021 by CGWB has been utilized to prepare various maps showing depth to water level and fluctuation of water level. Depth to water level maps is useful in dealing with problems of water logging and artificial recharge, where the relative position of water level with reference to the ground surface is of critical importance. Water level fluctuation maps (rise or fall) are indispensable for estimation of change in storage in the aquifer. For the purpose of presentation, Gujarat state has been divided into three regions, namely,

a) the Kachchh region comprising Kachchh district,
b) the Saurashtra region comprising Amreli, Bhavnagar, Botad, Devbhumi Dwarka, Gir Somnath, Jamnagar, Junagadh, Morbi, Porbander Rajkot and Surendranagar districts; and
c) the mainland Gujarat.

The mainland Gujarat has been further subdivided into two regions, namely, North Gujarat comprising, Ahmedabad, Anand, Arvalli, Banaskantha, Dahod, Gandhinagar, Kheda, Mahesana, Mahisagar, Panchmahals, Patan and Sabarkantha districts; South Gujarat comprising Bharuch, Chhota Udepur, Narmada, Navsari, Surat, Tapi, The Dangs Vadodara and Valsad districts.

Source: https://www.india.com/wp-content/uploads/2015/09/water-scarcity-in-bonei-forest-division_6112.jpg

4 http://cgwb.gov.in/Regions/WCR/Reports/Gujarat%20State%20Groundwater%20Year%20Book%202020-21.pdf

2.3 Groundwater policies and governance in the state

Central Ground Water Authority (CGWA), Ministry of Water Resources, River Development and Ganga Rejuvenation constituted under the Environment (Protection) Act of 1986 vide Gazette notification no. S.O.38 (E) dated 14.01.1997, has the mandate of regulating ground water development and management in the country. In 23 States/ Union Territories ground water development is being regulated by Central Ground Water Authority. The remaining States/ Union Territories are regulating ground water development through ground water legislation enacted by them or through Government Orders.

CGWA has been regulating ground water development for its sustainable management in the country through measures such as issue of advisories, public notices and grant of No Objection Certificates (NOC) for ground water withdrawal. Central Ground Water Authority has framed guidelines for grant of NOC for withdrawal of groundwater, which have been revised from time to time. Last revision in guidelines was done in 2015 to bring existing industries/ infrastructure/ mining projects under the purview of NOC. On 12th December 2018 CGWA notified revised guidelines for ground water extraction vide notification S.O. No. 6140 (E), which will be effective from 1st June 2019. The revised guidelines aim to ensure a more robust ground water regulatory mechanism in the country.

Salient features of the revised guidelines

Water Conservation Fee: One of the important features of the revised guidelines is the introduction of the concept of Water Conservation Fee (WCF). The WCF payable varies with the category of the area, type of industry and the quantum of ground water extraction and is designed to progressively increase from safe to over-exploited areas and from low to high water consuming industries as well as with increasing quantum of ground water extraction. Through this design, the high rates of WCF are expected to discourage setting up of new industries in over-exploited and critical areas as well as act as a deterrent to large scale ground water extraction by industries, especially in over-exploited and critical areas. The WCF would also compel industries to adopt measures relating to water use efficiency and discourage the growth of packaged drinking water units, particularly in over-exploited and critical areas.

Other salient features of the revised guidelines include

- encouraging use of recycled and treated sewage water by industries
- provision of action against polluting industries
- mandatory requirement of digital flow meters, piezometers and digital water level recorders (with or without telemetry depending upon quantum of extraction)
- mandatory water audit by industries abstracting ground water 500 m3/day or more in safe and semi-critical and 200 m3/day or more in critical and over-exploited assessment units
- mandatory roof top rain water harvesting except for specified industries
- Measures to be adopted to ensure prevention of ground water contamination in premises of polluting industries/ projects.

Major Policies and Legislations Governing Ground Water Resources in Gujarat	
Gujarat State Water Policy-2015 (Draft)	• Proposal to frame water framework law. • Ecological needs of the river should be determined, through scientific study, recognizing that the natural river flows are characterized by low or no flows, small floods (freshets), large floods, etc., and should accommodate developmental needs • Prioritizing water allocation • Proposal to evolve benchmarks for water uses for different purposes • Exploitation of groundwater shall be regulated and controlled to prevent environmental adverse effect
The Gujarat Irrigation and Drainage Act, 2013 and Rules 2014, Amended in 2019	• Application of water for purpose of canals • Regulate water supply through canals • Allows government for construction and maintenance of field channels.
The Gujarat Water Users' Participatory Irrigation Management Act, 2007	• Establishment of Water User's Association for each service area. • Irrigation management by water users associations. • Empowering WUA to construct field channels if required • Autonomy to WUA to set water charges

Source: https://mcmscache.epapr.in/post_images/website_350/post_16076677/full.jpg

2.4 Locally appropriate solutions for groundwater management

2.4.1 Community driven ground water recharge initiative through defunct borewells

The Kachchh district receives minimal rainfall throughout Gujarat. The water table is submerged due to irregular rainfall and exploitation. The continuous decline in water table has caused several problems, including increased salt content, fluoride problems, reduced drill yields, and high well failure rates. The continuous submergence of the mainland, the infiltration of seawater from the central bay, and the infiltration of orchids from the north appear to be "squeezing" the Kutch area of its freshwater resources. Long-term use of saltwater groundwater for irrigation has led to reduced agricultural and horticultural productivity and soil fertility in these areas. Villagers are forced to switch to producing cash and salt-tolerant crops such as BT cotton. Due to its location, geographical location and lack of drinking water, the area has not achieved industrial growth. Currently the state government encourages new industries and the area has a unique coastline, so many projects to develop this coastline along with new coastal industries are queued.

Salt is another problem in the Kutch coastal area. The rise in salinity is exacerbated by low rainfall, uneven precipitation, and abuse of groundwater. This has an indirect impact on the health of the villagers living in the area. Villagers complain that they have more kidney and stomach problems. MS pipe shafts have a very short service life due to their high corrosion rate. In recent years, RCC pipe manholes have been built due to their longer service life and lower cost than MS pipes.

Vivekanand Research and Training Institute (VRTI) a reputed civil society organization, which has been working with the farmers in the Kachchh for a long time, and Arid Communities Technologies (ACT) having expertise in hydro-geological approach came together to seek permanent solutions to groundwater issues in the arid Kachchh. Groundwater recharge through defunct borewells in the area emerged as a feasible and scalable option since there are number of defunct borewells available in the area.

Source: https://borewellinfo.files.wordpress.com/2016/12/31-july.jpg

2.4.1.1 Intervention

The process started with identification of the catchment area for rainwater and the slope of the terrain is ascertained to ensure the flow of water to the bore wells. The area was carefully chosen, devoid of impurities and residues like agro chemicals, to avoid groundwater contamination.

At two identified points, as per shown in the following figure, two 5x 5 feet cement structures were constructed for inflow and outflow of water with filtering chambers. This was to ensure gravity flow of water from the inflow to the outflow structure. The structures were filled with 45-65 mm size stones up to four feet of the structure, and above which one feet of medium coarse sand is spread. The distance between the two structures is maintained around 50 meters to ensure the recharge is successful. From the rainwater inflow structure, a pipe made of PVC/iron/ cement with 8-10 inches diameter is connected with the outflow structure. This measurement is specific to areas like Kachchh to maintain the flow of water from the inflow to the outflow chamber. The defunct bore well is connected to the outflow chamber.

During the monsoon, the navigated water flows through the built chambers which rejuvenates the bore well. This technique revives groundwater in about 400-meter radius, as per ACT. It was reported by the farmers of intervention areas that bore well recharge technique has raised the groundwater level and their electricity charges have also reduced. By judiciously using the improved groundwater through drip irrigation system, these farmers are hopeful of cultivating both in Kharif and Rabi seasons.

Interestingly, role of VRTI was to aware local farmers about the concept and the entire financial resources for the project came from the community-based organizations of the area. For instance, in Moti Rayan village, where it benefitted 65 bore wells, contributions came from Patidar Samaj (₹1 lakh); and its leaders (₹5,000); Jain Samaj (₹20,000); bore well owners (₹12,000 -14,000 each) and the 170 farmers in the bore well recharge command area contributed ₹1,000 each. This makes it a unique example of community-based ground water recharge initiative.

This intervention was implemented in about 19 villages of Mandvi and it draw attention of other villages also. Now an initiative is underway to identify the defunct bore wells in each village of Mandvi so that these defunct bore wells could be developed as ground water recharge structures under the MGNREGA. If this project materializes and is implemented according to the suitability of the places, it would benefit the enterprising farmers of the rain starved Kachchh district and inspire farmers in other rainfed regions of the country to save rainwater and revive the bore wells.

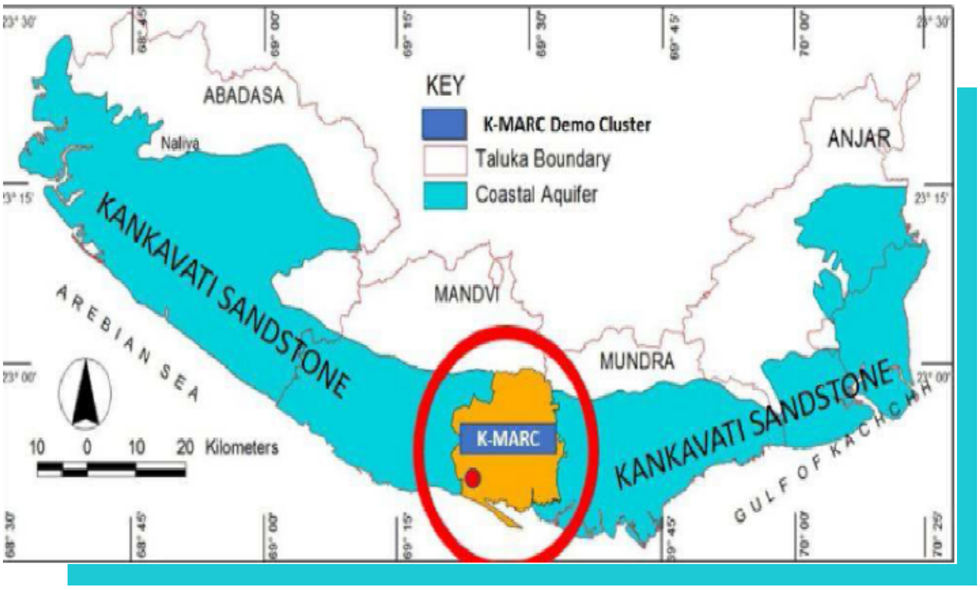
2.4.1.2 Impact

The intervention has positive impact on only on ground water level but also on water quality in the villages. Due to improvement in quality of water risks of health hazards are minimized. On the other hand, improved quality of water impacted positively on agriculture yields and it was reported by the farmers that there has been an increase in agriculture yields after the intervention in the villages. The increased agriculture, leads towards increment in farm income and prosperity of the area.

2.4.2 Maska Model of participatory groundwater management

Kachchh is the largest district of Gujarat, in the western-most part of India. It is an arid district, with very scanty and irregular rainfall across the all blocks. The Kanakavati sandstone is spread across Abdasa, Mandvi, Mundra and Anjarblocks in Kachchh district of Gujarat and is the only dominant groundwater resource in coastal Kachchh areas. Around 5.43 lakh people in these 4 blocks – 3 lakh rural people and 2.43 lakh urban people depend on the shared aquifer for their water needs. Industries in the region - thermal power projects, ports and other manufacturing industries and Special Economic Zones (SEZs) are also heavily dependent on groundwater making it economically significant. Three of the 4 blocks including Mandvi have been declared dark zones by the CGWB. The water has high TDS in all blocks, and over 50% of all villages in Abdasa block report saline ingress. The aquifer being shared between a variety of users and uses has led to competition and conflict between various groups and irregular rainfall worsen the situation.

Location of Maska (K-MARC)



Maska is a coastal village of Mandvi block in Kachchh with a total population of 5617 (as per Census 2011). The village is totally depended on ground water for meeting out its domestic and agriculture demand. Being a coastal village Maska used to suffer not only from ground water depletion but at the same time, salinity was a major issue affecting daily lives of local villagers badly. TDS concentration of drinking water borewell was 6800 PPM.

Over time, drastic population growth, consumption-oriented lifestyles are other factors put severe pressures on the aquifer which has affected both quantity and quality of water available. Due to over-draft of ground water a vacuum was created underground there which was filled through sea water intrusion, this polluted remaining groundwater as well hence people of Maska suffer from salinity. In this situation ground water management becomes important to maintain the ground water level and as well as to prevent ground water quality.

2.4.2.1 Intervention

Arid Communities and Technologies (ACT) is a well-known professional Civil Society Organization based at Bhuj- Kachchh working on Participatory Ground Water Management as one of its major objectives. ACT has worked extensively in the Kanakavati sandstone to demonstrate a science based participatory approach to help manage the aquifer. In Maska ACT initiated a participatory ground water management project named; Kankavati Manage Aquifer Recharge through Community, (K-MARC).

The Participatory Groundwater Management approach of ACT has the following steps:

- Awareness generation among local community and Capacity building.
- Understand the aquifer better through participatory learning methods.
- Analysis of situation for designing most appropriate intervention.
- Involving all stakeholders throughout the process.
- Sharing information with the community and government.

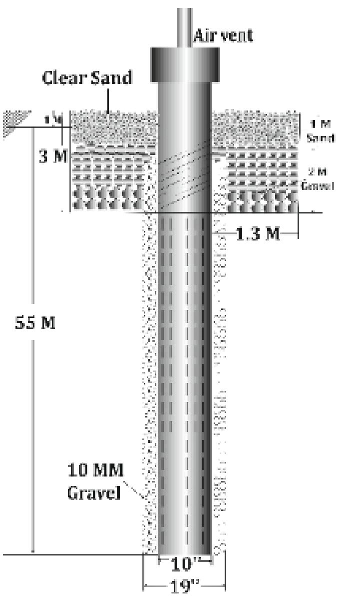
In awareness component, ACT organized number of interactive sessions in form of public meetings, orientation, training workshops and Participatory Rural Appraisal activities at village level just to ensure participation of the local community in proposed ground water management initiative. During the consultation process community was oriented on technical issues such as water balance, institutional deficit infrastructure at the same time community shared its traditional knowledge and experience. During the next phase of understanding aquifer, Bhujal Jaankar, (trained barefoot geologists) collected baseline data from the village which were essential for preparing Village Water Security Plan such as land use pattern, surface water and ground water estimation, assessment of local water uses etc.

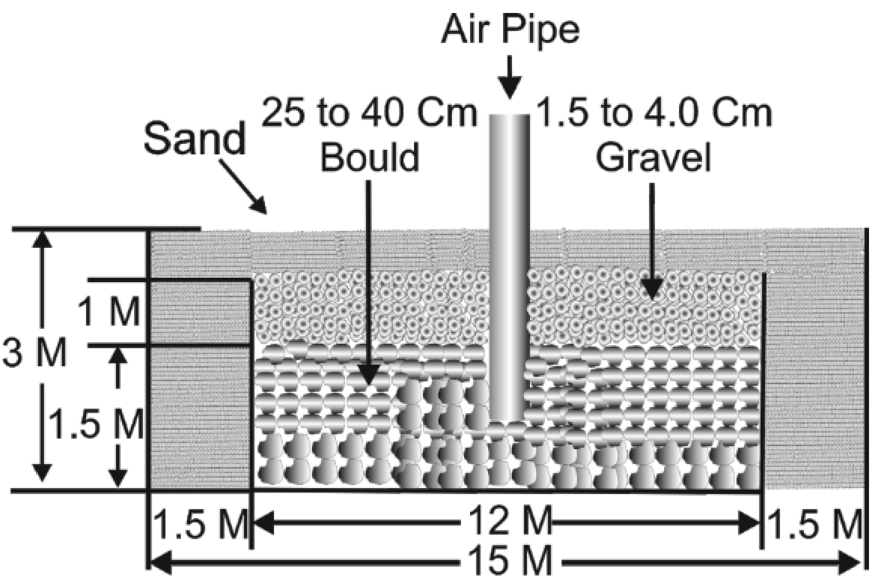
During data collection from the field Bhujal Jaankar oriented local people about the current ground water situation and future consequences. After data collection analysis process started involving local community, Panchayat and other stakeholders, which went up to selection of appropriate intervention for ground water management at village level.

In Maska, community who was the major stakeholder has been involved in the planning and site identification process to make process more effective and a right fit. To improve the water quality and dilute sea water salinity impact, a riverbed has been identified with support of local community and gram Panchayat. Two check dams have been improved by desilting and repairing. The upstream check dam's storage capacity has been increased by de-silting of about 8000 cum, resulting in increased storage capacity of about 23000 cum, with silt distributed to the village farm. The downstream side check dam abutment wall was repaired to store overflowing water from upstream structures at end point of the rivulet. Three injection structures have been constructed in the surface water harvesting structures to recharge groundwater at various depths:

1. A 50 m deep tube well for deeper aquifer recharge (as per given in the figure)
2. River bed recharge to trap surface runoff and provide lateral flow to the shallow zone
3. Convert one defunct and dry open well into filter well again to recharge at intermediate depth.

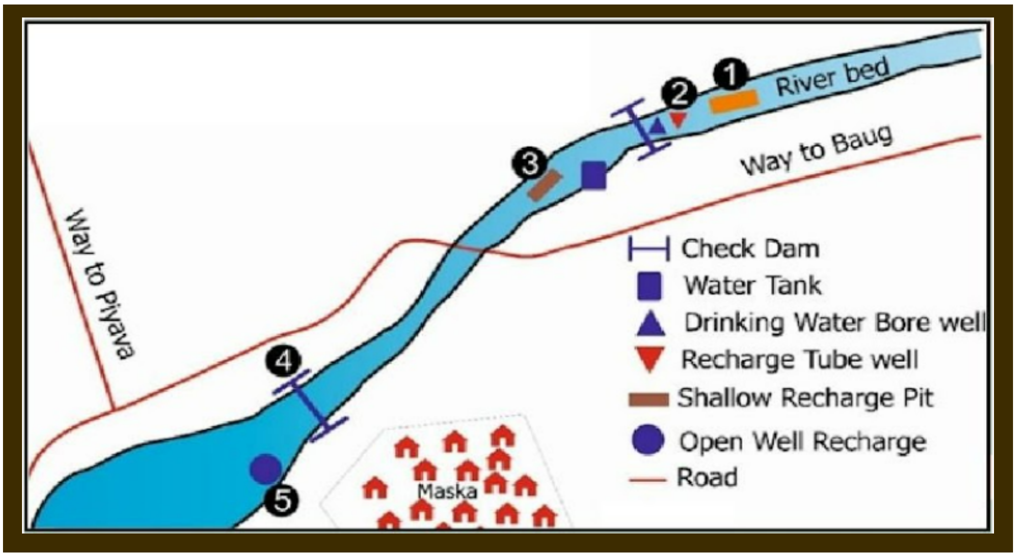
Tube well recharge structure for deeper aquifer recharge Shallow recharge structure





Overview of shallow and deeper aquifer recharge structures

Overview of various structures developed under the intervention



All these interventions have been made during post monsoon season of year 2018 and pre monsoon season of year 2019.

2.4.2.2 Financial cost of the intervention

The total financial out lay of the intervention was 7.31 lakh rupees. As per data given in the following table an amount of 3.15 lakh rupees was incurred on de-silting of local pond which increased its water storage capacity.

A shallow recharge pit of 3 meters was also developed under this intervention, which cost 2.15 lakh rupees. An amount of 1.39 lakh rupees invested for development of the tube well recharge structure. For restoration of a check dam 55,000 rupees incurred while for another open well recharge structure 7,000 rupees were incurred.

Financial cost incurred on the groundwater management solution

S.N.	Activity	Investment (INR)
1.	Pond De-silting (8000 cum) and spread of slit in 48 ha. of farm areas.	3,15,000
2.	Shallow Recharge pit of 3 m (D) x 15 M (W) x 15 M (L) size	2,15,000
3.	Recharge tube-well (50 m depth)	1,39,000
4.	Check dam restoration	55,000
5.	Open well recharge	7,000
	Total	**7,31,000**

2.4.2.3 Impact

Maska is a good example of blending traditional knowledge with modern science and technology for ground water management. The intervention in Maska resulted not only in improvement in ground water level but also quality of the groundwater.

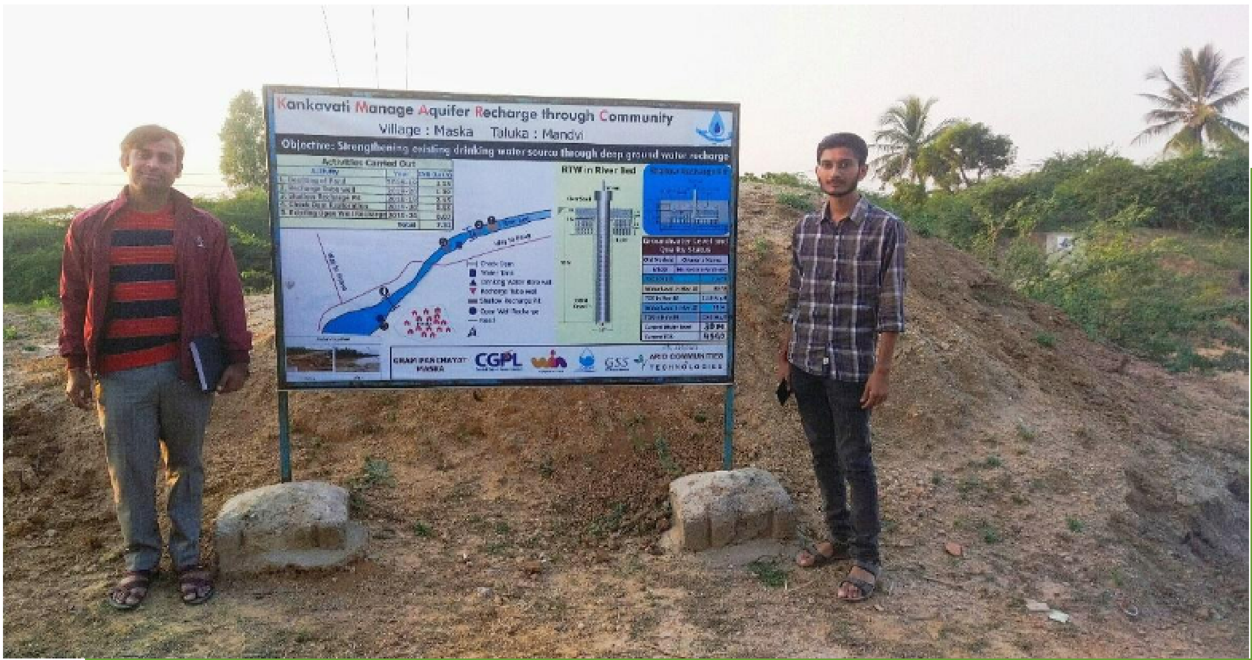
Pre and intervention comparative analysis of Water level and TDS

S.N.	**Parameter**	**Before Intervention**	**After Intervention**
1.	Water Level (M)	**95** (November 2018)	**91** (November 2019)
		98 (January 2019)	**91** (January 2020)
		90 (March 2019)	**91** (March 2020)
		97 (May 2019)	**95** (May 2020)
2.	TDS (PPM)	**6110** (November 2018)	**1600** (November 2019)
		6100 (January 2019)	**1910** (January 2020)
		6110 (March 2019)	**2080** (March 2020)
		7490 (May 2019)	**2690** (May 2020)

An improvement of average two meters in ground water level and decrease of 50% in salinity was observed within one year after the project implementation. Pre-intervention, the water level used to deplete from April and salinity level used to reach up to 7400 PPM by July. Post intervention the scenario has a remarkable change in TDS. The lowest TDS value was recorded 1200 PPM, in September 2019. After which, the groundwater uses increased and TDS reached up to 2690 which was within permissible limits.

This intervention ensured drinking water security for people of Maska for longer period in a year which itself is an indicator of success of the intervention. Based on the results so far, continuous recharge for three year is predicted to ensure stability in water level as well water quality round the year.

Researcher at the intervention site at Maska



2.4.2.4 Conclusion

Maska is a remarkable example of participatory ground water management solution in coastal area of Gujarat. ACT, which was implementing agency made efforts to ensure active participation of not only local community but also other stakeholders from government, local Gram Panchayat, and civil society organizations such as Costal Gujarat Power Limited, WIN Foundation and GSS. These agencies not only participate but also contributed which made this intervention successful.

3. Lessons from the fieldwork in Gujarat – The eightfold path

This is a multi-state study of locally appropriate solutions of groundwater management to draw policy lessons from them. In each state, we found exceptional work at micro level ensuring sustainable, efficient and equitable management of groundwater resources. Based on our findings from ten different states, we have developed eight principles which can guide our policy formulation and actions on ground. This section attempts to describe this eightfold path in the context of Gujarat.

3.1 Need for a new approach to achieve sustainable, equitable, efficient use

The diverse physiographic, climatic, topographic and geological conditions have given rise to diversified groundwater situations in different parts of the state. Occurrence and movement of groundwater is controlled by rock formations of varied composition and structure and range in age from Archean to Recent. Similarly, the landform varies from the hilly tract to the uplands of Kachchh and Saurashtra, the alluvial plains extend from Banaskantha in the north to Valsad in the south, the low-lying coastal tract surrounding the Kachchh and Saurashtra uplands and the marshy to saline tracts of the Rann of Kachchh and little Rann of Kachchh. The topography and rainfall virtually control the runoff and groundwater recharge.

Gujarat is covered by a number of large and small river basins, which are characterized by representing varied and complex hydrogeological, agro-climatic and hydrological features. Large rivers like Narmada, Mahi, Tapi, and Sabarmati flow through the state and form their own basins.

Given this highly diverse physiography, hydrology and hydrogeology besides varying rainfall patterns, the regional potential of groundwater recharge and withdrawal is also highly uneven. In such conditions, locally appropriate approaches for groundwater recharge and withdrawal is important.

3.2 The efficacy of participatory data collection

According to the data published by the Central Ground Water Board, the seasonal water level fluctuation shows a rise in 87% of the total wells monitored in the Gujarat state area during the Pre and Post Monsoon of 2020. Fall in water level is observed mainly in Kachchh, Saurashtra and central part of Gujarat as isolated patches. In the state, the maximum rise of 25.05 m is recorded at Goraj in Junagadh district whereas the maximum decline of 12.93 m is observed at Samkhiari in Kachchh district. In the North Gujarat region, 87% of the total well analysed shows rise in water level. Maximum rise was 21.90 m at Bavaliya in Mahisagar district. Out of the total well analysed, maximum rise (39%) is observed in the category of 0-2 m. Few isolated patches of fall are observed in Banaskantha, Mahisagar, Mahesana and Dahod districts.

The Meta data presented in the above paragraph has been collected by expert agencies, which gives us detailed information about groundwater development. However, such Meta data is not enough to instigate people to act or change their behaviors. To effectively manage ground water resources, participatory data collection plays a vital role in sensitizing people and changing their behavior. It further helps them to take collective decisions related to water conservation and usage.

The participatory groundwater management program of ACT in Maska is a good example of blending traditional knowledge with modern science and technology for ground water management. The intervention in Maska resulted not only in improvement in ground water level but also quality of the groundwater.

3.3 Understanding the prevailing policy framework and using it beneficially

Policies have a crucial role in regulating and managing natural resources to ensure sustainable usage and equitable distribution of benefits. Gujarat has two major legislations to manage water resources in the state. The Gujarat Water Users' Participatory Irrigation Management Act, 2007 provides for the constitution of water user's associations (WUAs) for equitable and sustainable distribution of irrigation water. This law gives a lot of autonomy to WUAs related to construction of field channels and fixing water charges.

The second legislation to manage water resources in the state is The Gujarat Irrigation and Drainage Act, 2013 and Rules 2014, Amended in 2019. This legislation provides for developing infrastructure and institutions required for sustainable and equitable distribution of irrigation water.
The state has also drafted the Gujarat State Water Policy in 2015, but it is yet to be enacted. This draft policy proposes to enact the water framework law in the state. It also proposes a mechanism for sustainable management of groundwater resources in the state.

3.4 Whistleblowing in the face of non-Implementation of laws and regulations

Once the community is involved with collecting the data and understands the prevailing policy, laws and regulations, it can become a watchdog against any violations. Moreover, demands can be raised for more appropriate laws and policies. Like in many other parts of the country, concerned individuals and institutions have been raising voices against non-implementation of existing laws in the state. India has updated its national water policy in 2012 that has set new priorities. However, the Gujarat has not yet updated its state policy on water. Policy gaps arising in the field must be communicated to the policy makers.

3.5 Planning for balancing demand with supply

Gujarat has only two percent of total water resources in India that feed nearly 5% of the country's population. The total water availability in Gujarat is 50 BCM of which the groundwater is only 12 BCM. Most of the surface water (nearly 80%) in the state is being used for irrigation, so industrial and domestic supply is largely met by groundwater resources.

According to the data published by the Central Ground Water Board, the seasonal water level fluctuation shows rise in 87% of the total wells monitored in the Gujarat state area during the Pre and Post Monsoon of 2020. Fall in water level is observed mainly in Kachchh, Saurashtra and central part of Gujarat as isolated patches. In the state, the maximum rise of 25.05 m is recorded at Goraj in Junagadh district whereas the maximum decline of 12.93 m is observed at Samkhiari in Kachchh district. In the North Gujarat region, 87% of the total well analysed shows rise in water level. Maximum rise was 21.90 m at Bavaliya in Mahisagar district. Out of the total well analysed, maximum rise (39%) is observed in the category of 0-2 m.

Few isolated patches of fall are observed in Banaskantha, Mahisagar, Mahesana and Dahod districts. The gap in demand and supply of the groundwater is increasing exponentially. The urgent need is to balance this gap both by enhancing recharge capacities and rationalizing demand.

3.6 Enhancing supply by groundwater conservation and recharge

This study has documented two successful examples of groundwater conservation to enhance supply of groundwater. The example documented in the Kuchh region has attempted to utilize defunct tubewells for groundwater recharge. On the other hand, the Maska model of groundwater management used an integrated approach to manage quality and quantity of the ground water.

Intervention in Maska recorded an improvement of average two meters in ground water level and decrease of 50% in salinity within one year after the project implementation. Pre-intervention, the water level used to deplete from April and salinity level used to reach up to 7400 PPM by July. Post intervention the scenario has a remarkable change in TDS. The lowest TDS value was recorded at 1200 PPM, in September 2019. After which, the groundwater use increased and TDS reached up to 2690 which was within permissible limits.

3.7 Rationalising demand for water by rationalising prices for crops and energy

India has 18% of world population, having 4% of world's fresh water, out of which 80% is used in agriculture. India receives an average of 4,000 billion cubic meters of precipitation every year. However, only 48% of it is used in India's surface and groundwater bodies. A dearth of storage procedure, lack of adequate infrastructure, inappropriate water management has created a situation where only 18-20% of the water is actually used. India's annual rainfall is around 1183 mm, out of which 75% is received in a short span of four months during monsoon (July to September). This results in run offs during monsoon and calls for irrigation investments for the rest of the year.

Examples documented in this report shows that wherever the supply of the water has increased due to locally appropriate solutions, the agricultural productivity has also increased. In many cases farmers have started harvesting two crops in a year. Such developments are really good, but it is necessary to rationalize demand to ensure sustainability of demand and supply of water. Moreover, pricing of energy and water is an important factor to ensure sustainability.

3.8 Building capacity of the community for the above functions is a must

It is very clear that the 'one size fits all' approach is not going to solve the problem of groundwater. Every step from groundwater recharge to the utilization of water has deep social, economic, geological, hydro geological and geo morphological underpinning. Therefore, it is necessary to understand physical and social sciences in each region to experiment locally appropriate solutions for groundwater management. Moreover, this exercise cannot be done without building capacities of the community. It is worth mentioning here that all successful interventions documented in this study have attempted to develop the capacity of people.

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