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SELECT CASE STUDIES

RAIN WATER HARVESTING *and* ARTIFICIAL RECHARGE

Central Ground Water Board
Ministry of Water Resources
New Delhi
May 2011

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RAIN WATER HARVESTING *and* ARTIFICIAL RECHARGE

CENTRAL GROUND WATER BOARD

MINISTRY OF WATER RESOURCES

NEW DELHI

Prepared & Compiled under the Technical Guidance of

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Central Ground Water Board
Ministry of Water Resources

FOREWORD

Groundwater is the major source of freshwater that caters to the demand of ever growing domestic, agricultural and industrial sectors of the country. This renewable resource is being indiscriminately exploited by several users. On the other hand, rapid urbanization and land use changes has resulted in reduced natural infiltration /recharge of aquifers. This has lead to various problems related to quantity and quality and issues like the decline in water levels, depletion of groundwater resource and quality deterioration. There is thus an imperative need for augmenting the valuable ground water resource. Artificial recharge and roof top rainwater harvesting is one such method that can revive this precious resource. Several traditional and scientifically proven artificial recharge and rainwater harvesting techniques have been adopted in different parts of the country. These structures have proven to be viable option for augmenting the groundwater aquifers by making use of surplus surface runoff.

The pioneering efforts by Central Ground Water Board (CGWB) have been instrumental in popularizing several cost-effective recharge techniques suitable for different hydrogeological conditions of the country. CGWB has already implemented numerous demonstrative schemes of artificial recharge to ground water across the country.

The untiring efforts of the Government organizations, scientific community & NGO's with people's active participation have shown remarkable results in reducing the declining trends of the groundwater resources in select pockets of the country. An effort has been made to compile such kind of success stories in this report. The report throws light on the recharge techniques practiced traditionally in different regions of the country.

This report would be of immense help to the water managers, NGO's, local bodies all those who are concerned with recharging of the groundwater resources and monitoring its impact.

New Delhi
May, 2011

Dr.S.C.Dhiman
Chairman, CGWB

Preface

In the last few decades rapid urbanization coupled with technological development in construction of deep tube wells have contributed to large-scale exploitation of groundwater. This has resulted in lowering of water table so much that many dug wells and tube/bore wells giving previously sufficient yield have decreased now in their yield and ultimately drying up. The situation becomes more precarious during summer. In many parts of the country, ground water development has already reached a critical stage, resulting in acute scarcity of the resource. Artificial recharge is the technique that can revive and sustain development of groundwater. Several traditional and scientifically proven artificial recharge methodologies have been adopted in different regions of the country.

Central Ground Water Board has been in the forefront of activities for augmenting ground water resources through scientifically designed artificial recharge structures for harvesting runoff which otherwise runs off into sea. A number of pilot schemes and demonstrative artificial recharge schemes have been implemented by the CGWB in association with various State Government organizations since the 8th plan period. These are aimed at popularizing cost-effective ground water augmentation techniques suitable for various hydrogeological settings, to be replicated by other agencies elsewhere in similar areas.

The work done by Central Ground Water Board and other state and non-governmental agencies involved in the water sector have provided the basic inputs necessary for the preparation of this report. The present compilation highlights case studies in artificial recharge and impact of such measures in ameliorating problems related to groundwater.

I hope this report will be useful to all agencies engaged in monitoring the impact of the artificial recharge schemes across the country.

New Delhi
May, 2011

Sushil Gupta
Member (SML), CGWB

SELECT CASE STUDIES

RAIN WATER HARVESTING *and* ARTIFICIAL RECHARGE

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RAIN WATER HARVESTING *and* ARTIFICIAL RECHARGE

I. INTRODUCTION

In the last three decades an exponential growth in number of ground water structures has been observed. This has lead to enormous withdrawal of groundwater for various uses of agricultural, industrial and other domestic needs. This resource has become an important source of drinking water and food security for teeming millions of the state. It provides 70 percent of water for domestic use in rural areas and about 50 percent of water for urban and industrial areas. The significant contribution made for Green Revolution and also as primary reliable source of irrigation during drought years has further strengthened the people's faith in utilisation of ground water as dependable source.

The speedy and uncontrolled usage of ground water has also created many problems. The intensive ground water development in many parts of the country has resulted in depletion of ground water levels and availability of the resource. The pristine ground water quality too became its victim. Though, for the State as a whole the availability of ground water resources appears quite comfortable but localised areas have shown the deleterious effects of excessive ground water development. To maintain sustainability of ground water resources artificial recharge to ground water is being practiced. Subsurface reservoirs are very attractive and technically feasible alternatives for storing surplus monsoon runoff. These subsurface reservoirs can store substantial quantity of water. The sub-surface storages have advantages of being free from the adverse effects like inundation of large surface area and no gigantic structures are required. The conduit functions of aquifers thereby reducing the cost intensive surface water conveyance system. The effluence resulting from such sub-surface storage at various surface intersection points in the form of spring line, or stream emergence, would enhance the river flows and improve the presently degraded ecosystem of riverine tracts, particularly in the outfall areas. Central Ground Water Board started Artificail Recahrge Studies during VIII the Plan (1992-1997) during which recharge studies in Maharashtra, Karnataka, Andhra Pradesh, Delhi, Kerala, Madhya Pradesh, Tamil Nadu, West Bengal, & Chandigarh were takenup. The recharge works were takenup as wide spread declines were observed in the water level in the country. The studies were takenup with a objective to identify suitable artificial recharge structure in different hydrogeological terrains. The studies have been continued during different five year plans till date.

II. GROUND WATER DEVELOPMENT SCENARIO OF THE COUNTRY

Annual precipitation in India is of the order of 4000 BCM (including snowfall) and the natural runoff in the rivers is computed to be about 1869 BCM. The utilizable surface water and replenishable ground water resources are of the order of 690 BCM and 433 BCM respectively. Thus, the total water resources available for various uses, on an annual basis, are of the order of 1123 BCM. Although the per capita availability of water in India is about 1869 cubic meters as in 1997 against the benchmark value of 1000 Cu m signifying 'water-starved' condition, there is wide disparity in basin-wise water availability due to uneven rainfall and varying population density in the country. The availability is as high as 14057 cu m per capita in Brahmaputra/ Barak Basin and as low as 307 cu m in Sabarmati basin. Many other basins like Mahi, Tapi, Pennar are already water stressed.

The ground water availability in the Indian sub-continent is highly complex due to diversified geological formations, complexity in tectonic framework, climatological dissimilarities and changing hydro-chemical environments. Ground water development in different areas of the country is not uniform. There is intensive development of ground water in certain areas, which has resulted in over – exploitation of the ground water resources and led to declining trend in levels of ground water. As per the latest assessment of ground water resources carried out jointly by the Central Ground Water Board and the concerned States, out of 5723 assessment units (Blocks/ Mandals/Talukas) in the country, 839 units in various States have been categorized as 'Over-exploited' (Figure.1) i.e. the annual ground water extraction exceeds the annual replenishable resource and significant decline in long term ground water levels has been observed either in pre- monsoon or post-monsoon or both. In addition, 226 units are 'Critical' i.e. the stage of ground water development is above 90 % and within 100% of annual replenishable resource and significant decline is observed in trend of long term water levels in both pre-monsoon and post-monsoon periods. The state-wise statuses of over-exploited and critical areas and criteria for categorization are given in Table 1 & 1a.

Table.1. State-wise Ground Water Resources Availability, Utilization and Stage of Development in India (in BCM)

Sl. No.	States / Union Territories	Annual Replenishable Ground Water Resources	Natural Discharge during non-monsoon season	Net Annual Ground Water Availability	Annual Ground Water Draft	Stage of Ground Water Development (%)	Categorization of assessment Units (numbers)	
							Over-exploited	Critical
	States							
1	Andhra Pradesh	36.5	3.55	32.95	14.9	45	219	77
2	Arunachal Pradesh	2.56	0.26	2.3	0.0008	0.04	0	0
3	Assam	27.23	2.34	24.89	5.44	22	0	0
4	Bihar	29.19	1.77	27.42	10.77	39	0	0
5	Chhattisgarh	14.93	1.25	13.68	2.8	20	0	0
6	Delhi	0.3	0.02	0.28	0.48	170	7	0
7	Goa	0.28	0.02	0.27	0.07	27	0	0

Sl. No.	States / Union Territories	Annual Replenishable Ground Water Resources	Natural Discharge during non-monsoon season	Net Annual Ground Water Availability	Annual Ground Water Draft	Stage of Ground Water Development (%)	Categorization of assessment Units (numbers)	
							Over-exploited	Critical
8	Gujarat	15.81	0.79	15.02	11.49	76	31	12
9	Haryana	9.31	0.68	8.63	9.45	109	55	11
10	Himachal Pradesh	0.43	0.04	0.39	0.12	30	0	0
11	Jammu & Kashmir	2.7	0.27	2.43	0.33	14	0	0
12	Jharkhand	5.58	0.33	5.25	1.09	21	0	0
13	Karnataka	15.93	0.63	15.3	10.71	70	65	3
14	Kerala	6.84	0.61	6.23	2.92	47	5	15
15	Madhya Pradesh	37.19	1.86	35.33	17.12	48	24	5
16	Maharashtra	32.96	1.75	31.21	15.09	48	7	1
17	Manipur	0.38	0.04	0.34	0.002	0.65	0	0
18	Meghalaya	1.15	0.12	1.04	0.002	0.18	0	0
19	Mizoram	0.04	0.004	0.04	0.0004	0.9	0	0
20	Nagaland	0.36	0.04	0.32	0.009	3	0	0
21	Orissa	23.09	2.08	21.01	3.85	18	0	0
22	Punjab	23.78	2.33	21.44	31.16	145	103	5
23	Rajasthan	11.56	1.18	10.38	12.99	125	140	50
24	Sikkim	0.08	0	0.08	0.01	16	0	0
25	Tamil Nadu	23.07	2.31	20.76	17.65	85	142	33
26	Tripura	2.19	0.22	1.97	0.17	9	0	0
27	Uttar Pradesh	76.35	6.17	70.18	48.78	70	37	13
28	Uttarakhand	2.27	0.17	2.1	1.39	66	2	0
29	West Bengal	30.36	2.9	27.46	11.65	42	0	1
	Total States	432.42	33.73	398.7	230.4	58	837	226
	Union Territories							
1	Andaman & Nicobar	0.33	0.005	0.32	0.01	4	0	0
2	Chandigarh	0.023	0.002	0.02	0	0	0	0
3	Dadra & Nagar Haveli	0.063	0.003	0.06	0.009	14	0	0
4	Daman & Diu	0.009	0.0004	0.008	0.009	107	1	0
5	Lakshadweep	0.012	0.009	0.004	0.002	63	0	0
6	Pondicherry	0.16	0.016	0.144	0.151	105	1	0
	Total UTs	0.597	0.036	0.556	0.181	33	2	0
	Grand Total	433.02	33.77	399.25	230.6	58	839	226

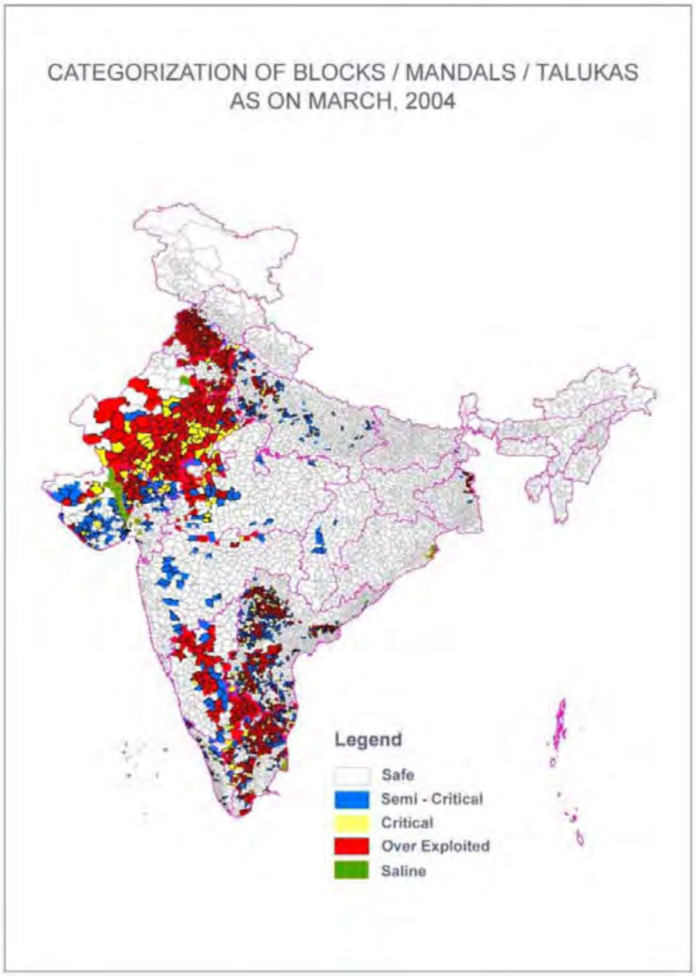


Fig-1a. Categorization of Assessment Units Based on the Stage of Ground Water Development in India (As on March 2004)

Table.1a. Criteria for categorization of assessment units.

Sl.no	Stage of groundwater development	Significant long term decline		Categorization
		Pre-monsoon	Post-monsoon	
1	< = 70 %	No	No	Safe
2	> 70 % & < 90 %	No	No	Safe
		Yes/no	No/yes	Semi-Critical
3	> 90 % & <= 100 %	Yes/no	No/Yes	Semi-Critical
		Yes	Yes	Critical
4	> 100 %	Yes/no	No/Yes	Over-exploited
		Yes	Yes	Over-exploited

III. NEED FOR ARTIFICIAL RECHARGE

Natural replenishment of ground water reservoir is slow and is unable to keep pace with the excessive continued exploitation of ground water resources in various parts of the country. This has resulted in declining ground water levels and depleted ground water resources in large areas of the country. In order to augment the natural supply of ground water, artificial recharge to ground water has become an important and frontal management strategy. The efforts are basically augmentation of natural movement of surface water into ground water reservoir through suitable civil structures. The techniques of artificial aquifer recharge interrelate and integrate the source water to ground water reservoir and are dependent on the hydrogeological situation of the area.

The rainfall occurrence in the country is monsoon dependent and in large part of the country rain fall is limited to about three months period ranging from around 20 to 30 days. The natural recharge to ground water reservoir is restricted to this period only. The artificial recharge techniques aim at increasing the recharge period in the post-monsoon season for about 3 more months providing additional recharge. This results in providing sustainability to ground water development during the lean season.

There is thus a need to prepare a systematic implementation plan for augmenting ground water resources under various hydrogeological situations. However specific emphasis needs to be given in the areas where ground water levels are declining and water scarcity is being experienced. In this report emphasis has been given to the areas with declining trend and deep ground water levels.

IV. TRADITIONAL PRACTICES OF ARTIFICIAL RECHARGE

India is a vast country with very deep historical roots and strong cultural traditions. These are reflected in our social fabric and institutions of community life. In spite of social movements of varied nature through the millennia, we have retained the spirit and essence of these traditions and have remained attached to our roots. Some of our traditions, evolved and developed by our ancestors thousands of years ago have played important roles in different spheres of our life. One of the most important among these is the tradition of collecting, storing and preserving water for various uses.

The tradition probably started at the dawn of civilization with small human settlements coming up on the banks of rivers and streams. When, due to vagaries of nature, rivers and streams dried up or the flow in them dwindled, they moved away to look for more reliable sources of water. In due course of time, large settlements came up along the banks of perennial rivers that provided plentiful water. As the population increased, settlements developed into towns and cities and agriculture expanded. Techniques were developed to augment water availability by collecting and storing rainwater, tapping hill and underground springs and water from snow and glacier melt etc. Water came to be regarded as precious and its conservation and preservation was sanctified by religion. Various religious, cultural and social rituals prescribed purification and cleansing with water. Water itself had many applications in different rituals. Development of reliable sources of water such as storage reservoirs, ponds, lakes, irrigation canals etc. came to be regarded as an essential part of good governance. Emperors and kings not only built various water bodies but also encouraged the village communities and individuals to build these on their own. Wide-ranging laws were enacted to regulate their construction and maintenance and for conservation and preservation of water and its proper distribution and use.

Different regions of the country practiced variety of rainwater harvesting and artificial recharge methods.

A. Trans-Himalayan Region

The Trans-Himalayan region of India consists of the cold deserts of Ladakh and Kargil in Jammu and Kashmir, and the Lahaul and Spiti valleys of Himachal Pradesh. Traditional recharge structure practiced here is the Zing.

Zings are water harvesting structures found in Ladakh. They are small tanks, in which collects melted glacier water. Essential to the system is the network of guiding channels that brings the water from the glacier to the tank. As glaciers melt during the day, the channels fill up with a trickle that in the afternoon turns into flowing water. The water collects towards the evening, and is used the next day.

B. Western Himalaya region

The western Himalayan region consists of the western half, which stretches from the Kashmir valley to the Uttarakhand region. Traditional recharge structure practiced here are the Kul, Naula, Kuhi and Khatri.

Kuls are water channels found in precipitous mountain areas. These channels carry water from glaciers to villages in the Spiti valley of Himachal Pradesh. Where the terrain is muddy, the kul is lined with rocks to keep it from becoming clogged. In the Jammu region too, similar irrigation systems called kuhls are found.

Naula is a surface-water harvesting method typical to the hill areas of Uttaranchal. These are small wells or ponds in which water is collected by making a stone wall across a stream

Khatris are structures, about 10 x 12 feet in size and six feet deep carved out in the hard rock mountain. These traditional water harvesting structures are found in Hamirpur, Kangra and Mandi districts of Himachal Pradesh There are two types of khatris: one for animals and washing purposes in which rain water is collected from the roof through pipes, and other used for human consumption in which rainwater is collected by seepage through rocks. Interestingly, the khatris are owned by individual as well as by a community. There are government khatris as well, which are maintained by the panchayat.

Kuhls are a traditional irrigation system in Himachal Pradesh-
surface channels diverting water from natural flowing streams (khuds). A typical community kuhl services six to 30 farmers, irrigating an area of about 20 ha. The system consists of a temporary headwall (constructed usually with river boulders) across a khud (ravine) for storage and diversion of the flow through a canal to the fields. By modern standards, building kuhls was simple, with boulders and labour forming the major input. The kuhl was provided with moghas (kuchcha outlets) to draw out water and irrigate nearby terraced fields. The water would flow from field to field and surplus water, if any, would drain back to the khud. The kuhls were constructed and maintained by the village community.

C. Eastern Himalaya Region

Eastern Himalayan region comprises of the states of Sikkim and Arunachal Pradesh and the Darjeeling district of West Bengal. Traditional artificial recharge method practiced here is the Apatani.

Apatani is a wet rice cultivation cum fish farming system practiced in elevated regions of about 1600 m and gentle sloping valleys, having an average annual rainfall about 1700 mm and also rich water resources like springs and streams. This system harvests both ground and surface water for irrigation. It is practiced by Apatani tribes of ziro in the lower Subansiri district of Arunachal Pradesh.

In Apatani system, valleys are terraced into plots separated by 0.6 meters high earthen dams supported by bamboo frames. All plots have inlet and outlet on opposite sides. The inlet of low lying plot functions as an outlet of the high lying plot. Deeper channels connect the inlet point to outlet point. The terraced plot can be flooded or drained off with water by opening and blocking the inlets and outlets as and when required. The stream water is tapped by constructing a wall of 2-4 m high and 1 m thick near forested hill slopes. This is conveyed to agricultural fields through a channel network.

D. Northeastern Hill Ranges

Northeastern hill ranges stretches over six state namely, Assam, Nagaland, Manipur, Mizoram, Meghalaya and Tripura in the Indian boundary and over Bangladesh and Myanmar. Traditional artificial recharge practiced here are the Zabo, Cheo-oziihi and Bamboo-drip Irrigation.

The *zabo* (the word means 'impounding run-off') system is practiced in Nagaland in north-eastern India. Also known as the ruza system, it combines water conservation with forestry, agriculture and animal care. Villages such as Kikruma, where zabos are found even today, are located on a high ridge. Though drinking water is a major problem, the area receives high rainfall. The rain falls on a patch of

protected forest on the hilltop; as the water runs off along the slope, it passes through various terraces. The water is collected in pond-like structures in the middle terraces; below are cattle yards, and towards the foot of the hill are paddy fields, where the run-off ultimately meanders into.

Bamboo Drip Irrigation

Meghalaya has an ingenious system of tapping of stream and springwater by using bamboo pipes to irrigate plantations. About 18-20 litres of water entering the bamboo pipe system per minute gets transported over several hundred metres and finally gets reduced to 20-80 drops per minute at the site of the plant. This 200-year-old system is used by the tribal farmers of Khasi and Jaintia hills to drip-irrigate their black pepper cultivation. Bamboo pipes are used to divert perennial springs on the hilltops to the lower reaches by gravity. The channel sections, made of bamboo, divert and convey water to the plot site where it is distributed without leakage into branches, again made and laid out with different forms of bamboo pipes. Manipulating the intake pipe positions also controls the flow of water into the lateral pipes. Reduced channel sections and diversion units are used at the last stage of water application. The last channel section enables the water to be dropped near the roots of the plant. Bamboos of varying diameters are used for laying the channels. Other components are small pipes and channels of varying sizes used for diversion and distribution of water from the main channel. About four to five stages of distribution are involved from the point of the water diversion to the application point.

E. Brahmaputra Valley

Brahmaputra valley is located between the two parallel hill ranges of Arunachal Pradesh, with Bhutan to the north and northeastern hill ranges of Meghalaya, North Cachar and Nagaland to the south. Traditional artificial recharge practices here are the Dongs and Dungs/Jampois. *Dongs* are ponds constructed by the Bodo tribes of Assam to harvest water for irrigation. These ponds are individually owned with no community involvement. *Dungs or Jampois* are small irrigation channels linking rice fields to streams in the Jalpaiguri district of West Bengal

F. Indo-Gangetic Plains

Indo-Gangetic plains forms the important zone of human concentration in India has these plains are enclosed by numerous small and large rivers. Artificial recharge structures practiced traditionally here are the Ahars-Pynes, Bengal's Inundation channels, Dighis and Baolis.

Dighi is a square or circular reservoir with steps to enter. Each dighi had its own sluice gates. People were not allowed to bathe or wash clothes on the steps of the dighi. However, one was free to take water for personal use. People generally hired a kahar or a mashki to draw water from the dighis. Most of the houses had either their own wells or had smaller dighis on their premises. In the event of canal waters not reaching the town and the dighis consequently running dry, wells were the main source of water. Some of the major wells were Indara kuan near the present Jubilee cinema, Pahar-wala-kuan near Gali-pahar-wali, and Chah Rahat near Chhipiwara (feeding water to the Jama Masjid).

Baolis are stepwells built by sultans and their nobles and maintained. These baolis were secular structures from which everyone could draw water. Gandak-ki-baoli (so named because its water has gandak or sulphur) was built during the reign of Sultan Iltutmish. The water of this beautiful rock-hewn baoli is still used for washing and bathing. Adjacent to this, there are the ruins of other baolis like Rajon-ki-baoli, a baoli in the Dargah of Kaki Saheb, and a caved baoli behind Mahavir Sthal. During this period baolis were built in other parts of the city too.

G. Thar Deserts

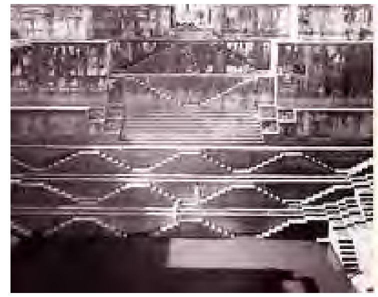
The Thar desert covers an area of 44.6 million hectare, of which 27.8 million hectare lies in India and rest in Pakisthan. Western Rajasthan, Kutch region of Gujarat, Bhatinda & Ferozepur districts in Punjab and most of Hisar & parts of Mohindergarh districts of Haryana fall under the Thar desert. Many traditional artificial recharge structures have been practiced, they are the Kunds/Kundis, Kuis/Beris, Baoris/bers, Jhararas, Nadi, Tobas, Tankas, Khadins, Vav/Vavdi/Baoli/Bavadi, Virdas & Paar.

Kund or kundi looks like an upturned cup nestling in a saucer. These structures harvest rainwater for drinking, and dot the sandier tracts of the Thar Desert in western Rajasthan and some areas in Gujarat. Essentially a circular underground well, kunds have a saucer-shaped catchment area that gently slopes towards the centre where the well is situated. A wire mesh across water-inlets prevents debris from falling into the well-pit. The sides of the well-pit are covered with (disinfectant) lime and ash. Most pits have a dome-shaped cover, or at least a lid, to protect the water. If need be, water can be drawn out with a bucket. The depth and diameter of kunds depend on their use (drinking, or domestic water requirements). They can be owned by only those with money to invest and land to construct it. Thus for the poor, large public kunds have to be built.

Kuis / Beris are found in western Rajasthan, these are 10-12 m deep pits dug near tanks to collect the seepage. Kuis can also be used to harvest rainwater in areas with meagre rainfall. The mouth of the pit is usually made very narrow. This prevents the collected water from evaporating. The pit gets wider as it burrows under the ground, so that water can seep in into a large surface area. The openings of these entirely kuchcha (earthen) structures are generally covered with planks of wood, or put under lock and key. The water is used sparingly, as a last resource in crisis situations.

Baoris/Bers are community wells, found in Rajasthan, that are used mainly for drinking purposes. Most of them are very old and were built by banjaras (mobile trading communities) for their drinking water needs. They can hold water for a long time because of almost negligible water evaporation.

Jhalaras were human-made tanks, found in Rajasthan and Gujarat, essentially meant for community use and for religious rites. Often rectangular in design, jhalaras have steps on three or four sides. Jhalars areground water bodies which are built to ensure easy & regular supply of water to the surrounding areas.The jhalars are rectangular in shape with steps on three or even on all the four sides of the tank . the steps are built on a series of levels. The jhalaras collect subterranean seepage of a talab or a lake located upstream. The water from these jhalaras was not used for drinking but for only community bathing and religious rites . Jhodhpur city has eight jhalaras two of which are inside the town & six are found outside the city. The oldest jhalara is the mahamandir jhalara which dates back to 1660 AD.



Nadis are village ponds, found near Jodhpur in Rajasthan. They are used for storing waterfrom an adjoining natural catchment during the rainy season. The site was selected by the villagers based on an available natural catchments and its water yield potential. Water availability from nadi would range from two months to a year after the rains. In the dunal areas they range from 1.5 to 4.0 metres and those in sandy plains varied from 3 to 12 metres. The location of the nadi had a strong bearing on its storage capacity due to the related catchment and runoff characteristics.

Tobas is the local name given to a ground depression with a natural catchment area. A hard plot of land with low porosity, consisting of a depression and a natural catchment area was selected for the construction of tobas

Tankas (small tank) are underground tanks, found traditionally in most Bikaner houses. They are built in the main house or in the courtyard. They were circular holes made in the ground, lined with fine polished lime, in which raiwater was collected. Tankas were often beautifully decorated with tiles, which helped to keep the water cool. The water was used only for drinking. If in any year there was less than normal rainfall and the tankas did not get filled, water from nearby wells and tanks would be obtained to fill the household tankas. In this way, the people of Bikaner were able to meet their water requirements. The tanka system is also to be found in the pilgrim town of Dwarka where it has been in existence for centuries. It continues to be used in residential areas, temples, dharamshalas and hotels.

Khadin, also called a dhora, is an ingenious construction designed to harvest surface runoff water for agriculture. Its main feature is a very long (100-300 m) earthen embankment built across the lower hill slopes lying below gravelly uplands. Sluices and spillways allow excess water to drain off. The khadin system is based on the principle of

harvesting rainwater on farmland and subsequent use of this water-saturated land for crop production. First designed by the Paliwal Brahmins of Jaisalmer, western Rajasthan in the 15th century, this system has great similarity with the irrigation methods of the people of Ur (present Iraq) around 4500 BC and later of the Nabateans in the Middle East. A similar system is also reported to have been practised 4,000 years ago in the Negev desert, and in southwestern Colorado 500 years ago.

Vav / Vavdi / Baoli / Bavadi, Traditional stepwells are called vav or vavadi in Gujarat, or baolis or bavadis in Rajasthan and northern India. Built by the nobility usually for strategic and/or philanthropical reasons, they were secular structures from which everyone could draw water. Most of them are defunct today. Stepwell locations often suggested the way in which they would be used. When a stepwell was located within or at the edge of a village, it was mainly used for utilitarian purposes and as a cool place for social gatherings. When stepwells were located outside the village, on trade routes, they were often frequented as resting places. Many important stepwells are located on the major military and trade routes from Patan in the north to the sea coast of Saurashtra. When stepwells were used exclusively for irrigation, a sluice was constructed at the rim to receive the lifted water and lead it to a trough or pond, from where it ran through a drainage system and was channelled into the fields.

Virdas are shallow wells dug in low depressions called jheels (tanks). They are found all over the Banni grasslands, a part of the Great Rann of Kutch in Gujarat. They are systems built by the nomadic Maldharis, who used to roam these grasslands. Now settled, they persist in using virdas. These structures harvest rainwater. The topography of the area is undulating, with depressions on the ground. By studying the flow of water during the monsoon, the Maldharis identify these depressions and make their virdas there. Essentially, the structures use a technology that helps the Maldharis separate potable freshwater from unpotable salt water. After rainwater infiltrates the soil, it gets stored at a level above the salty groundwater because of the difference in their density. A structure is built to reach down (about 1 m) to this upper layer of accumulated rainwater. Between these two layers of sweet and saline water, there exists a zone of brackish water. As freshwater is removed, the brackish water moves upwards, and accumulates towards the bottom of the virda.

Paar is a common water harvesting practice in the western Rajasthan region. It is a common place where the rainwater flows from the agar (catchment) and in the process percolates into the sandy soil. In order to access the rajani pani (percolated water) kuis or beris are dug in the agor (storage area). Kuis or beris are normally 5 metres (m) to 12 m deep. The structure was constructed through traditional masonary technology. Normally six to ten of them are constructed in a paar. However depending on the size of the paar the numbers of kuis or beris are decided. Bhatti mentions that there are paars in Jaisalmer district where there are more than 20 kuis are in operation. This is the most predominant form of rainwater harvesting in the region. Rainwater harvested through PAAR technique is known as Patali paani.

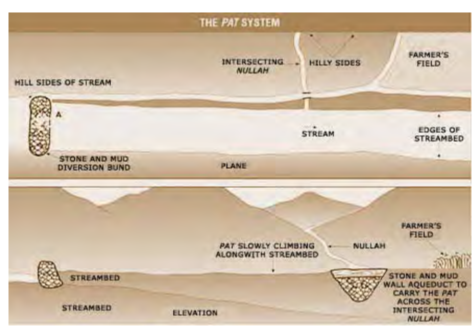
H. Central Highlands

The central highlands comprises of the semi-arid uplands of the eastern Rajasthan, the Aravalli range, uplands of the Banas-Chambal basin in Rajasthan, the Jhansi and Mirzapur uplands of UP, eastern hilly regions of The Dangs & Panchmahals of Gujarat, northern MP uplands, the Sagar, Bhopal & Ratlam plateaus of central MP and the Narmada region. Traditional artificial structures practiced here are the Talab/Bandhis, Saza/Kuva, Johads, Naada/Bandh, Pat, Rapat, Chandela tank, Bundela tank.

Talabs/Bandhis are reservoirs. They may be natural, such as the ponds (pokhariyan) at Tikamgarh in the Bundelkhand region. They can be human-made, such the lakes in Udaipur. A reservoir area of less than five bighas is called a talai; a medium sized lake is called a bandhi or talab; bigger lakes are called sagar or samand. The pokhariyan serve irrigation and drinking purposes. When the water in these reserviors dries up just a few days after the monsoon, the pond beds are cultivated with rice

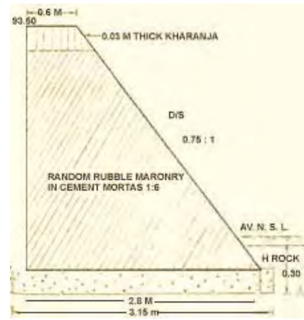
Saza Kuva is an open well with multiple owners (saza = partner), saza kuva is the most important source of irrigation in the Aravalli hills in Mewar, eastern Rajasthan. The soil dug out to make the well pit is used to construct a huge circular foundation or an elevated platform sloping away from the well. The first is built to accomodate the rehat, a traditional water lifting device; the sloping platform is for the chada, in which buffaloes are used to lift water. Saza kuva construction is generally taken up by a group of farmers with adjacent landholdings; a harva, a man with special skills in groundwater detection, helps fix the site.

Johads are small earthen check dams that capture and conserve rainwater, improving percolation and groundwater recharge. Starting 1984, there has been revival of some 3000 johads spread across more than 650 villages in Alwar district, Rajasthan. This has resulted in a general rise of the groundwater level by almost 6 metres and a 33 percent increase in the forest cover in the area. Five rivers that used to go dry immediately following the monsoon have now become perennial, such as the River Arvari, has come alive.



Naada/bandha are found in the Mewar region of the Thar desert. It is a stone check dam, constructed across a stream or gully, to capture monsoon runoff on a stretch of land. Submerged in water, the land becomes fertile as silt deposits on it and the soil retains substantial amounts of water.

Pat system was devised according to the peculiarities of the terrain to divert water from swift-flowing hill streams into irrigation channels called pats. The diversion bunds across the stream are made by piling up stones and then lining them with teak leaves and mud to make them leakproof. The pat channel has to negotiate small nullahs that join the stream off and on and also sheer cliffs before reaching the fields. These sections invariably get washed away during the monsoons. Stone aqueducts have to be built to span the intervening nullahs. The villagers irrigate their fields by turns. The channel requires constant maintenance and it is the duty of the family irrigating the fields on a particular day to take care of the pat on that particular day. It takes about two weeks to get the pat flowing and the winter crop is sown in early November.



Rapat is a percolation tank, with a bund to impound rainwater flowing through a watershed and a waste weir to dispose of the surplus flow. If the height of the structure is small, the bund may be built of masonary, otherwise earth is used. Rajasthan rapats, being small, are all masonry structures. Rapats and percolation tanks do not directly irrigate land, but recharges well within a distance of 3-5 km downstream. Silting is a serious problem with small rapats and the estimated life of a rapat varies from 5 to 20 years.

Chandela Tanks were constructed by stopping the flow of water in rivulets flowing between hills by erecting massive earthen embankments, having width of 60m or more. These hills with long stretches of quartz reefs running underneath them, acted as natural ground water barrier helping to trap water between the ridges. The earthen embankments were supported on both sides with walls of coarse stones, forming a series of stone steps. These tanks are made up of lime and mortar and this is the reason why these tanks survived even after thousand years but the only problem, which these tanks are facing, is siltation of tank beds. Chandela tanks usually had a convex curvature somewhere in the middle of the embankment; many older and smaller tanks were constructed near the human settlement or near the slopes of a cluster of hills. These tanks served to satisfy the drinking water needs of villagers and cattle.

Bundela Tanks are bigger in size as compared to Chandela tanks. These tanks had solidly constructed steps leading to water in the tank; But these structures had chabootaras, pavillions and royal orchards designed to show off the glory of the king who built them. But these tanks are not as cost effective and simple as Chandela tanks. These tanks were constructed to meet the growing water demands in the area, maintenance of these tanks was done by the person employed by the king but in case of smaller tanks villagers collectively removed silt and repair embankment.

I. Eastern Highlands

The eastern Plateau extends across Bihar, MP and Orissa district. The uplands of south Bihar (Chotanagpur plateau),north eastern MP uplands covering Rewa, Santhal Parganas & Singhbhum and extends into West Bengal. Traditional artificial recharge structure practiced here is the Katas/Mundas/Bandhas.

Katas/Mundas/Bandhas were the main irrigation sources in the ancient tribal kingdom of the Gonds (now in Orissa and Madhya Pradesh). Most of these katas were built by the village headmen known as Gountias, who in turn, received the land from the Gond kings. Land here is classified into four groups on the basis of its topography: aat, (highland); mal (sloped land); berna (medium land); and bahal (low land). This classification helps to select. A kata is constructed north to south, or east to west, of a village. A strong earthen embankment, curved at either end, is built across a drainage line to hold up an irregularly-shaped sheet of water. The undulations of the country usually determine its shape as that of a long isosceles triangle, of which the dam forms the base. It commands a valley, the bottom of which is the bahal land and the sides are the mal terrace. As a rule, there is a cut high up on the slope near one end of the embankment from where water is led either by a small channel or tal, or from field to field along terraces, going lower down to the fields. In years of normal rainfall, irrigation was not needed because of moisture from percolation and, in that case, the surplus flow was passed into a nullah. In years of scanty rainfall, the centre of the tank was sometimes cut so that the lowest land could be irrigated.

J. Deccan Plateau

Deccan plateau constitutes the major portion of south Indian tableland, i.e the elevated region lying east of the western ghats. These plateaus occupy large parts of Maharashtra, Karnataka & a small portion of AP. The traditional structures practiced here are the Cheruvu, Kohil tanks, Bhandaras, Phad, Kere and The Ramtek Model.

Cheruvu are found in Chitoor and Cuddapah districts in Andhra Pradesh. They are reservoirs to store runoff. Cheruvu embankments are fitted with thoomu (sluices), alugu or marva or kalju (flood weir) and kalava (canal).

Kohlis, a small group of cultivators, built some 43,381 water tanks in the district of Bhandara, Maharashtra, some 250-300 years ago. These tanks constituted the backbone of irrigation in the area until the government took them over in the 1950s. It is still crucial for sugar and rice irrigation. The tanks were of all sizes, often with provisions to bring water literally to the doorstep of villagers

Bandharas are check dams or diversion weirs built across rivers. A traditional system found in Maharashtra, their presence raises the water level of the rivers so that it begins to flow into channels. They are also used to impound water and form a large reservoir. Where a bandhara was built across a small stream, the water supply would usually last for a few months after the rains. They are built either by villagers or by private persons who received rent-free land in return for their public act. Most Bandharas are defunct today.

Phad The community-managed phad irrigation system, prevalent in northwestern Maharashtra, probably came into existence some 300-400 years ago. The system operated on three rivers in the Tapi basin - Panjhra, Mosam and Aram - in Dhule and Nasik districts (still in use in some places here). The system starts with a bandhara (check dam or diversion-weir) built across a rivers. From the bandharas branch out kalvas (canals) to carry water into the fields. The length of these canals varies from 2-12 km. Each canal has a uniform discharge capacity of about 450 litres/second. Charis (distributaries) are built for feeding water from the kalva to different areas of the phad. Sarangs (field channels) carry water to individual fields. Sandams (escapes), along with kalvas and charis, drain away excess water. In this way water reaches the kayam baghayat (agricultural command area), usually divided into four phads (blocks). The size of a phad can vary from 10-200 ha, the average being 100-125 ha. Every year, the village decides which phads to use and which to leave fallow. Only one type of crop is allowed in one phad. Generally, sugarcane is grown in one or two phads; seasonal crops are grown in the others. This ensures a healthy crop rotation system that maintains soil fertility, and reduces the danger of waterlogging and salinity.

Tanks, called *kere* in Kannada, were the predominant traditional method of irrigation in the Central Karnataka Plateau, and were fed either by channels branching off from anicuts (chech dams) built across streams, or by streams in valleys. The outflow of one tank supplied the next all the way down the course of the stream; the tanks were built in a series, usually situated a few kilometres apart. This ensured a) no wastage through overflow, and b) the seepage of a tank higher up in the series would be collected in the next lower one.

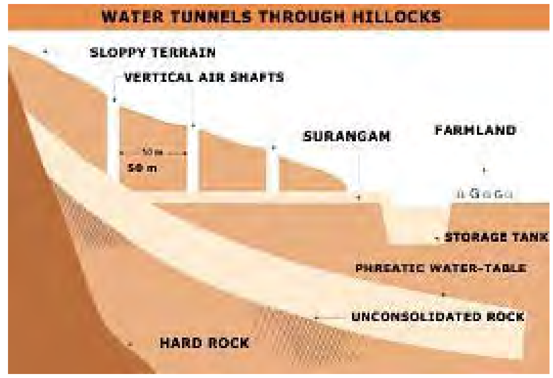
The Ramtek model has been named after water harvesting structures in the town of Ramtek, Maharashtra. A scientific analysis revealed an intricate network of groundwater and surface waterbodies, intrinsically connected through surface and underground canals. A fully evolved system, this model harvested runoff through tanks, supported by high yielding wells and structures like baories, kundis, and waterholes. This system, intelligently designed to utlise every raindrop falling in the watershed area is disintegrating due to neglect and ignorance. Constructed and maintained mostly by malguzars (landowners), these tanks form a chain, extending from the foothills to the plains, conserving about 60-70 per cent of the total runoff. Once tanks located in the upper reaches close to the hills were filled to capacity, the water flowed down to fill successive tanks, generally through interconnecting channels. This sequential arrangement generally ended in a small waterhole to store whatever water remained unstored.

The presence of the Ramtek ridge in the middle, having a steep slope on both sides, results in quick runoffs and little percolation. This might have led the residents of the southern plains of the Ramtek hills to construct different types of water conservation structures (like tanks) where they could trap the maximum.

K. Western Ghats

Western ghats constitutes a narrow strip of long running hill range running from north to south of the western coast of India. It extends from Gujarat to Kerala, passing through Maharashtra, Goa & Karnataka. The traditional artificial recharge structure practiced here is the Surangam.

Surangam word is derived from a Kannada word for tunnel. It is also known as thurangam, thorapu, mala, etc, in different parts of Kasaragod. It is a horizontal well mostly excavated in hard laterite rock formations. The excavation continues until a good amount of water is struck. Water seeps out of the hard rock and flows out of the tunnel. This water is usually collected in an open pit constructed outside the surangam. A surangam is about 0.45-0.70 metres (m) wide and about 1.8-2.0 m high. The length varies from 3-300 m. Usually several subsidiary surangams are excavated inside the main one. If the surangam is very long, a number of vertical air shafts are provided to ensure atmospheric pressure inside. The distance between successive air shafts varies between 50-60 m. The approximate dimensions of the air shafts are 2 m by 2 m, and the depth varies from place to place. Surangams are similar to qanats which once existed in Mesopotamia and Babylon around 700 BC. 2 By 714 BC, this technology had spread to Egypt, Persia (now Iran) and India. The initial cost of digging a surangam (Rs 100-150 per 0.72 m dug) is the only expenditure needed, as it hardly requires any maintenance. Traditionally, a surangam was excavated at a very slow pace and was completed over generations.



L. Eastern Ghats

Eastern ghats are the rugged hilly terrain running parallel to the eastern coastline of India. These ghats covers three regions, South Orissa highlands, Chittoor & Rayalaseema region in Andhra Pradesh and the uplands & Nilgiris region of Tamilnadu. Traditional artificial recharge structure practiced here is the Korambu.

Korambu is a temporary dam stretching across the mouth of channels, made of brushwood, mud and grass. It is constructed by horizontally fixing a strong wooden beam touching either banks of the canal. A series of vertical wooden beams of appropriate height is erected with their lower ends resting firmly on the ground and the other ends tied to the horizontal beam. Closely knitted or matted coconut thatch is tied to this frame. A coat of mud is applied to the matted frame. A layer of grass is also applied carefully which prevents dissolution of the applied mud. Korambu is constructed to raise the water level in the canal and to divert the water into field channels. It is so built that excess water flows over it and only the required amount of water flows into the diversion channels. The height of the Korambu is so adjusted that the fields lying on the upstream are not submerged. Water is allowed to flow from one field to another until all the field are irrigated. They are built twice a year especially before the onset of the monsoon season in order to supply water during winter and summer season. In Kasargod and Thrissur districts of Kerala, Korambu is known as chira.

M. Eastern Coastal plains

Eastern coastal plains is a wide and long stretch of land that lies between the eastern ghats and the Bay of Bengal. These plains can be divided into seven subdivision, they are the Mahanadi Delta of Orissa, Southern AP plains, Krishna and Godavari Delta in AP, Kanyakumari coast, Sandy littoral, Coromandal or Madras coast in Tamilnadu. Traditional artificial recharge structure practiced here is the Eri /Ooranis.

Eris (tanks) water approximately one-third of the irrigated area of Tamil Nadu. Eris have played several important roles in maintaining ecological harmony as flood-control systems, preventing soil erosion and wastage of runoff during periods of heavy rainfall, and recharging the groundwater in the surrounding areas. The presence of eris provided an appropriate micro-climate for the local areas. Without eris, paddy cultivation would have been impossible. Till the British arrived, local communities maintained eris. Historical data from Chengalpattu district, for instance, indicates that in the 18th century about 4-5 per cent of the gross produce of each village was allocated to maintain eris and other irrigation structures. Assignments of revenue-free lands, called manyams, were made to support village functionaries who undertook to maintain and manage eris. These allocations ensured eri upkeep through regular desilting and maintenance of sluices, inlets and irrigation channels. The early British rule saw disastrous experiments with the land tenure system in quest for larger land revenues. The enormous expropriation of village resources by the state led to the disintegration of the traditional society, its economy and polity. Allocations for maintenance of eris could no longer be supported by the village communities, and these extraordinary water harvesting systems began to decline.

N. The Islands

The Indian Island comprises of the Andaman & Nicobar islands in the Bay of Bengal and Lakshadweep islands in the Arabian Sea. Traditional artificial recharge structure practiced here is the Jackwells.

Jackwells are pits used to collect rainwater drop by drop. The difference in the physiography, topography, rock types and rainfall meant that the tribes in the different islands followed different methods of harvesting rain and groundwater. For instance, the southern part of the Great Nicobar Island near Shastri Nagar has a relatively rugged topography in comparison to the northern part of the islands. The shompen tribals here made full use of the topography to harvest water. In lower parts of the undulating terrain, bunds were made using logs of hard bullet wood, and water would collect in the pits so formed. They make extensive use of split bamboos in their water harvesting systems. A full length of bamboo is cut longitudinally and placed along a gentle slope with the lower end leading into a shallow pit. These serve as conduits for rainwater which is collected drop by drop in pits called Jackwells. Often, these split bamboos are placed under trees to harvest the throughfalls (of rain) through the leaves. A series of increasingly bigger jackwells is built, connected by split bamboos so that overflows from one lead to the other, ultimately leading to the biggest jackwell, with an approximate diameter of 6 m and depth of 7 m so that overflows from one lead to the other.

Note:- Extracts Reproduced from the Publication "Dying Wisdom" , Centre for Sceicne and Environment, New Delhi and " India Water Portal" (http://www.indiawaterportal.org) are duly acknowledged with thanks.

V. PLANNING OF ARTIFICIAL RECHARGE PROJECTS

Basic requirement of Artificial recharge

- Availability of non-committed runoff in space and time
- Identification of suitable hydrogeological environment and sites for augmenting sub-surface reservoir through cost effective artificial recharge techniques.

The remaining criteria and inputs required for planning the scheme are:

A) Identification of Area

- Areas where ground water levels are declining on regular basis.
- Areas where substantial amount of aquifer has already been desaturated.
- Areas where availability of ground water is inadequate in lean months.
- Areas where salinity ingress is taking place.
- Urban Area where decline in water levesl is observed.

B) Hydrometerological studies

- Rainfall pattern in the area.
- Evaporation losses from the area.
- Climatological features that effectthe planning of artificial recharge.

C) Hydrological studies

- Insitu precipitation on the watershed.
- Surface (canal) supplies from large reservoirs located within basin
- Surface supplies through trans basin water transfer.
- Treated municipal and industrial wastewaters.
- Hydrological investigations are be carried out in the Watershed/Sub-basin/basin for determining the source water availability

D) Soil infiltration studies

- Control the rate of infiltration
- Prerequisite study in cases of artificial recharge through water spreading methods
- Infiltration rates can be estimated by soils infiltration tests using Cylinder or flood infiltro-meters instruments.

E) Hydrogeological studies

- Is the prime importance study
- First step is to synthesize all the available data on hydrogeology from different agencies.
- Study of satellite imagery for identification of geomorphic units.
- Regional Hydrogeological maps indicating hydrogeological units, both at shallow and deeper levels.
- Water table contours to determine the form of the water table and the hydraulic connection of ground water with rivers, canals etc.

- Depths to the water table (DTW) for the periods of the maximum, minimum and mean annual position of water table.
- Ground water potential of different hydrogeological units and the level of ground water development.
- Chemical quality of ground water in different aquifers.

F) Aquifer Geometry:

- Data on the sub-surface hydrogeological units, their thickness and depth of occurrence
- Disposition and hydraulic properties of unconfined, semi-confined and confined aquifers in the area

G) Chemical Quality of Source Water

- Quality of raw waters available for recharge is determine
- Treatment before being used for recharge
- Relation to the changes in the soil structure and the biological phenomena which take place when infiltration begins
- Changes expected to the environmental conditions.

VI. ARTIFICIAL RECHARGE TECHNIQUES AND DESIGN

A variety of methods have been developed to recharge ground water. Artificial recharge techniques can be broadly categorized into:

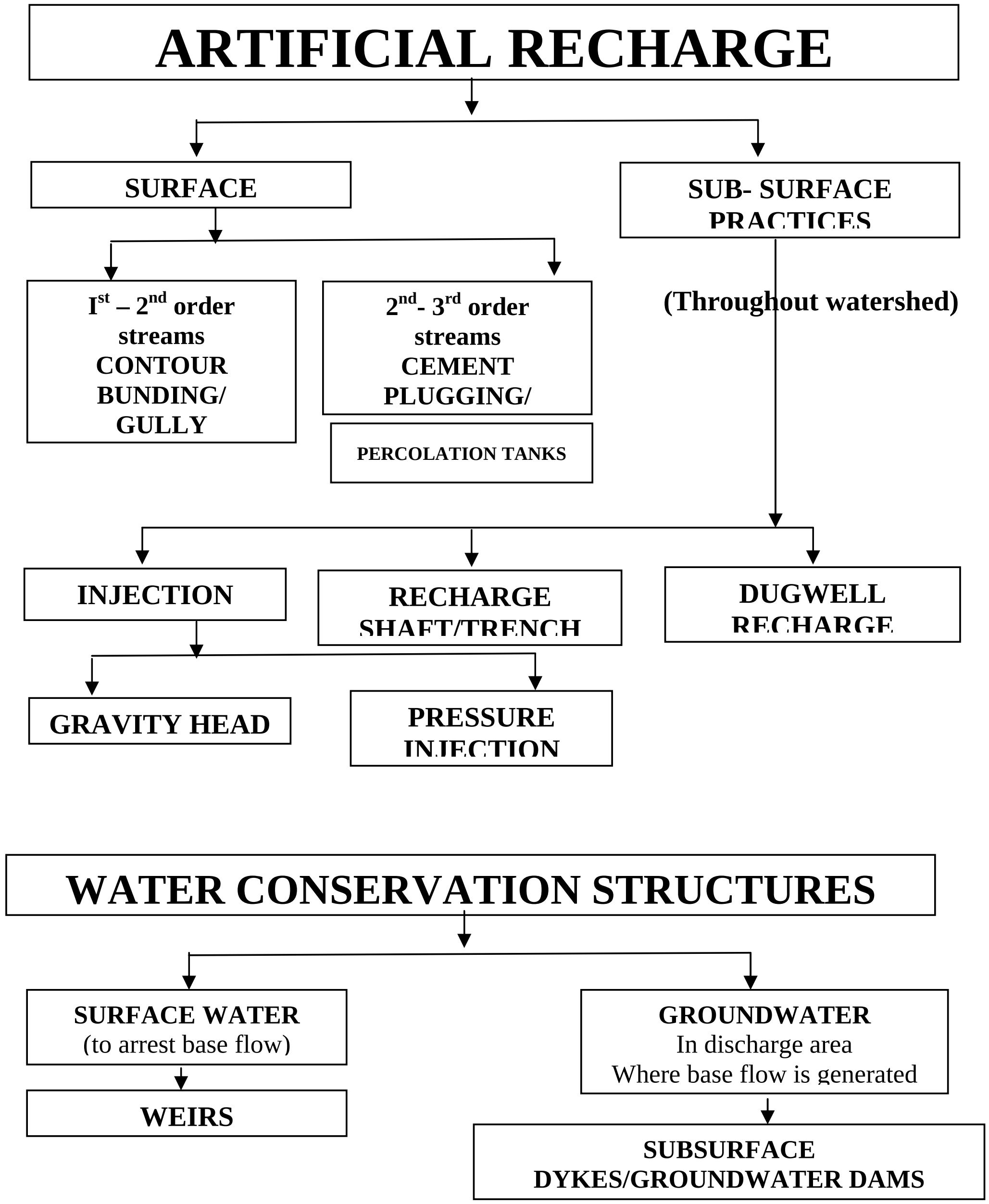
a. Direct surface techniques
- Flooding
- Basins or percolation tanks
- Stream augmentation
- Ditch and furrow system
- Over irrigation

b. Direct sub surface techniques
- Injection wells or recharge wells
- Recharge pits and shafts
- Dug well recharge
- Bore hole flooding
- Natural openings, cavity fillings.

c. Combination surface – sub-surface techniques
- Basin or percolation tanks with pit shaft or wells.

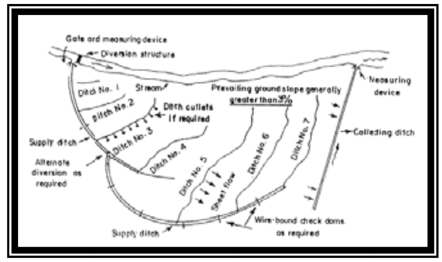
d. Indirect Techniques
- Induced recharge from surface water source.
- Aquifer modification

Although no two projects are identical, most use variation or combination of direct method, direct-sub-surface, or indirect techniques. A schematic diagram of the artificial recharge methods used is given as flowchart below.



Flowchart showing the various artificial recharge practices

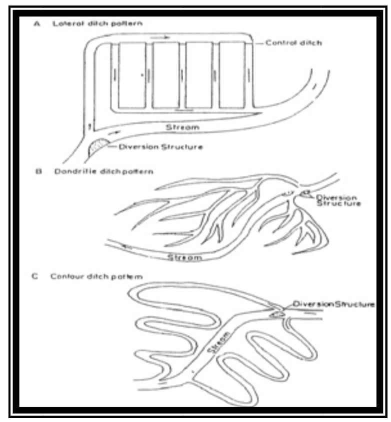
Ditch and Furrow Method: In areas with irregular topography, shallow, flat bottomed and closely spaced ditches or furrows provide maximum water contact area for recharge water from source stream or canal. This technique requires less soil preparation than the recharge basins and is less sensitive to silting. Generally three patterns of ditch and furrow system are adopted.



Lateral Ditch Pattern : The water from stream is diverted to the feeder canal/ditch from which smaller ditches are made at right angles. The rate of flow of water from the feeder canal to these ditches is controlled by gate valves. The furrow depth is kept according to the topography and also with the aim that maximum wetted surface is available along with maintenance of uniform velocity. The excess water is routed to the main stream through a return canal along with residual silt.

Dendritic Pattern : The water from stream can be diverted from the main canal to a series of smaller ditches spread in a dendritic pattern. The bifurcation of ditches continues until practically all the water is infiltrated in the ground.

Contour Pattern : The ditches are excavated following the ground surface contour of the area. When the ditch comes closer to the stream a switch back is made and thus the ditch is made to meander back and forth to traverse the spread are repeatedly. At the lowest point down stream, the ditch joins the main stream, thus returning the excess water to it.

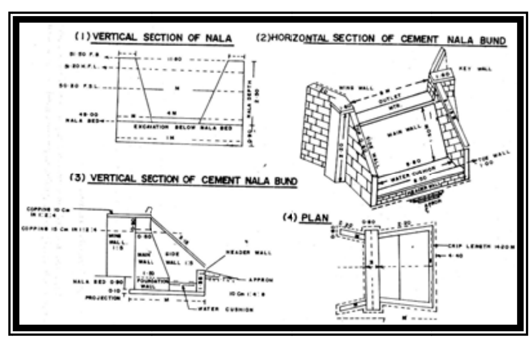


Spreading Basin or Percolation Tanks

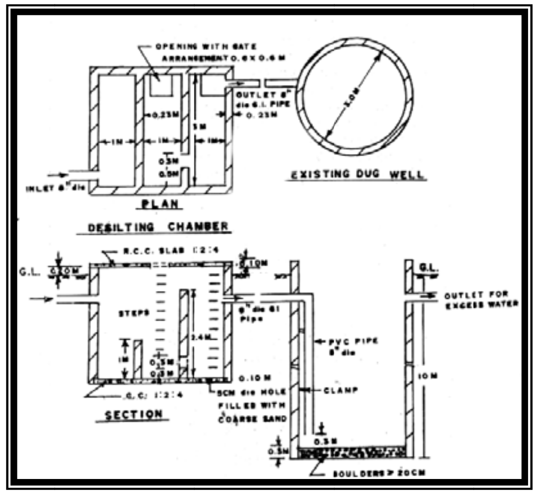
Recharge basins are either excavated or enclosed by levees. In alluvial areas, multiple recharge basins are generally constructed parallel to streams for recharging purposes. Percolation tanks surface water storage constructed over a permeable land area so that the runoff is made to percolate and recharge the ground water storage.

Gully Plug / Check Dam / Nala Bund / Gabbion Structures

Gully Plugs, are small runoff conservation structures built across small gullies and streams conserve runoff and enhance recharge locally during rainy season. The sites for gully plugs are chosen wherever there is a local break in slope to permit accumulation of adequate water behind the plugs. Check dams / plugs, small bunds or weirs are also constructed across selected nala sections to impede the flow of surface water in the stream channel for allowing longer period of recharge through channel bed. Nala bunds and check dams are constructed across first or

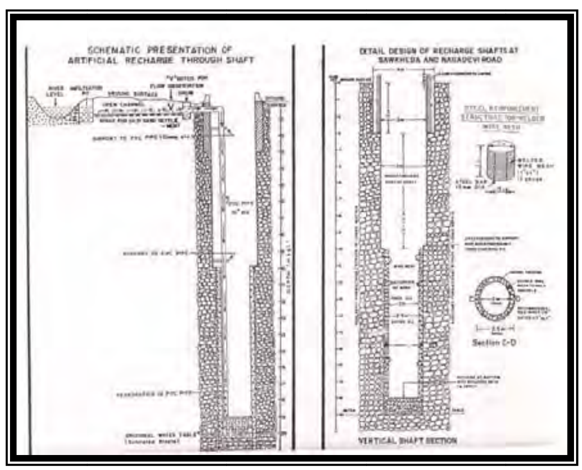


second order streams in areas having gentler slopes. To harness the maximum runoff in the stream, series of check dams are constructed.Gabbion is low height structure, commonly constructed across small stream to conserve stream flow with practically no submergence beyond stream course. The boulders locally available are stored in a steel wire mesh and put across the stream channel as a small dam by anchoring it to the stream side. The excess water overflows these structures storing some water to serve as source for recharge.



Dug Well Recharge In alluvial as well as hard rock areas, there are thousands of dug wells which have either gone dry or the water levels have declined considerably. These dug wells can be used as structures to recharge. Ordinary dug wells/ bore wells and tube wells can be used as recharge wells, whenever surplus water is available. In such cases recharge takes place by gravity flow. In areas where water levels are declining due to over development, using available abstraction structures for recharging aquifers is the immediately available option. In areas of heavy ground water exploitation, the dug wells and shallow bore wells often get partially or fully dried up during summer. The formation exposed in these wells is permeable and the unsaturated horizon of phreatic aquifer can be good repository of water if recharged with surplus available water. These wells can be used for pumping as well as for recharging process.

Recharge Shafts/Pits/Trenches



It is the most efficient and cost effective structures to recharge the aquifer directly. In the areas where source of water is available either for some time or perennially e.g. base flow, springs etc. the recharge shaft can be constructed. Recharge shafts are constructed in the situation when phreatic aquifers are not hydraulically in connection with the surface water. Generally on a regional scale impermeable layers or lenses form barrier between the surface water and water table, and thus the water spreading methods show low efficiency in recharge. For effective recharge of the aquifers, the less permeable zones are required to be penetrated so that the aquifer zones can receive recharge. The recharge shafts can be constructed in two different ways viz. Vertical and lateral. Vertical recharge shafts can be further improvised with or without injection well. Recharge pits overcome the difficulty of artificial recharge of phreatic aquifer from surface water sources. Recharge pit is excavated sufficiently deep to penetrate less permeable strata. Recharge trench is a special case of recharge pit, in which sometimes bore wells are drilled to increase its recharge capabilities. In case aquifers are located below the land surface and overlain by poorly permeable strata, a recharge shaft similar to a recharge pit but much smaller in cross section is constructed.

Artificial Recharge through Injection Well

Injection well is a recharge well similar to tube well but made with the purpose of augmenting the ground water storage of a confined aquifer by pumping-in treated surface water under pressure. Injection well is generally opted when land is scarce, as in urban areas. The aquifer to be replenished is generally over-exploited. In certain hydrogelogical setting, the aquifers do not get natural replenishment from the natural recharge because of the confining layers of low permeability and need direct injection of water through recharge well. Artificial recharge of aquifers by injection recharge wells is also suitable for coastal regions to arrest the ingress of sea water and also to combat the problems of land subsidence in areas where confined aquifers are heavily pumped. Water for recharging is to be properly treated for removal of suspended material, chemical stabilization and bacterial control. Chlorination of recharge water can also be done to prevent development of bacterial growth. The injection well is to be periodically redeveloped for efficient running.

Induced Recharge from Surface Water Sources

It is an indirect method of initiating recharge by pumping from aquifer hydraulically connected with surface water to induce recharge to ground water reservoir. When the cone of depression intercepts river recharge boundary, a hydraulic connection gets established with surface source which starts providing part of the pumpage yield. For obtaining very large water supplies from river bed / lake bed or waterlogged areas, collector wells are constructed. Such wells have been installed in river beds at Delhi, Gujarat, Tamil Nadu and Orissa. In areas where the phreatic aquifers adjacent to the river are of limited thickness, horizontal wells are more appropriate than vertical wells. Collector well with horizontal laterals and infiltration galleries get more induced recharge from the stream.

Subsurface Dykes/ Underground Bandharas

Subsurface dyke is a subsurface barrier across a stream which retards the natural subsurface / ground water flow of the system and stores water below ground surface to meet the demand during the period of need. The main purpose of ground water dam is to arrest the flow of ground water out of the sub-basin and increase the storage within the aquifer.

Roof Top Rainwater Harvesting and Aquifer Recharge

In urban areas where open land is not commonly available, roof top rain water can be conserved and used for recharge of ground water. This approach requires connecting the outlet pipe from roof top to divert the rain water to either existing wells / tube wells / bore wells or specially designed recharge trench / recharge shaft cum bore well. Drain pipes, roof surfaces and storage tanks should be constructed of chemically inert materials such as plastics, aluminum, galvanized iron or fiber glass, in order to avoid contaminating the rainwater.

The impact of recharge through these structures to ground water regime is local, but if implemented on a massive scale, it can raise the water level remarkably and increase the sustainability of water supply through shallow depth ground water structures.

VII. EFFORTS OF CENTRAL GROUND WATER BOARD ON ARTIFICIAL RECHARGE AND RAIN WATER HARVESTING

A. Pilot / Demonstrative Schemes

Experiments on artificial recharge to aquifers started in India from 1970 onwards by Central & State Governments and individually by NGOs in various parts of the country where early signs of overexploitation of ground water were noticed. The Central Ground Water Board undertook artificial recharge experiments through injection well around Kamliwara in Central Mehsana where sufficient water was available from Saraswati river during monsoon period. A detailed injection experiment was carried out at the Kamliwara site by injecting water from the source well in Saraswati riverbed to the injection well by 5cm dia. siphon of galvanized pipe, at a rate of 225 m^3/day for 250 days. There was a buildup of 5 meters in the injection well and 0.6 to 1.0 m in wells in areas 150 m away. These experiments indicated the feasibility of ground water recharge through injection well in the area.

Similarly spreading test through channel and recharge pit were carried in coastal areas of Saurashtra, Gujarat. The Board undertook another artificial recharge study in the Ghaggar river basin with the assistance of UNDP during the period 1976-78 at Kandi area and Narwana Branch area, Dabkheri and indicated area as suitable for recharge through ponds and spreading basin in Kandi area and through injection wells at Narwana.

Several experimental recharge and rainwater harvesting pilot projects were carried out at Saurashtra, Ahmedabad city and Kutch in Gujarat, farm rain water management at Raipur, Percolation tanks/check dams in Andhra Pradesh, Percolation channels and Bandharas in Maharashtra, subsurface dykes in Kerala, roof top rain water harvesting and recharge in urban and hilly areas by the Board, State Governments and Non Government Organisations. Details of artificial recharge structure constructed during different five year plan under Central Sector Schemes are given in table. 2a.

Table.2a AR studies taken by CGWB during different five year plans

Plan	States	Cost (Rs in Cr)
VIII (1992-1997)	Maharashtra, Karnataka, Andhra Pradesh, Delhi, Kerala, Madhya Pradesh, Tamil Nadu, West Bengal, & Chandigarh (Total States-9)	3.23
IX (1997-2002)	Andhra Pradesh, Arunachal Pradesh, Assam, Bihar, Chandigarh, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Jharkhand, Karnataka , Kerala, Lakshdweep, Madhya Pradesh , Maharashtra, Meghalaya, Mizoram, Nagaland, NCT Delhi, Orissa, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, And West Bengal (Total States-25)	33.31
X (2002-2007)	Andhra Pradesh, Karnataka, Madhya Pradesh, & Tamil Nadu (Total States-4)	5.60
XI (2007-20012)	Arunachal Pradesh, Punjab, Tamil Nadu, Kerala, Karnataka ,West Bengal , Andhra Pradesh, Uttar Pradesh & Madhya Pradesh, Chandigarh, Gujarat, Maharashtra, Jharkhand, Delhi, Himachal Pradesh, Jammu and Kashmir, Orrisa, Rajasthan and Bihar. (Total States-19)	63.96

Artificial recharge schemes undertaken during the various plans are depicted in the figure 2 and details of the schemes are presented in Annexure I. In general artificial recharge strcutures like percolation tanks, recharge shafts, recharge wells, watershed

Location of Artificial Recharge schemes undertaken by CGWB during various five year plan

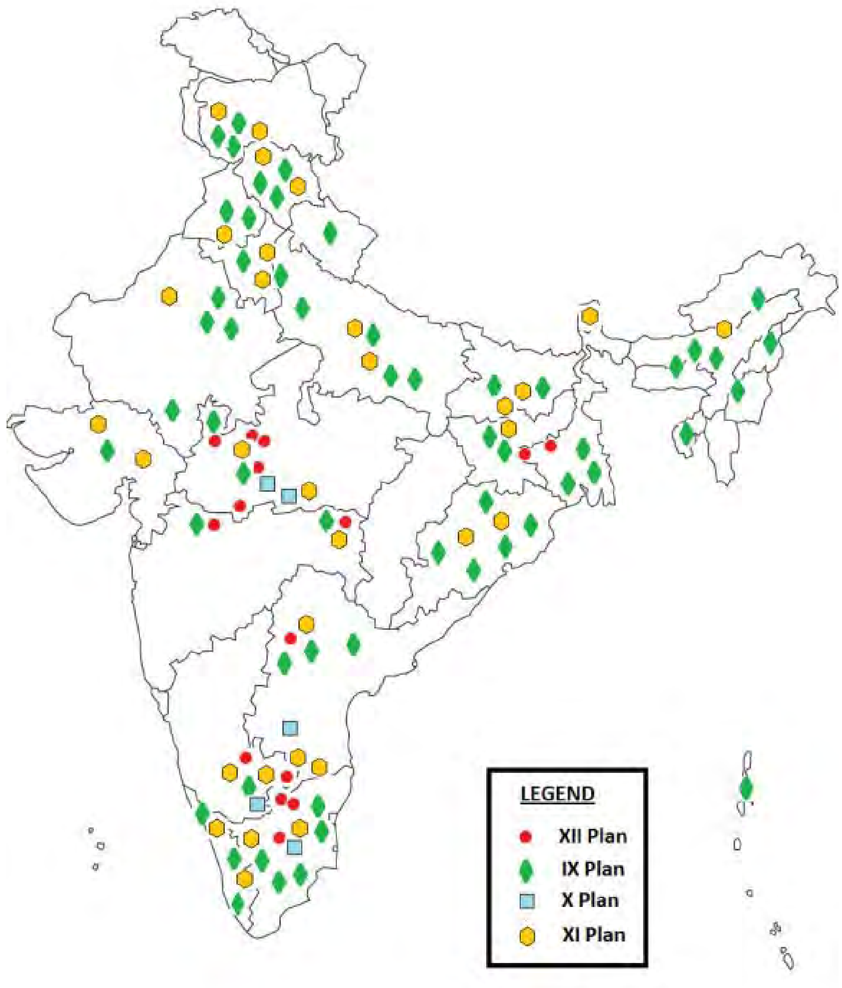


Figure 2. . Location of Artificial Recharge schemes undertaken by CGWB during various five year plan

treatment, checks dams, subsurface dykes, vented dam, cross bund, create work gully plugging, Siphon pit, loose boulder check dam, Roof top rain water harvesting and Micro water shed management were undertaken in various plan.

VIII & IX PLAN : As demonstrative schemes, CGWB undertook Central Sector Scheme on "Study of Recharge to Groundwater" under VIII & IX Plan which were implemented through State Government with the objective of dissemination of technical know how to the State Government and other agencies for successful replication of the methodology elsewhere in the country under similar hydrogeological set up. During VIII Plan, 24 projects were taken up mainly in the state of Maharashtra, Karnataka, Delhi, Chandigarh, Madhya Pradesh, Kerala, Tamil Nadu etc. and 62 artificial recharge structures viz percolation tank, check dam, sub-surface dyke, recharge shaft, recharge wells, roof top rain water harvesting systems etc. were constructed and their impact on groundwater regime was evaluated. Further, under the IX Plan, 165 projects involving construction of more than 670 artificial recharge structures viz Percolation tanks, Check dams, Recharge Shafts/Trench/Pit, Sub-Surface Dykes, Roof Top Rain Water Harvesting Systems etc have been taken up in 27 States and UTs. The efficacies of constructed recharge structures have been evaluated.

X PLAN : In Tenth Five year plan, special emphasis is given to implementation of rain water harvesting at schools for utilization of rain runoff and creation of mass awareness amongst school children. In Fresh Water Year – 2003, the Ministry of Water Resources had approved and sanctioned 19 projects on construction of roof top rainwater harvesting structures at Government buildings in the states of AP, Assam, Bihar, Karnataka, Kerala, Madhya Pradesh, Orissa, Punjab, Sikkim, Tamil Nadu and Uttar Pradesh and UT of Chandigarh. These projects were constructed under technical guidance of Central Ground Water Board with funds under Grant-in-Aid provided to the concerned state Governments for total amount of Rs.208.55 lakhs.

Similarly, demonstrative projects of Roof top rainwater harvesting were also implemented through NGO's in 100 schools in rural area of 13 states viz Andhra Pradeh, Delhi, Gujarat, Himachal Pradesh, Kerala, Madhya Pradesh, Maharashtra, Orrisa, Rajasthan, Sikkim, Tamil Nadu, Uttaranchal and West Bangal.

In 2005-2007, project on rainwater harvesting from Roof tops of remote government rural schools for collection of rainwater for drinking and use in two toilets for girls in 413 schools in rural areas in 15 states were sanctioned by the Ministry of Water resources. The Central Ground Water Board facilitated the work by providing technical guidance in designing, monitoring and implementation through its expert scientists.

During X plan demonstrative scheme on "Rain Water Harvesting and Artificial Recharge to Ground Water" has been taken at 8 identified areas in Andhra Pradesh, Tamil Nadu, Karnataka and Madhya Pradesh.The approved cost of projects is Rs. 5.95 crores for implementation by the departments of states under overall technical guidance of CGWB during 2006-08 with 100% funding by the Central Government. The norms adopted in the implementation of MaNational Rural Employment Guarantee Scheme (NREGS) by the Ministry of Rural Development are being followed in implementation of civil works of the present scheme. Under this scheme, priority is given to hard rock areas having over-exploited ground water resources. The first installment of 70% of the approved cost of the project is released after approval of the project to the implementing agencies. The next installment of 30% of the approved cost is released on recommendation of State Level Technical Coordination Committee on physical progress and after utilization of 70% of initial funds released to the implementing agency. On completion of civil works of recharge facility, impact assessment studies will be taken up to demonstrate the efficacy of artificial recharge and rain water harvesting in above mentioned sites selected on scientific basis in different hydrogeological situations. Successful examples would be replicated by the states in similar set ups in future.

XI Plan : The scheme will be implemented in identified fesible areas of various States, particularly in Over-exploited and Dark blocks, drought prone and water scarcity areas, coastal areas & islands affected by saline water ingress, areas of inland salinity, urban areas showing steep decline in ground water levels and in sub-mountainous / hilly areas of the country. The fund earmarked for demonstrative recahrge projects is RS. 100 Crores in XI plan. Total of 64 artificial recharge schemes under central sector schemes, amount to be Rs.63.96 Crores have been sanctioned and details are given in table 2b.

2b. State wise funds approved and released during XI Plan (in lakhs)

Sl. No	State	Cost approved	Fund released	Cost approved	Fund released	Cost approved	Fund released	Cost approved	Fund released	Cost approved	Fund released
		2008-09		2009-10		2010-11		2011-12		G.Total	
1	Tamil Nadu	111.00	33.30	415.35	368.45	0	0.00	0.00	30	526.35	431.75
2	Andhra Pradesh	0.00	0.00	130.02	91.01	75.18	52.64	348.84	283.194	554.04	426.85
3	Kerala	39.05	11.72	0.00	0.00	0	10.82	13.48	9.435	52.53	31.97
4	West Bengal	111.09	33.33	0.00	0.00	0	44.44	0.00	0	111.09	77.76
5	Arunachal Pradesh	259.67	77.90	0.00	0.00	0	103.87	0.00	0	259.67	181.77
6	Punjab	179.45	53.84	0.00	0.00	0	0.00	80.88	56.62	260.33	110.46
7	Chandigarh (UT)	0.00	0.00	0.00	0.00	776.03	543.22	0.00	0	776.03	543.22
8	Karnataka	0.00	0.00	109.16	76.41	96.585	67.61	194.16	135.91	399.90	279.93
9	Uttar Pradesh	0.00	0.00	720.06	504.44	1060.64	728.50	0.00	0	1780.70	1232.94
10	Madhya Pradesh	0.00	0.00	0.00	0.00	431.86	302.30	0.00	0	431.86	302.30
11	Himachal Pradesh	0.00	0.00	0.00	0.00	0	0.00	179.53	125.655	179.53	125.66
12	Rajasthan	0.00	0.00	0.00	0.00	0	0.00	34.30	24.012	34.30	24.01
13	Jammu Kashmir	0.00	0.00	0.00	0.00	0	0.00	78.11	54.677	78.11	54.68
14	Orrissa	0.00	0.00	0.00	0.00	0	0.00	464.36	325.04	464.36	325.04
15	Bihar	0.00	0.00	0.00	0.00	0	0.00	96.01	67.21	96.01	67.21
16	Gujarat	0.00	0.00	0.00	0.00	316.24	221.368	0	0	316.24	221.37
17	Maharashtra	0.00	0.00	0.00	0.00	15.15	10.605	0	0	15.15	10.61
18	Delhi	0.00	0.00	0.00	0.00	0	0.00	43.44	30.41	43.44	30.41
19	Jharkhand	0.00	0.00	0.00	0.00	16.49	11.543	0	0	16.49	11.54
	Total	700.26	210.08	1374.59	1040.31	2788.175	2096.91	1533.11	1142.163	6396.14	4489.46

B. Dug well Recharge in Hard Rock Areas of the Country

Scheme "Artificial recharge to ground water through dugwells" is being implemented in seven states namely Tamil Nadu, Gujarat, Madhya Pradesh, Maharshtra, Andhra Pradesh, Karnataka & Rajsthan for construction of recharge facility on irrigation dugwells owned by the farmers. The main aim of the dug well recharge scheme is to increase the recharge to the ground water reservoir by utilizing the runoff generated in the agriculture fields, which otherwise goes as waste. The scheme has large potential not only because of its capacity to recharge shallow aquifers but also it is economically affordable for local people.

The CGWB and State Ground Water Departments are providing technical guidance for optimum benefit and creating awareness amongst beneficiaries. 4454669 number of irrigation dugwells located in 1155 blocks of seven participating states are envisaged to be covered for construction of recharge facilities with the objective of recharging aquifers through runoff available in agricultural fields during rains. The total cost of the project is Rs.1798.71 Crores. Average cost of dug well recharge is Rs.4000/- which varies from Rs.3600 as in Maharashtra to Rs.5700 as in Andhra Pradesh. Under the scheme, owners of the irrigation dug wells belonging to small and marginal farmers are being provided 100 % subsidy, while other category farmers are provided 50% of the cost as subsidy.

Details of the subsidy released and structures constructed is given in table 3 below:

Table. 3 AR to Groundwater through Dugwell recharge scheme

s.no	States	Amount of Net Subsidy released (Rs in Cr)	No. Units for which net subsidy released	No. of dug well recharge Structures completed
1	Andhra Pradesh	Yet to be started		
2	Gujarat	48.414	141381	7629
3	Karnataka	26.078	68864	11007
4	Madhya Pradesh	40.147	93847	13855
5	Maharashtra	14.042	44632	38023
6	Rajasthan	29.806	88765	4396
	Tamil Nadu	103.831	275553	21055
Total		262.319	713042	95965

VIII. COMMON RECHARGE TECHNIQUES IMPLEMENTED BY CGWB

Flooding

A pilot project was implemented at Chetua to Jamuna, Pandua block, Hoogly district in West Bengal by the Central Ground Water Board in IX plan.

Recharge Basin or Percolation Tanks

Percolatation tanks have been constructed by CGWB at Watershed TE-11 Jalgaon district, Maharashtra, at Chirakulam in Kottayam district, Kerala, Sikheri village and Tumar watershed in Mandsaur & Dewas districts Madhya Pradesh, Narasipuram in Alandurai watershed, Thondamuthur and Vedapatti village in Virdhunagar district of Tamil Nadu and in Mahboobnagar district, Andhra Pradesh in central sector scheme. Recharging of aquifers through percolation tanks in above projects has shown encouraging results during impact assessment studies.

Gully Plug / Check Dam / Nala Bund / Gabbion Structures

The Board has implemented artificial recharge projects by constructing such structures through state government agencies at Ayandikadayu, Chirayanki district, Kerala; Kadam nala, Pusaro nala, Brahmani nala and Tepra nala in Dumka district, Jharkhand; Gwalpahari, district Gurgaon, Haryana; Thano reserved forest area, Doiwala block, Uttarakhand; Chalokhar in Hamirpur district , Bhatti nala, Suhal nala and Naker khad in Kangra district of Himachal Pradesh; Dewal in Kathua district, J&K; Parol naggal & Chotti bari naggal of district Ropar in Punjab; Bangalore university campus in Karnataka. Substantial impact on augmentation of ground water has been noticed in areas around these structures.

Recharge Wells/Dug Well Recharge /Borehole Flooding

A project of roof top rain water harvesting through dug well recharge at Kavikulguru Institute of Technology and Science (KITS), Ramtek, Nagpur district, Maharshtra has been implemented. An area of 20 hectare had been benefited by storing 8000 cubic meters of water annually in addition to existing resources through this pilot scheme.

Recharge Pits/ Trench and Shafts

The recharge structures like lateral shafts with injection wells have been constructed on experimental basis at Deoli Ahir, in link channel of Hasanpur distributary in Mahendergarh district, Panipat district and near Markanda river in Shahbad block of Kurukshatra district in Haryana State as pilot recharge projects. Similarly Recharge pits with recharge shafts have been constructed at Lodi garden, New Delhi, at Choe no. 1 Bhakhara main line canal village Dhanetha , Samana block, Patiala and on Dhuri drain in Sangrur district, at low dam in village Majra, Tehsil Kharar in Ropar district in Punjab State. Recharge trenches with bore wells have been constructed in Midjil mandal in Mehboobnagar district in Andhra Pradesh and in Taliparamba taluk, Kannur in Kerala. Impact analysis of such projects indicated favorable recharging results.

Subsurface Dykes/ Underground Bandharas

Subsurface dyke is a subsurface barrier across a stream which retards the natural subsurface / ground water flow of the system and stores water below ground surface to meet the demand during the period of need. Central Ground Water Board has constructed subsurface dykes in Ayilam in Trivandrum district, Kerala, Kasrawad, district Kahrgone, Madhya Pradesh, Saltora block, Bankura district, West Bengal, Nallanpillai Petral village, Villupuram, Tamil Nadu, at Walmi Farm, Madhya Pradesh and Karnataka state.

Roof Top Rainwater Harvesting and Aquifer Recharge

In urban areas where open land is not commonly available, roof top rain water can be conserved and used for recharge of ground water. Urban housing complexes, historical forts and institutional buildings generally have large roof area and can be utilised for harvesting roof top rainwater to recharge the depleted aquifers. More than 50 roof top rain water harvesting and recharge projects have been implemented by the Central Ground Water Board at Assam, Delhi, Chandigarh, several building in Punjab, Jaipur and Udiapur in Rajasthan, Kangra in Himachal Pradesh, Ahmedabad in Gujarat, Kannur in Kerala, Patna in Bihar, Lucknow in Uttar Pradesh, Dewas and Musakhedi in Madhya Pradesh and Gurgaon and Faridabad in Haryana State.

IX. SUCCESS STORIES OF ARTIFICIAL RECHARGRE IN STATES

A. ANDHRA PRADESH

Andhra Pradesh (AP) state covers an area of 2,75,069 km^2. Physiographically, it has three major features Coastal plains, Eastern ghats and western pedeplain. The state experiences a variable rainfall pattern with minimum rainfall of 561 mm to maximum of 1113 mm. Nearly 84% of the State is underlain by hard crystalline and consolidated formations like Archaean, Cuddapah, Dharwars, Kurnool, Deccan Traps etc. The rest of the State is underlain by semi-consolidated formation like Gondwanas and Tertiaries and unconsolidated deposits like Recent alluvium. The yield of wells ranges between 2-5 m3/hr in Dharwars comprising schist, phyllites, amphibolites and epidiorites. In granite gneiss, khondalites and charnokites, the yield ranges between 10-35 m^3/hr. In Cuddapahs, the yield ranges between 7-50 m^3/hr. In shales and Deccan traps, the yield ranges between 0.5-1.5 m^3/hr and 10-40 m^3/hr, respectively. The yield of wells in soft rocks like Gondwana sand stone varies from 12-220 m^3/hr. The alluvial formations are confined mainly in the delta region where the tubewells yield from 15-60 m^3/hr.

The annual replenishable groundwater resource of the state is 36.50 bcm with a net annual groundwater availability of 32.95 bcm. Ground water draft (as on 31st march 2004) is 14.9 bcm with a stage of ground water development of 45%. Out of the 1231 assessment units in the state, 219 have been categorised as over exploited and 77 have been categorised as critical from ground water development point of view.

Artificial recharge Techniques suitable for the state

Major portion of the state is covered by Achaeans and pre-Cambrians (Cuddapah). The structures suitable for this terrain are the Check dams, Gully plugs, nalla bunds, recharge pits and percolation tanks/ponds.

Recharge pits/ shafts and trench with injection wells are ideally suited for Semi-consolidated and unconsolidated formations. In Rajahmundry region multilayered aquifer system exists recharge shaft with injection wells and percolation ponds with injection wells are suitable. For the urban areas the Roof top Rainwater harvesting with artificial recharge structures like recharge shafts and recharge pits with/without tubewells are suitable.

Details of some recharge structures constructed in state and benefits observed from these structures are described below:

1 Groundwater Recharge in Pulakuntlapalle Micro Hydrological Unit

Pulakuntlapalle micro hydrological unit is located in primary catchment area of Dhiguvetigadda Hydrological Unit in Ramasamudram Mandal, Chittoor dist (Figure.3). The study area (322 Ha) lies between 130 27’ 32” N to 130 26’ 12” N latitude and 780 23’ 18” E to 780 24’ 10” E longitude. Recharge techniques executed are described below:

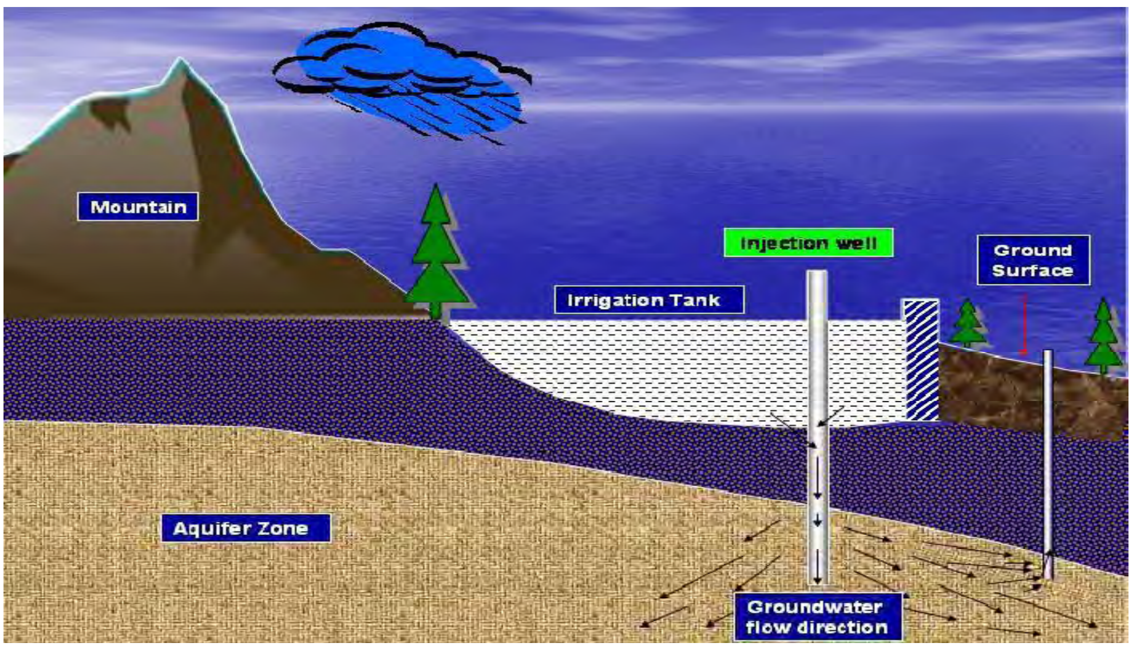


Figure.3 Artificial Recharge technique adopted in Pulakuntlaplle.

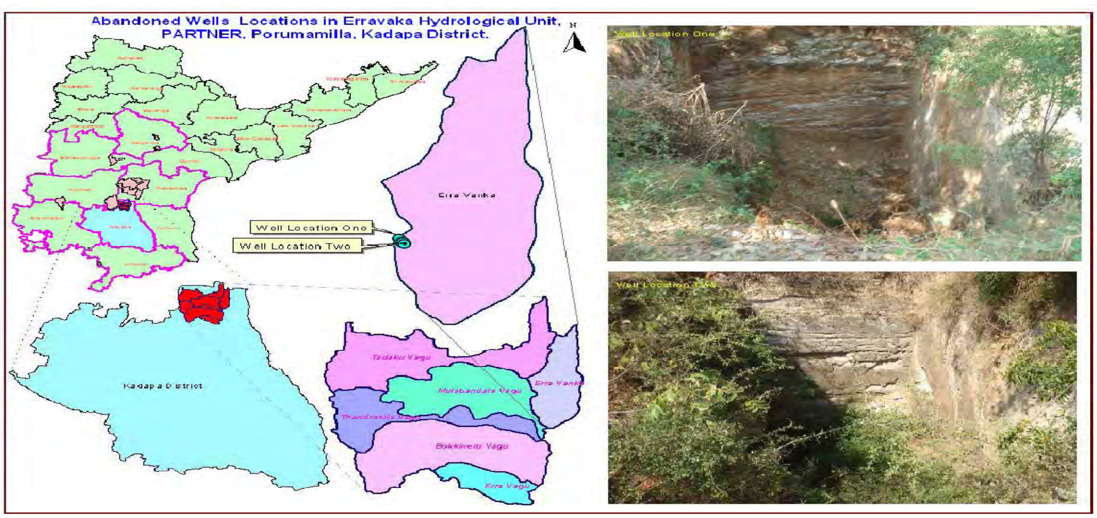
De-siltation of the tanks done to the fullest extent of depth where the fracture system/ weathered granite system is traversing. Desilted material was used for both tank bund strengthening and application in catchment area fields. The water stored in the pit after rain infiltrates into the aquifer zone as recharge. The stored water spreads into the aquifer zone to all directions and recharging the groundwater. Three injection wells at Utlavani Cheruvu, Bayya Reddy Cheruvu and Kothakunta drilled to a depth of 400 feet at pre-defined location based on the Geophysical Investigations. Recharge shaft constructed to ensure the higher rate of good quality recharge to the deeper aquifers.One check dam was constructed to conserve the soil moisture and to maintain the ecological balance to some extent in the vicinity.

Impact of artificial recharge on local ground water system

Before artificial recharge, the groundwater flow direction was from North to SE part of the area. But after construction, of recharge structures the flow direction spreads to all surrounding areas.

- The average water level rise was 3 m higher in the area of recharge as compared with the average water level rise in non recharging areas.
- In recharge area, additional groundwater amount is 2,36,241 cubic meters.
- By using this additional recharge amount the local farmers are being benefited.
- Now additionally 79 acres area can be irrigated by additional groundwater available through recharge.
- Some bore wells that were dry up to September 2005, started functioning for the irrigation uses. In Pulakuntlapalle, there were 35 functioning wells as well as 7 defunct wells. After the influence of AGR structure, all the defunct wells are functioning.
- Some parameters like fluoride were also diluted due to recharge.
- There is no ground water quality deterioration after construction of recharge structures influence. The fluoride content was more than the preferable limits before AGR impact (1.8 mg/l), later it reduced to 1.0 mg/l. The total hardness also diluted after the AGR impact.
- As the silt was removed to its fullest extent (i.e. ranging from 4 ft to 8ft bgl), it has accelerated the rate of ground water recharge The silt was collected and tested in the laboratory for fertility. The richness of the soil fertility was explained to the community in the capacity building training. The mode and method of execution of each structure and its role in AGR was also discussed with the community in detailed.

2. Pilot project on Recharging of Abandoned dug wells in Chennareddy Palle Village, Pendlimarri Mandal, Kadapa District of Andhra Pradesh with community participation



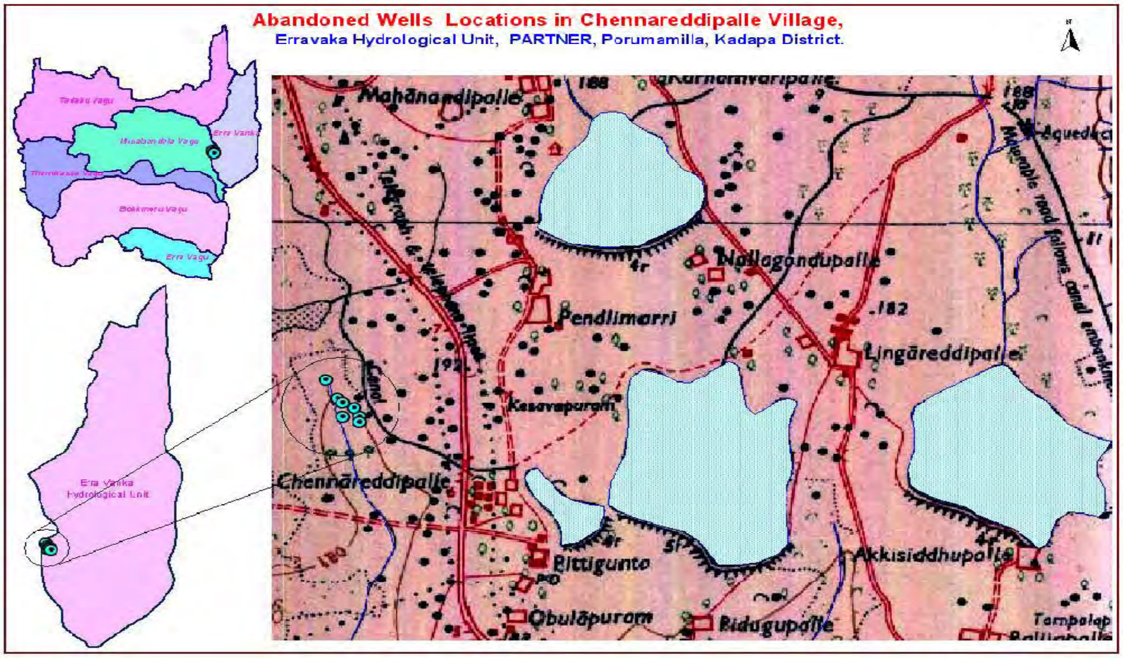


Figure.4 location of the Abandoned dugwells in Chennareddy palle village, AP

Andhra Pradesh Farmers (AMGS) has been involved with DSMG in Yerravanka Hydrological Unit since 2004. Crop water balance estimation indicated deficit in water balance in the Hydrological Unit. For improving the groundwater situation through reduced pumping with demand side interventions, improving crop water efficiency and crop diversification, supply side interventions such as recharging through abandoned wells was taken up. Wherever suitable sites were available, artificial groundwater recharge of open wells was taken up by the communities with technical guidance from the project (figure.4).

Average rainfall of the area was 750mm and 75 - 80% of the rainfall received through influence of South West monsoons spread over from July to October with average 35 rainy days per year. Highest rainfall of 1572.5mm was recorded during the year of 1996-97. Six out of 14 years reported, less than average rain fall and the least rain fall reported is 285.6 mm during the monsoon year 1999 – 2000.

Depletion water levels were observed in Pendlimarri, Lingareddi Palli and Chennareddi Palli habitations. Many bore wells went dry during summer 2006 and presence of silt in the surface water bodies also hampered recharging process. Towards meeting the objectives, Ground water Management Committees (GMC) had been established in all the habitations comprising of men and women members. GMC's played major watch dog role, preventing over exploitation of ground water resources in the area.

The main objectives of the pilot were to:

- Favorably alter the natural conditions to enhance the groundwater recharge at a micro basin level.
- To improve the groundwater levels in micro basin.

- Initiate artificial injection of runoff generated from peak storms at favorable locations.
- Facilitate the technology, skills and knowledge for better understanding the ground water system in the area to the community enabling longer sustainability.

Component of People's Participation in recharging of abandoned open wells

The area proposed for Artificial Groundwater Recharge belonged to the people of Chennareddypalli villages and Part of Yerravaka habitations. The bore wells, the principal source of water were unable to cope up the demand of the community. Lots of money was being invested to get the required water in the form of drilling new bore wells but the result was multifold loss. At this juncture, APFAMGS project personnel associated with people and slowly incorporated the idea of comprehensive groundwater management through people's participation. As the projects concept was in line with the need of the farmers, the response and involvement of the community was encouraging. During this process, the farmers were made to analyze the situation and were able to develop the action plan of their own to improve the groundwater situation in their micro HU. The various stages of people's participation in activity were:

- Demand from the people for recharge measures during informal as well as in GMC meetings.
- Expressed their willingness to extend participation in the activities. Requested the project to extend the support and explore the avenues for groundwater recharge.
- Involved in evolving the situation of groundwater resources.
- During feasibility studies, all the GMC members actively shared their opinions and extended their cooperation.
- After getting the technical feasibility, Combined GMC'S meeting were organized and discussed their role in RECHARGE OF ABANNDONED OPEN WELLS execution.
- Permission from the Panchayati Raj Institution (GP) was obtained by GMC.

B. CHHATTISGARH

Chhattisgarh state covers an area of 1,35,000 Km^2 with a population of nearly 2 crore. Average annual rainfall in the state is nearly 1200 mm. Over 80% of the populace in the state are dependent on agriculture and allied activities. Geologically, the state is a part of Central Indian Shield consisting of lithounits ranging in age from Archaean to Recent. Nearly 60% of the state is covered by crystalline and metamorphic rocks. Precambrian Chhattisgarh Supergroup of rocks occupies nearly 27% area of the state. Semi-consolidated rocks and others occupy only 13% area of the state. By and large, these lithounits have limited ground water potential.

Groundwater potential zone is restricted to weathered mantle, caverns, fracture and formation contacts. Rocks belonging to Gondwana super group are the next major litho units of the area. The sandstones have primary and occasional secondary porosity. They form thick and extensive unconfined to confined aquifers down to 300 mbgl. Groundwater some times occurs under free flow conditions in localized belts. At places high groundwater temperature even up to 50^0 centigrade have been recorded. The unconsolidated formation of Quaternary age comprising alluvium, clay, silt, laterite etc. form thin and extensive unconfined aquifers in several isolated patches and near major river courses with thickness up to 30 mbgl.

Depth to water level is governed by geological formations and topography. The premonsoon water level of Raipur,Dhamtari and Mahasamund varies from 1.35mbgl to 15.10mbgl while the postmonsoon water level varies from 0.61mbgl to 8.26mbgl.The premonsoon and postmonsoon water levels of Bilaspur, Janjgir-champa and Korba districts range between 1.19mbgl and 17.33 & 0.7mbgl and 13.27mbgl respectively. Similarly the premonsoon and postmonsoon water levels of Rajnandgaon, Durg and Kawardha districts range between 1.67mbgl and 23.05mbgl & 0.81 mbgl and 14.43 mbgl respectively.

On an average groundwater meets 90% and 13.4% of total drinking and irrigation water requirements respectively. Ground water draft (as on 31st march 2004) is 2.8 bcm with a stage of ground water development of 20.5%. Out of the 146 blocks in the state, 138 have been categorised as safe and the remaining 8 have been categorised as semi-critical from ground water development point of view. There are no critical or over exploited blocks in the state.

Artificial recharge Techniques suitable for the state

In Chhattisgarh all programmes of groundwater recharge and conservation should be taken up in the form of small watershed management. The main objective of such watershed management programme should be to control the surplus surface runoff during the monsoon which indirectly gives benefits such as control/ reduction in soil erosion and flood control in addition to augmenting the groundwater storage. A watershed can broadly be classified in three zones i.e. (i) high sloping area, ii) moderately sloping area iii) relatively gently sloping area/ terrain. Given a similar climate, hydrology, soil and hydrogeological features for a watershed, following structures are recommended to augment recharge from surplus runoff to saturate vadose zone.

a) High sloping area:
Contour trenching on hilly slopes, bench terracing, stone terracing at steep slopes, diversion channels across slopes, afforestation.

b) Moderately sloping area:
Contour or graded bunding, gully protection, nala bunding and check dams, etc. Construction of percolation tanks and or groundwater dams (sub- surfaces dykes), basin spreading, contour cultivation, gravity flow in existing dug wells.

c) Gently sloping to flat terrain:
Groundwater dams, water-spreading techniques, gravity flow in existing dug wells. Surplus water storage bodies, which are constructed for storing the monsoon runoff and thereby recharging the groundwater, should be designed properly taking all precautions so that during heavy storms they should not be washed away. The evaporation losses from these bodies will be very high if water is allowed to be stored beyond the month of February.

Details of some recharge structures constructed in state and benefits observed from these structures are described below:

1. Rainwater Harvesting and Artificial Recharge Gujra Sub-Watershed (Block: Patan, District: Durg)

Location: Gujra Sub-Watershed, Block, Patan. The watershed lies in Patan block of Durg district within north latitudes 21°04'30" and 21°14'30" and east longitudes 81°23'00" and 81°34'00".

Implementing Agency: Public Health Engineering Department (PHED) and funded by the centrally sponsored accelerated rural water supply programme of Ministry of Rural Development, Govt. of India.

Year of Completion : 2003-05
Cost of the Project : Rs 2.67 crore
Average annual rainfall : 1200 mm.

Type of Structures

Types and numbers of structures constructed in Gujra sub-watershed		
Sl. No.	Type of structure	No. of Structures constructed
1	Masonry stop dam	23
2	Percolation Tank	12
3	Boulder Check dam	25
4	Silt trap/Nala bund	13
5	Desilting of pond	28
	Total	101

Salient aspects of the engineering structures constructed in Gujra sub-watershed	
Type of Structure	Salient features
Masonry dams: Stone masonry dams were constructed on 2nd and 3rd order streams.	Span 10 to 12m Height 1 to 1.5 m Foundation (cement concrete) depth 1 to 1.2
Boulder Check Dams: Constructed on 2nd order stream (figure.5).	Span 6 to 10m Height 1 to 1.2m
Silt trap: These are simple masonry Structures	Height 0.5 to 0.7 m
Percolation Tank (figure.6)	With masonry west weir and earthen side bunds
Desilting of Ponds	Existing village ponds were desilted

Figure.5 Check dam at Mehra kala

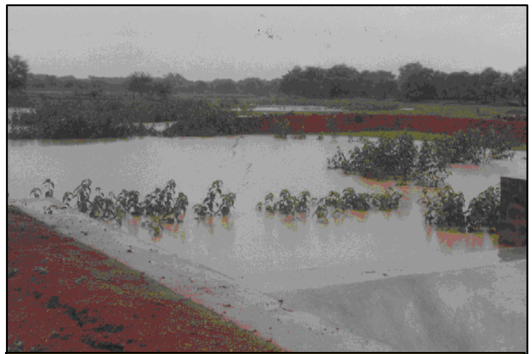


Figure. 6 Percolation tank at Tarri

IMPACT: Water Level Conditions (Before and After the Implementation of the Project)

A set of 8 observation wells was established in the watershed to monitor the effect of the project. During the first three years (2001-2004), pre-monsoon water levels were in the range of 17 to 31m in all the observation wells. In the next three years (2005-2008), pre-monsoon water levels in these wells remained within 5 to 13m. Similarly for the post monsoon period, water levels recorded in the initial two years were in the range of 14 to 23, which improved to 5 to 8m in the 3rd year. During the last 3 years, post monsoon water levels were recorded to be in the range of 2 to 6m. Variation of monthly water levels in a representative well (at Achanakpur) is shown in Figure.7

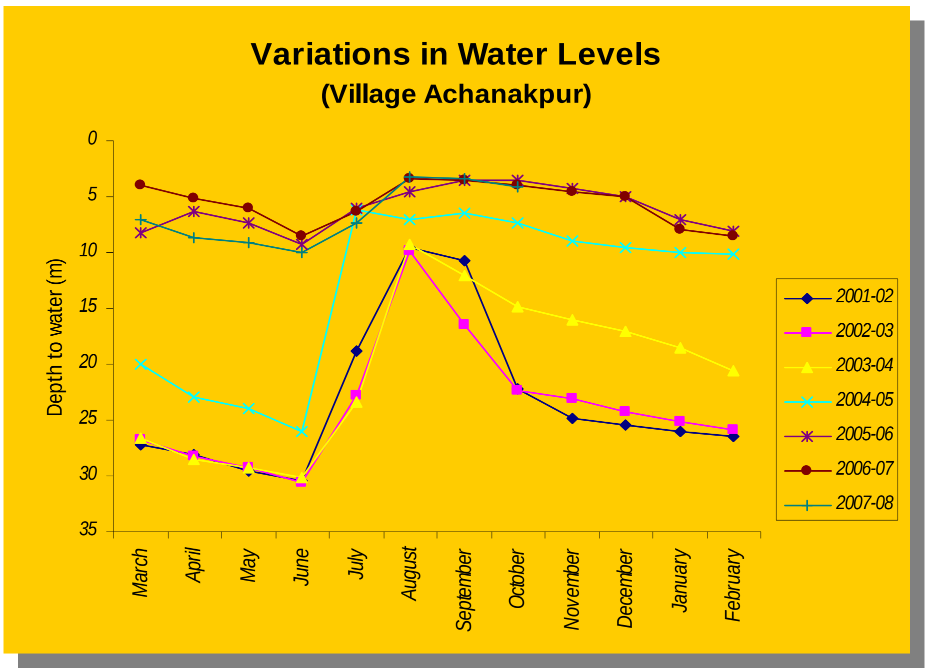


Fig.7. Monthly variations in water levels in different years in a representative observation well at Achanakpur in Guira sub-watershed

Irrigation, Agriculture and Other Aspects

The significant improvement in water level conditions, in turn, resulted in improvement of soil moisture conditions and agricultural production. The sustainability of the ground water abstraction structures was ensured because of this project. Due to rise in water levels, the dug wells in the area, which were rendered useless prior to the implementation of the project because of lowering water levels, got revived. People started constructing new dug wells as well. Inspite of groundwater abstraction has significantly increased in the area., water level have not further deteriorated.

2. RAINWATER HARVESTING UNDER JOINT FOREST MANAGEMENT PROGRAMME - (Implemented by Department of Forest)

Achievements of forest department under this programme are given here.

a. BELARBAHRA VILLAGE (Block: Nagri, District: Dhamtari)

Belarbahra village is adjacent to a protected forest in Dhamtari District. In addition to other development activities like facilitating honey culture etc. providing better irrigation facilities were also the priorities of the joint forest management committee. To start with they deepened a village tank named Dhau talab. Risai Jharan, a spring flowing from the hills used to fall directly to the paddy fields there by destroying the crop and the field. The villagers constructed a canal of 1 Km length and channeled the spring flow to Dhau talab. It solved two purposes, routing the stream through the canal saved the paddy fields from being degraded and the water thus transported to Dhau Talab was stored and used for irrigation. This resulted in 37% (to 150 ha) increase in total irrigated area (Kharif) and nearly 19% increase in total production.

b. ALEKHUNTA VILLAGE (Block: Nagri, District: Dhamtari)

In Alekhunta village of Dhamtari district, the Forest Management Committee has set an example in water resources Management. Alekhunta village, home to 64 families with a total population of 267 was almost entirely dependent on forest. Under JFM Programme, a stop dam of 10m width was constructed along Futhamuda stream. The stored water was then distributed to different parts of the village with construction of 2 canals, one of 4 Km length and the other of 3 Km length. There was 350 acres of arable land and there was no irrigation facility. This construction provided irrigation facilities to the entire 350 acres (during kharif only) of land and resulted in 80% increase in agricultural productivity in the village.

c. JHUNJHRAKASA VILLAGE (Block: Nagri, District: Dhamtari)

Jhunjhrakasa village is on Birgudi-Ghattasilli road in Dhamtari district. The village has a population of 503. Paddy cultivation in the village used to be completely dependent on monsoon rain. Under the Joint Forest Management Programme, the Forest Management Committee has constructed a stop dam across Jhura Nala as a result of which 200 acres of land could be brought under assured irrigation. In addition to this the Forest management Committee has also constructed 18 sluice gates thereby facilitating irrigation in additional 90 acres. The villagers in Jhunjhrakasa are now started taking the second crop in 80 acres of land.

3. WATER CONSERVATION MEASURES BY AFPRO (ACTION FOR FOOD PRODUCTION)

A. DISTRICT: BILASPUR

KHONDRA VILLAGE, Block: Masturi, District: Bilaspur

Pre-project scenario: There was severe soil erosion by streams in the agricultural lands in foothill areas, rendering marginal farmers landless. No source of irrigation except one water harvesting structure that provided critical irrigation to approximately 30 acres of kharif crop i.e. paddy

There were only two water harvesting structures (ponds) in the village that were utilised for washing, bathing, drinking water for cattle etc.

Type of Structures Constructed:

Gabion: One stream which is used to cause erosion to about 12 acres of land, one gabion has been constructed to reduce the runoff velocity of stream water, divert a part of it while letting the rest to spill over it.

One diversion canal was constructed to let the runoff diverted by the gabion to a pond that was constructed with the objective of storing the diverted water.

Cost of the Structure: Rs.15,000/-

Reclamation of 12 acres of land that was rendered unfit for cultivation thus providing livelihood option for the seven farmers who had virtually become landless because of erosion.

Creation of a water body (pond) that is used to provide critical irrigation for paddy in about 25 acres of land. In addition, it is also used for pisciculture by women Self Help Groups (SHGs).

Indirect benefit to about 50 acres of land in the form of protection from soil erosion the intensity of which has been reduced after the construction of the structure. About 15 families are benefited by it.

Gravity Irrigation Scheme: There was an existing water harvesting structure across one of the streams which was used for washing clothes, bathing and to meet drinking requirement of animals. A sluice gate installed at one side of it provided water for kharif crop in about 30 acres of land.

It was planned to increase the storage area of the structure and to install a gravity irrigation mechanism in it. Increase in the storage area would further reduce the intensity of soil erosion that the overflow from the structure was causing.

A trench was dug for laying the pipe about 4m below the ground level and the strata was rocky. Every family contributed its own share of digging and time limit was fixed for it. It was interesting to note that the mechanism for controlling the flow of water through the pipe is an innovative approach where an iron rod has been fixed with concrete and a mechanism for lifting / bringing down has been built up. It has reduced its cost and time required for construction.

The scheme provided irrigation to 100 acres of paddy. When sowing was delayed in rest parts of the area, Khondra people could do it on time due to the scheme. The structure is expected to initiate second cropping in the village. About 75 farmers would get the benefit of the structure.

B. DISTRICT: KANKER

VILLAGE GUMJIR AND PUSAGHATI , Block: Antagarh, District: Kanker

Types of Structure:

Rain water Harvesting

Gumjir and Pusaghati villages were not having even a single water body prior to the implementation of the project. Under the present project, total eight ponds have been constructed. These ponds are used by the community for washing clothes, bathing and for drinking purpose of the cattle. The common pond at Pusaghati is also used for fishery purpose.

Diversion channels

The area is subjected to heavy soil erosion due to the intense runoff and sandy nature of the soil. Another problem prevalent in the area is that the runoff coming from the hill fills the agricultural fields with sand thus affecting the crop yield drastically.

Stream cause soil erosion and sand filling in the agricultural fields. The interventions were planned in series – first a gabion was constructed at the foothill. This gabion reduced the velocity of runoff and divert a part of it to the uplands & provided the much needed water for irrigation to it. Then further down of it four loose boulder structures have been constructed at suitable places. Finally, the above mentioned diversion channel has been constructed to divert the runoff from the fields (Figure.8). The channel is connected with the main stream flowing through the village. Thus the sand and excess water is safely diverted to the main stream.

Fig. 8. Nala Diversion work at Gumjir, along with the beneficiaries

It was a very low cost watershed treatment and the results were wonderful in the monsoon that followed. Later three more diversion channels were constructed. These diversion channels have been very successful in diverting the excess runoff and also prevented the entry of sand into the agricultural fields.

DISTRICT: BASTAR

VILLAGE AMADONGRI, BLOCK: JAGDALPUR, DISTRICT: BASTAR

Types of Structures:

Bunding : In the village Amadongri a large portion of cultivable land was lying fallow due to poor water retention capacity of the land. The farmers used to grow paddy in the low lying land which were properly bunded and leave the other areas. During the planning phase it was decided to improve the condition of the uplands by constructing field bunds in them. This activity has been very successful in improving the land condition and thereby bringing additional land (approximately 300 acres) under cultivation. The field reports say that the yield of

Fig.9. Pond at the field of Manglu

paddy has increased approximately from 1.5-2 qtls per acre to 4-5 qtls per acre.

Pond construction: The village was having only one pond during begining of the project. This was the community pond that used to dry up in summer. It was deepened and now it holds water for the entire year fulfilling the domestic need of the community (figure.9 to 10).

Besides this, three more ponds have been constructed, two of which are on personal lands of beneficiaries. The purpose of these ponds is to provide water for their animals and benefit the lands at the downstream through percolation. The pond at the field of Manglu has been constructed only for Rs.10,000/- approximately and its size is 18m*18m*1.75m.


Fig.9a. Increased crop area

The ponds constructed for Madda and Manglu are personal but their access is open for all so far as the requirement of cattle or domestic needs of the human beings are concerned. The owner may practice fishery in their ponds and enjoy exclusive rights over it.

Contour Bunding: The idea of constructing contour bunds was new to the community of Amadongri. The community was taken for an exposure trip to Mariguda watershed area in Jagdalpur where they were exposed to the benefits of contour bunding. Secondly community was convinced that the height of the bunds would be kept less and provisions for disposing excess water would also be there that would prevent their crops from any possible damage due to water logging condition.


Fig 10: Contour bund

The land selected for contour bunding was upland that was undergoing severe soil erosion because there were no bunds in it at all. The community was taking maize, and some local cereals called as kodo, kutki in it. But after the construction of contour bunds, they are now able to take paddy in it and also some second crop like gram, mustard etc that can grow in the moisture present in the soil naturally. About 113 acres of land has been covered under contour bunding.

C. N C T, Delhi : National Capital Territory (NCT) Delhi covers an area of 1483 Sq.km. The Ground water availability in the territory is controlled by the hydrogeological situation characterized by occurrence of alluvial formation and hard rocks such as quartzite. The hydrogeological set up and the following distinct physiographic units further influence the ground water occurrence: (1) Older Alluvial Plain on the eastern and western side of the ridge. (2) Yamuna Flood Plain deposits. (3) Isolated and nearly closed Chattarpur alluvial basin. (4) NNE-SSW trending Quartzite Ridge. The yield of tube wells ranges between 18-144 m^3/hr in Yamuna Flood Plain aquifers. In Older Alluvium of eastern and western sides of the ridge, the yield of tube wells ranges between 12 to 36 m^3/ hr. Tube wells constructed in Chattarpur alluvial basin tapping the aquifers of both alluvium and weathered and fractured quartzite yield about 9 to 27 m^3/hr. Discharge of tube wells constructed in Quartzites varies from 6-15 m^3/hr.

The high rate of population growth and high level of urbanization in NCT, Delhi has resulted in over-development of ground water resources. Thus in about 75% area of NCT, Delhi ground water levels are declining at an alarming rate of 0.20 m per annum. The annual replenishable groundwater resource of the state is 0.30 bcm with a net annual groundwater availability of 0.28 bcm. Ground water draft (as on 31st march 2004) is 0.48 bcm with a stage of ground water development of 170%. Out of the 09 assessment units in the state, 07 have been categorised as over exploited and 02 have been categorised as safe from ground water development point of view.

In order to increase the natural ground water resource rain water harvesting and artificial recharge to ground water has become increasingly important in ground water management. Some of the case studies of rain water harvesting and artificial recharge are elaborated below:

Artificial recharge structures suitable for the state

Geologically, Delhi state is occupied by quartzites of pre-cambrian period and alluvium deposits classified as older and newer alluvium. The artificial recharge structures suitable for the quartzites are the check dams/nalla bunds and percolation pond/tanks. For the urban areas it is the Roof top Rainwater harvesting. Recharge shafts and recharge pits with tubewells.

The rain water harvesting and recharge pilots implemented in NCT district of Delhi by utilizing runoff generated from roof top, roads, paved area and bare ground are given below:

a. Artificial recharge to ground water in Presidents Estate .
b. Artificial recharge to ground water in Prime Ministers Office.
c. Artificial Recharge to ground water in Shram Shakti Bhawan.
d. Artificial Recharge to Ground water in Lodhi garden.
e. Artificial recharge to ground water in Safdarjung Hospital.
f. Artificial recharge project at Tughlak Lane and Surrounding areas
g. Artificial recharge project at Bunglow-5, Janpath Road, New Delhi
h. Artificial Recharge project in Sena Bhawan, New Delhi
i. Kushk Nala Artificial Recharge Project

In President Estate, runoff generated from 1.3 sq. Km of area is recharged through two abandoned dug wells, one recharge shaft and two trenches with borewells. This has resulted in rise in water levels ranging from 0.66 to 4.10 meters (Figure.11).

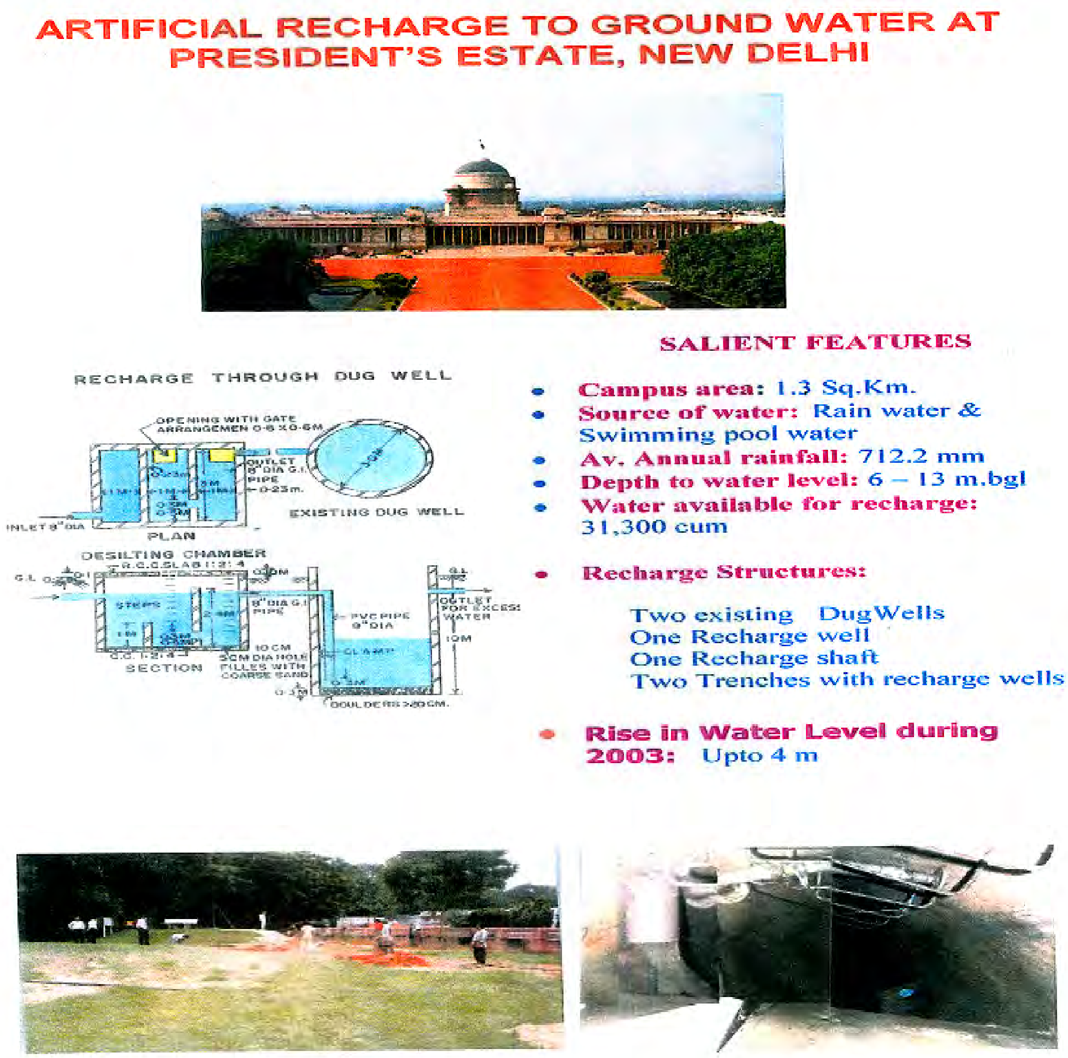


Figure.11. Artificial recharge design at President's Estate, New Delhi

The Kushak Nala pilot study was on a small nala originating from Birla Mandir and flowing west of Rashtrapati Bhawan. It has effective catchment area of 3.5 Sq.km. Under the artificial recharge scheme two gabion bunds and two nala bunds were constructed to recharge the 110000 Cubic meters of rain runoff generated in this watershed.

Rain water harvesting system at Shram Shakti Bhawan

From all the above projects it is estimated that about 225670 Cu.mts of runoff water is recharged to ground water from about 3.678 Sq.Km. of catchment area. The total cost of the these schemes were Rs: 60.12 lakhs (Figure.12).

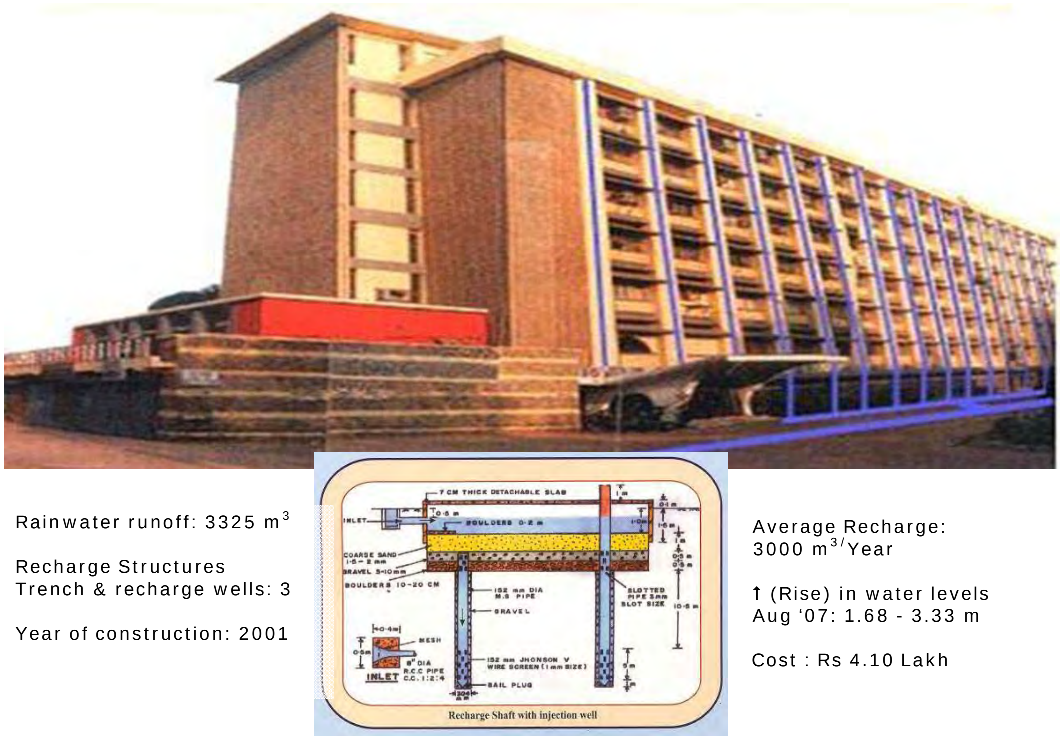


Figure.12. Rainwater harvesting system at Shram sakthi Bhawan, New Delhi

Artificial Recharge projects implemented in South, South West and West districts of NCT Delhi:

The details of different projects under various hydrogeological setting are given below:

HARD ROCK TERRAIN:

JNU – IIT - Sanjay Van Project: Under this project four check dams and one roof top rain water harvesting structure was constructed with the cost of 43.58 lakhs. Total reservoir capacity created in four check dams is 49048 Cu. mts.

The total capacity utilization of the created storage capacity is about 368% by repeated filling of the check dams. The total recharge to ground water is about 75.72 TCM which resulted in rise in water levels to the tune of about 13.70 m. Included in this project was the roof top rain water harvesting scheme taken up in Block-VI of IIT, Delhi campus. The rain water harvested was recharged to ground water through construction of injection wells and abandoned dugwell. It is seen that about 830 Cu. mt of rain water is recharge from the 1660 Sq. mt of roof area which resulted in rise in water level to the tune of about 2.29 to 2.87 m in one hectare of area.

Sultan Garhi Tomb Artificial Recharge Project: This project was implemented around Sultan Garhi Tomb (figure.13). Under this project, the three big quarries present in the tomb area were converted into recharge ponds by construction of proper bunds and diversion channel to divert runoff from Vasant Kunj-D block. Three recharge ponds were created. In order to increase the recharge rate, one recharge pit with tubewell and one recharge pit with borewell filled with gravel were constructed in these ponds. About 65000 Cu.mts of runoff is diverted to the recharge ponds from 0.99 Sq.km of catchment area. The total cost of the scheme was Rs. 6 lakhs.

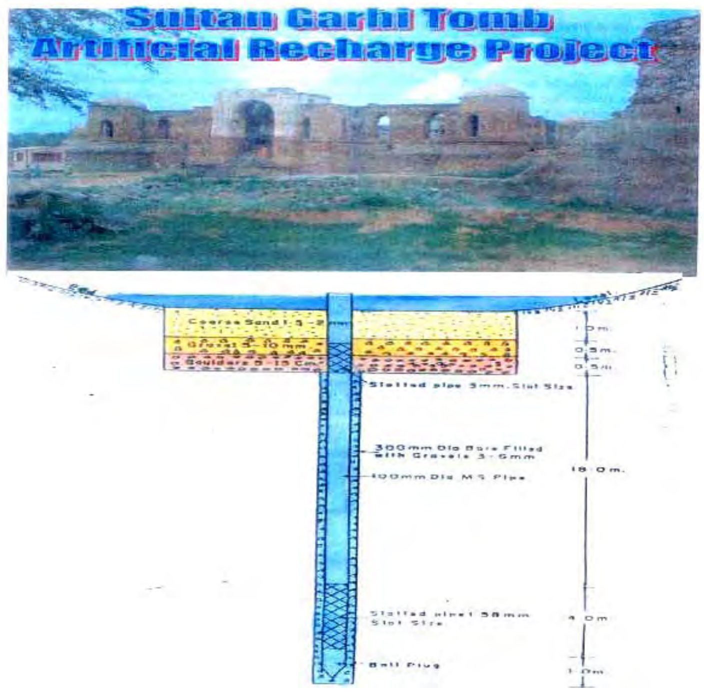


Figure.13. Artificial recharge design at Sultan Garhi Tomb

OLDER ALLUVIUM, WEATHERED AND FRACTURED HARD ROCK TERRAIN:

Four Artificial recharge projects were implemented in this hydrogeological environment. They are:

- Artificial Recharge to ground water in Vayusenabad-Residential area of Tughlkabad Air Force Station.
- Artificial Recharge to ground water in Meera Bai Politechnic, Maharani Bagh, New Delhi.
- Artificial Recharge to ground water in Central Park, D-Block Vasant Vihar, New Delhi.
- Artificial Recharge to ground water DTC Central Workshop-II, Okhla, New Delhi.

Under these projects also runoff generated from the urban environments like roof area, paved area, roads, parks and bare grounds present in these projects areas has been utilized for recharging the depleted aquifers. Recharge shafts with tubewells, recharge trenches with tubewells, lateral shafts with tubewells were constructed. It is estimated that about 42410 Cu.mts of runoff water is recharged to ground water from about 321325 Sq.mts of catchment area. The total cost of the above four schemes is Rs: 17.11 lakhs.

OLDER ALLUVIUM :

i) Two artificial recharge projects are implemented in these hydrogoelogical environments. They are located at:

- Artificial Recharge Project at Deen Dayal Upadhyaya Hospital, West district, Delhi.
- Artificial Recharge Project at Abhiyan Co-operative Group Housing Society Ltd., Plot No.15, Sector-12, Dwarka , South West district, Delhi.

In these two projects runoff generated from the complete campus i.e roof area, paved area, roads and other areas has been utilized for recharge purpose. It is estimated that about 8270 Cu.mts of runoff is being recharged from the 21970 Sq.mts of area. The total cost of these two schemes is Rs. 5.535 lakhs.
Details of few of the important projects located in different hydrogoelogical environments are as follows:

ii) Artificial Recharge to ground water in Indira Gandhi International Airport:

The area is underlain by alluvium of varying depths consists of clay, silt and silty sand mixed with kankar. Depth to water level is about 20 to 25 m bgl. In a catchment area of 5.59 Sq.km, the available runoff of 6144125 Cu.m. of water was utilized for recharging the ground water. 24 trenches with recharge tubewells are constructed at different locations in different drains which enabled no surface ponding of water. Artificial recharge design of the Indira Gandhi International Airport is represented in figure 14. A rise of water level upto 1 m was recorded after monsoon 2003.

Figure.14 Artificial recharge design of the Indira Gandhi International Airport

iii) Artificial Recharge to ground water at Link Road connecting NH-8 to Dwarka:

Delhi Development Authority has constructed 60 m wide road to connect Dwarka with N.H.-8. The runoff generated from the road is being collected in a drain constructed adjacent to the road. A series of shafts were constructed to recharge the runoff generated from the road. The shafts were constructed at a spacing of 250 to 300 m distance on both sides of the road.

iv) Artificial Recharge to ground water at Rajiv Gandhi Setu (AIIMS Crossing Flyover) New Delhi

Central Ground Water Board in NCT, Delhi, has provided technical designs for 33 flyovers. Intersection of Ring road and Aurobindo marg at AIIMS crossing is one of the most important flyovers in NCT, Delhi. Runoff from this green flyover is utilized for recharging to the aquifers. The total runoff available in this flyover is about 35000 cu.m., which is recharged to the aquifers through 10 recharge shafts constructed at different locations of the flyover (Figure.15). The shafts are associated with recharge tubewells of depth 25 m to recharge the ground water aquifers.

A number of artificial recharge to ground water schemes are being implemented by different agencies in NCT, Delhi. NDMC has implemented the scheme in different buildings and parks like Talkatora garden and Nehru Park etc. MES has implemented the scheme in Delhi cantt. area, Subroto park area and in its establishment in Gurgaon (Air Force Station Gurgaon, Mohammdpur Air Force Station etc).

i. Rain Water Harvesting and Artificial Recharge to Ground Water at 12 Akbar Road, New Delhi

The main objective of the study was solving waterlogging problems in the premises. Further, it would help in increasing the soil moisture and help in sustaining the green areas, arrest the declining ground water level and sustain the existing nearby ground water abstraction structures. The total area of the bungalow as per the plan is about 9521 sq km and about 6555 sq km of area was considered for estimating run-off from rooftop, paved and green area available for recharging (Figure.16 & 17). Two recharge pits are constructed. First structure is being constructed in front lawn of the premises having dimension 2mx2mx4m filled with 2.25 m of graded material along with two number of filter chambers. Second structure is having dimension 5m x 2m x 4m filled with 2.25 m of graded bedding along with four numbers of filter chambers.

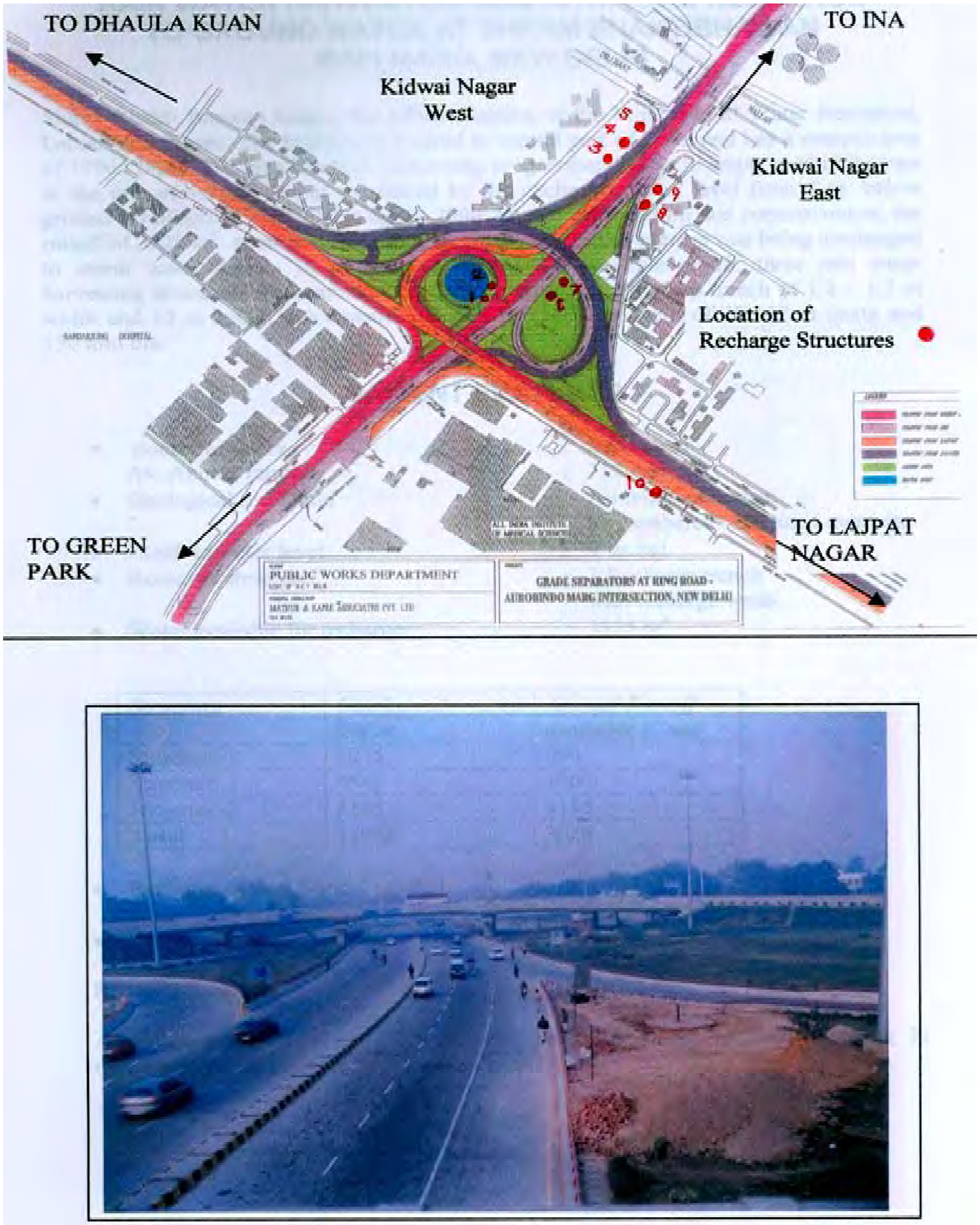


Figure.15 Artificial Recharge Structure at AIIMS Fly-over

Figure. 16 Rain Water Harvesting and Artificial Recharge to Ground Water at Gandhi Smriti Bhawan, Tees January Marg, New Delhi

The main purpose of this project was to solve the twin problems of declining water level and limited water logging in the area. The total catchment area providing runoff for rain water harvesting is 20400 sq. m. The total roof top area considered for surface runoff calculation is 4650 sq m, the total paved area considered for surface runoff calculation is 8700 sq m and the total green area considered for surface runoff calculation is 7050 sq m. The annual water harvesting capacity calculated as 6895 cum. The recharge structures constructed are trenches with recharge wells-5.

Figure.17. RWH & AR to Groundwater at Gandhi Smriti Bhawan

ii. Rain Water Harvesting and Artificial Recharge to Ground Water at Bungalow No. 78, Lodhi Estate, New Delhi

The main objective of this particular project is to propagate the concept of rainwater harvesting through a live demonstration project. The total area of the bungalow is 2810 sq m (Figure.18). The complex consists of main building, guesthouse, servant quarters, paved areas, roads and green lawns. Out of the total area of 2810 sq m, 2500 sq.m has been considered for effective rainwater harvesting through artificial recharge to ground water.

Figure.18 RWH & AR to Groundwater at bungalow 78 Lodhi Estate

iii. Implementation of Recharge techniques by Resident Assocations / schools Anand Lok Residents Association, August Kranti Marg, New Delhi.

The total 8 recharge pits with recharge bores have been constructed. Total Area is about 94,400 sq m and catchments area is about 59,798 sq m. Roof Top/Paved/Pucca Area is 46,298 sq. m (including road area). Open/Green Area is 13,500 sq m (9000+4500 for green area of individual plots). Annual Runoff is 20,600 cubic meters.

iv. Resident Welfare Association, J-Block, Saket, New Delhi

The recharge structures constructed are 3 recharge pits with 3 recharge bores (Figure.19). Total Area is about 80,000 sq m and total catchment area is about 50,000 sq m. Total roof top area is 25,000 sq m approx. Annual runoff is 12,200 sq m. One recharge structure was constructed in 2004 and two in 2007.

Figure.19. AR structure constructed at Resident Welfare Association, J-Block, Saket

v. Mira Model School, B-2 Block, Janakpuri, New Delhi.

The recharge structures constructed are 5 recharge pits with recharge shaft (Figure.20). The total catchment area is 16700 sq m. The total roof top area is 7493 sq m. The Annual runoff is 4466 cubic metre.

Figure.20. AR structure constructed at Mira model school, Janakpuri

vi. Som Vihar Apartment Owners Housing Maintenance Cooperative Society, Major Shamnath Sharma Marg, R.K. Puram, New Delhi.

The recharge structures constructed are 6 recharge pits with 6 recharge bores (Figure.21). The total catchment area is 28, 000 sq m. The total roof top area is 25,500 sq m. Annual runoff is 11000 cubic meter.

Figure.21. AR structure constructed at Som Vihar Apartment, RK Puram, New Delhi

vii. Resident Welfare Association, Mandakini Enclave, Alaknanda, New Delhi.

The recharge structures constructed are 6 recharge pits with 5 recharge bores and one abandoned tubewell (Figure.22). The total catchment area is about 80,000 cubic meters. The total roof top area is 45,000 sq m. Annual runoff is 20,235 cubic meter.

Figure.22. AR structure constructed at Resident Welfare society, Alaknanda New Delhi

viii. Individual house at Defence Colony, New Delhi

The recharge structure constructed is 1 recharge pit with a recharge bore (Figure.23). The total catchment area is 335 sq m. The roof top area is 200 sq m. The annual runoff is 95 cubic meter.

Figure.23. RTRWH & AR structure constructed at Defence colony, New Delhi

ix. Freesia Farm, New Delhi

The recharge structures constructed are 6 recharge trenches with 12 recharge shafts (Figure.24). The total catchment area is 20,400 sq m. Roof top area is 500 sq m. Annual runoff is 1410 cubic meters.

Figure.24. AR structure constructed at
Freesia Farm, New Delhi

D. KARNATAKA

Karnataka state covers an area of 191,791 km^2. The state is covered by peninsular gneisses, granites, schists, & basalts along with sedimentaries of Kaldagi and Bhima groups. The recent alluvium is restricted to coastal areas and stream courses. The water bearing and yield characteristics in hard rock are primarily controlled by the extent of weathering and fracturing. In limestone areas, solution cavities impart secondary porosity. The yield of tube wells tapping hard rocks is as high as 50 m^3/hr. The tube wells in sedimentaries can yield up to 15 m^3/hr.

The annual replenishable groundwater resource of the state is 15.93 bcm with a net annual groundwater availability of 15.30 bcm. Ground water draft (as on 31st march 2004) is 10.70 bcm with a stage of ground water development of 70%. Out of the 175 assessment units in the state, 65 have been categorised as over exploited and 03 have been categorised as critical from ground water development point of view.

Artificial recharge structures suitable for the state

Geologically, Karnakata state is a part of the peninsular shield comprising of gneiss, shicsts, granites and basalts. The artificial recharge structures suitable for these are the check dams/nalla bunds and percolation pond/tanks.

For the urban areas Roof top rainwater harvesting and artificial recharge structures with recharge shafts and recharge pits with/without tubewells are feasible.

Rain water harvesting and artificial recharge to the ground water in the state of Karnataka have been carried out at following location by state agencies and proved successful:

Rain Water Harvesting and Artificial Recharge in Gauribidanur & Mulbagal taluk of Kolar district

Desilting of pond was taken up for conservation of water in ponds. The Post desilting period revealed built up in ground water storage to the tune of 2-4.5 m downstream of the tanks. Watershed treatment revealed built up in ground water storage to the tune of 3-5 m in the phreatic zone. Point recharge structure has benefited storage in the deeper aquifers. Financial Incurrence: Gauribidanur & Mulbagal taluks of Kolar district- Cost of Project: 44.116 Lakhs

Artificial Recharge in Jnanbharathi campus, Bangalore University

A scheme on artificial recharge to ground water is executed in Jnanabharathi campus, Bangalore University which covered an area of about one sq km. The scheme on completion helped in harnessing 0.043 MCM (43,000 m^3) monsoon run off going as waste and improved ground water levels and sustainability of abstraction structure in the area through artificial recharge structures such as check dams and subsurface dyke. The salient features of the recharge scheme given in table.4.

Table.4. Salient features of the recharge scheme.

Catchment details	Check Dam 1	Check Dam 2	Check Dam 3
Area (sq. m)	260000	340000	410000
Yield (cu.m)	14860	19430	23430
Water available for recharge 75% of yield (cum.m)	11150	14570	17570

Artificial recharge structures were constructed to harness the natural surface water runoff (43290 cu.m) to recharge the aquifer system instead letting it into a drainage course. This helped to maintain the productivity of the existing water supply of the borewells which supply water to the University and Sports Authority of India campus. The scheme recharged about 21645 cu.m. (50% of 43290 cu.m.) of potable water into the depleting aquifer system in the area. Considering 20 years span of life for the structures, the annual investment with 10% rate of interest works out to Rs 80740.00. The cost per thousand litre of water harvesting works out to about Rs. 2.00. In addition to above, the possible intrusion of polluted Vrishabhavati water to the aquifer in the area would be prevented. Details of project are given in Table.5.

Table.5. AR Project taken up during freshwater year and their cost

S. NO.	Project Area	Cost of project (Rs. in lakhs)
1.	Raj Bhawan, Bangalore (phase-II)	12.2
2.	Armed Police Training School/Police Driving Maintenance school, Yelhanka, Bangalore	13.5
3.	Airmen Training station, Sambra, Belgaum	15.0
4.	Indian Institute of Horticulture Research, Hesaraghata, Bangalore	1.17
5.	Bangalore Development Authority, Head Office Building, Bangalore	12.5
Total		54.37

E. MADHYA PRADESH

The state of Madhya Pradesh covers an area of 3,08,000 km^2. Physiographically, the state can be divided into 6 units, they are the Saptura range, Vindhyan range, Malwa Plateau, Bundelkhand region, Mahakoshal range and valley regions. The state is underlain by formations in age ranging from Archaean to Recent. One fifth of the area is occupied by granite gneisses and meta-sedimentary rocks, whereas one tenth by Gondwanas comprising sand stones, lime stones & marbles. The Deccan Trap covers a larger part of the State whereas the Quaternary alluvium covers 6% of the State area. The alluvial deposits form prolific aquifers where tube wells can yield in the range of 50-80 m3/hr. The yield of tube wells in sand stones of Gondwanas ranges between 20-30 m3/hr; whereas in limestones of Gondwanas, it varies between 50-80 m3/hr. The yield of tube wells in basalts in select area ranges between 20-30 m3/hr.

As per long-term water level trend analysis (Pre monsoon and post monsoon) for the period between 1997-2006, the districts where high percentage of wells show declining trend (declines > 20 cm/year) during pre monsoon as well as post monsoon periods lies in northern and western parts of the state namely Bhind, Morena, Sheopur, Gwalior, Datia, Shivpuri, Khandwa, Burhanpur, Guna, Rajgarh, Shajapur, Ujjain, Indore and Barwani, Bhopal, Vidisha and Sehore districts. A total area of 36,335 Sq. Km. shows a declining trend in ground water levels. Maximum decline in ground water was observed in Ratlam, Mandsaur and Neemuch districts. 69 major watersheds have been identified in which declining trend of more than 0.10 m/ year was observed.The annual replenishable groundwater resource of the state is 37.19 bcm with a net annual groundwater availability of 35.33 bcm. Ground water draft (as on 31st march 2004) is 17.12 bcm with a stage of ground water development of 48%. Out of the 312 assessment units in the state, 24 have been categorised as over exploited and 05 have been categorised as critical from ground water development point of view.

Artificial recharge structures suitable for the state

Geologically, major portion of the state is occupied by Granitic gneisses and metasedimentary rocks with undulating topography. Contour bunding along the slopes and check dam/ nalla plugs and gully plugs are the suitable artificial recharge structures. Percolation ponds/tanks are ideally suited for the plain regions. In the alluvial deposit recharge pits, recharge shaft and trenches are suitable. For the urban areas Roof top rainwater harvesting and artificial recharge structures with recharge shafts and recharge pits with/without tubewells are feasible.

Artificial Recharge to Ground water and Rain Water Harvesting schemes have been implemented in various parts of the state in association with State Govt. departments, NGO's and Voluntary Organizations, Panchayats etc. to encourage rain water harvesting and artificial recharge activities in the state.

Some of the case studies on artificial recharge Ground water and rainwater harvesting taken up by various organizations/agencies are indicated below(Figure.25):

Figure.25. AR & RWH case studies

The "Malwa area" covering major part of the state experience declining trend of water levels, where ground water development has already reached to semi-critical, critical and over exploited categories. Uncontrolled pumping of ground water from shallow aquifers has caused shortage in water supply and drying up of dug wells which affecting socio-economic conditions of a bulk population of the State. Ground water levels in the phreatic aquifers are noticed declining rapidly and many dug wells are drying up by January and many remains dry throughout the year.

The watersheds have been identified for construction of suitable artificial recharge structures for augmenting the available ground water resources. Number of Artificial recharge structures, viz. Percolation tanks, Check dams/ Stop dams/ Cement Plugs, De-silting of existing tanks, Recharge shafts, Sub-surface dykes and Gabion structures and also Roof Top Rain Water Harvesting structures etc. were constructed by Central and State Govt. departments, NGO's and

Voluntary Organizations / village Panchayats. Artificial recharge studies taken up by CGWB with State Govt. departments, under Central Sector schemes and impact assessment studies were also carried out. A large number of recharge structures were also constructed by various state Govt. organizations with their own funds. The State Govt. as well as some NGO's have also undertaken Roof Top Rain Water Harvesting in the State in Dewas and Jhabua districts. Most of the Artificial recharge and Roof Top Rain Water Harvesting structures in the State were constructed in areas occupied by Deccan Trap basalts.

1. Artificial Recharge & Roof Top Rain Water Harvesting (RTRWH) taken up Under Central Sector Schemes

Details of various artificial recharge structures that were financed by Central Ground Water Board and implemented through various State agencies and results of their impact is also given below (Table.6).

Table.6 Details of AR structures financed by CGWB in MP

S.No.	Type of Structures	Location	Expenditure (Rs. Lakhs)	Implementing Agency	Status
1	Sub surface dyke	Bagh Dobhighat, Burhanpur district	1.00	Water Resources Department, Govt. of M.P.	Completed
2	Sub surface dyke	Chintaharan, Burhanpur district	0.925	Water Resources Department, Govt. of M.P.	Completed
3	Sub surface dyke	Barwa Kalan, Rajgarh district	2.0	P H E D	Completed
4	Check Dam, Sub surface dyke, Gabion structure	Londri Nala, Dewas district	3.2	P H E D	Completed
5	Check Dam, Gabion Structure, Sub surface dyke	WALMI campus, Bhopal	2.26	WALMI	Completed
6	Sub surface dyke	Kasrawad, Khargone district	2.38	Water Resources Department, Govt. of M.P.	Completed
7	Percolation Tank	Sikhedi, Mandsaur district	8.27	Water Resources Department, Govt. of M.P.	Completed
8	1000 RTRWH filters	Dewas	6.00	Collector, Dewas	Completed
9	Recharge Shafts	Dewas district	9.15	Water Resources Department, Govt. of M.P.	Completed
10	RTRWH in PHED Colony,	Indore City	6.94	PHED	Completed

	Musakhedi				
11	Check Dams and Gabion Structures	Tumar watershed, Mandsaur district	23.48	Water Resources Department, Govt. of M.P.	Completed
12	RTRWH in District Hospital	Dewas city	3.37	Water Resources Department, Govt. of M.P.	Completed
13	Check Dams, Sub surface dyke, percolation tank, Recharge shaft, Gabion structures, RTRWH	Choti- Kalisindh water shed, Sonkutch and Bagli Blocks, Dewas district	49.06	PHED	Completed
14	Check Dams, Percolation tank, Desilting of existing Tanks/Recharge shaft.	Bel water shed, Amla & Multai blocks, Betul district	99.81	PHED	Completed

2. Artificial Recharge Structures sub surface dykes at Dhobighat and Chintaharan in Utawali Watershed, Burhanpur district, M.P.

District : Burhanpur, M. P.
Location : 1. Dhobighat and 2. Chintaharan in Utawali Watershed
Type of Structures : Sub surface Dykes
Cost : Rs. 1.925 lakhs
(Sub Surface Dyke at Chintaharan District Burhanpur)
Implementing Agency : Water Resources Department, Govt. of M.P.
Geology : Alluvium and basalt

To prevent the drainage of alluvial aquifer, subsurface dykes were constructed across the Utawali stream in its downstream section before the contact of alluvium and basalt (Figure.26). The subsurface dykes effectively arrested the base flow from the area and helped in conserving ground water outflow. Due to construction of subsurface dykes, the base flow at Dhobighat has been completely stopped while at Chintaharan the rate of base flow has been reduced by 75%. The ground water level has also registered a rise in the dug wells in the upstream side of the dykes.

Figure.26. AR structure- Subsurface dyke under construction at Burhanpur District, M.P.

3. Artificial Recharge Structures (Sub surface Dykes) in Rajgarh district, M.P.

District	:	Raigarh, M. P.
Location	:	Barwa Kalan, Ajnar subbasin, Rajgarh district
Type of Structure	:	Subsurface Dykes
Cost	:	Rs. 2.0 lakhs
Implementing Agency	:	Public Health Engineering Department, Govt. of M.P.
Geology	:	Alluvium and basalt

Description: To arrest the subsurface out flow of ground water to the river Ajnar, in the form of base flow, subsurface dykes were constructed near Barwa Kalan village (Figure.27).

Impact: After the construction of the dykes, water level in the nearby dug wells registered a rise ranging from 0.80 to 3.80 metres. In the hand pumps, the rise was in the range of 6.0 to 12.0 meters. Due to rise in water level and the increased water column, the yield of dug wells showed a marked increase of 50% to 100%. Wells, which were dry by January end, now sustain pumping till April end. The Rabi crop area has increased from 97 to 121 Hectares. The number of irrigation wells, which were only 38, has increased to 102 irrigation wells.

Figure.27. Subsurface Dykes at Barwa Kalan, Ajnar sub basin, Rajgarh district

4. Artificial Recharge Structures (Sub surface Dyke, Boulder Check Dam and Gabion structure) in Londri Nala, Dewas district

District	: Dewas, M. P.
Location	: Londri Nala. Sonkotch Block, Dewas district, M.P
Structures	: Subsurface Dyke, Boulder Check Dam and Gabion
Cost	: Rs. 3.2 lakhs
Implementing Agency	: Public Health Engineering Department, Govt. of M.P
Geology	: Alluvium and basalt

Description : In Londri watershed, heavy base flow was occurring. To conserve this base flow, a subsurface dyke was constructed across the Londri nala (Figure.28). In addition, a boulder checks dam and gabion structure was also constructed. Due to these structures, the dug wells have shown a rise of 0.30 to 2.00 meters in water level.

Figure.28. Subsurface Dykes at Londri Nala, District Dewas

5. Artificial Recharge Structures (Sub surface Dyke, Nala bund, contour trenches) in WALMI farm, Bhopal

District	:	Bhopal, M. P.
Location	:	WALMI farm, Bhopal, M.P
Structures	:	Subsurface Dyke, Nala bund, contour trenches.
Expenditure	:	Rs. 2.26 lakhs
Implementing Agency	:	WALMI, Govt. of M.P.
Geology	:	Basalt

Description : WALMI had constructed a rainwater collection tank, for irrigation purposes, in its farm. However, due to unscientific site selection, water was seeping out from the vesicular basalt, which formed the base of the tank. A subsurface dyke has been constructed at the lower end of the rainwater collection tank to prevent the subsurface outflow of water. In addition, about 460 metres of contour trenches and a sand bag nala bund have been constructed in the catchment area of the rainwater collection tank to increase the inflow.

Due to the construction of the subsurface dyke, the average rate of water depletion reduced from 10 cm/day to 6 cm/day, the nala bund retained 500 cubic meters of water and recharged the pheratic aquifer.

6. Artificial Recharge Structures (Subsurface dykes) at Choti Kasrawad, Khargone district

District	:	Khargone
Location	:	Choti Kasrawad, Khargone district, M.P
Structures	:	Subsurface Dykes
Cost	:	Rs. 2.38 lakhs
Implementing Agency	:	Water Resources Department, Govt. of M.P.
Geology	:	Basalt

Description: It was observed that ground water seepage as base flow was very high in nalas due to steep gradient. Ground water level in the area was declining very fast after monsoon and ground water availability was also not adequate for irrigation.

After construction of the sub-surface dykes, the base flow was considerably reduced and as a consequence, rise in ground water level was recorded which ultimately increased the yield of the dug wells located in the vicinity of the dykes.

7. Artificial Recharge Structures (Percolation Tank, Check dams, Cement plug & Gabion structures) in Tumar watershed, Mandsaur district

Location	:	Tumar Watershed, Mandsaur district, M.P
Structures	:	Sikhedi Percolation tank Roopawali check dam Kheda check dam, Afzalpur Cement plug Gabion structures (19 nos)
Expenditure	:	Rs. 23.48 lakhs
Implementing Agency	:	Water Resources Department, Govt. of M.P.
Geology	:	Basalt

To study impact of these structures, water levels were recorded from June, 2000 to 2005, and it was found that Afzalpur observation well has shown a rise in post-monsoon water level of the order of 15 cm / year (figure.29). Water level trend analysis of observation wells located at village Roopawali reveals that there is a rise in water level in both pre & post –monsoon periods with rising rate 15cm/year and 22 cm/ year respectively. Water level at village Kheda shows a rising trend of 14cm/ year during post-monsoon.

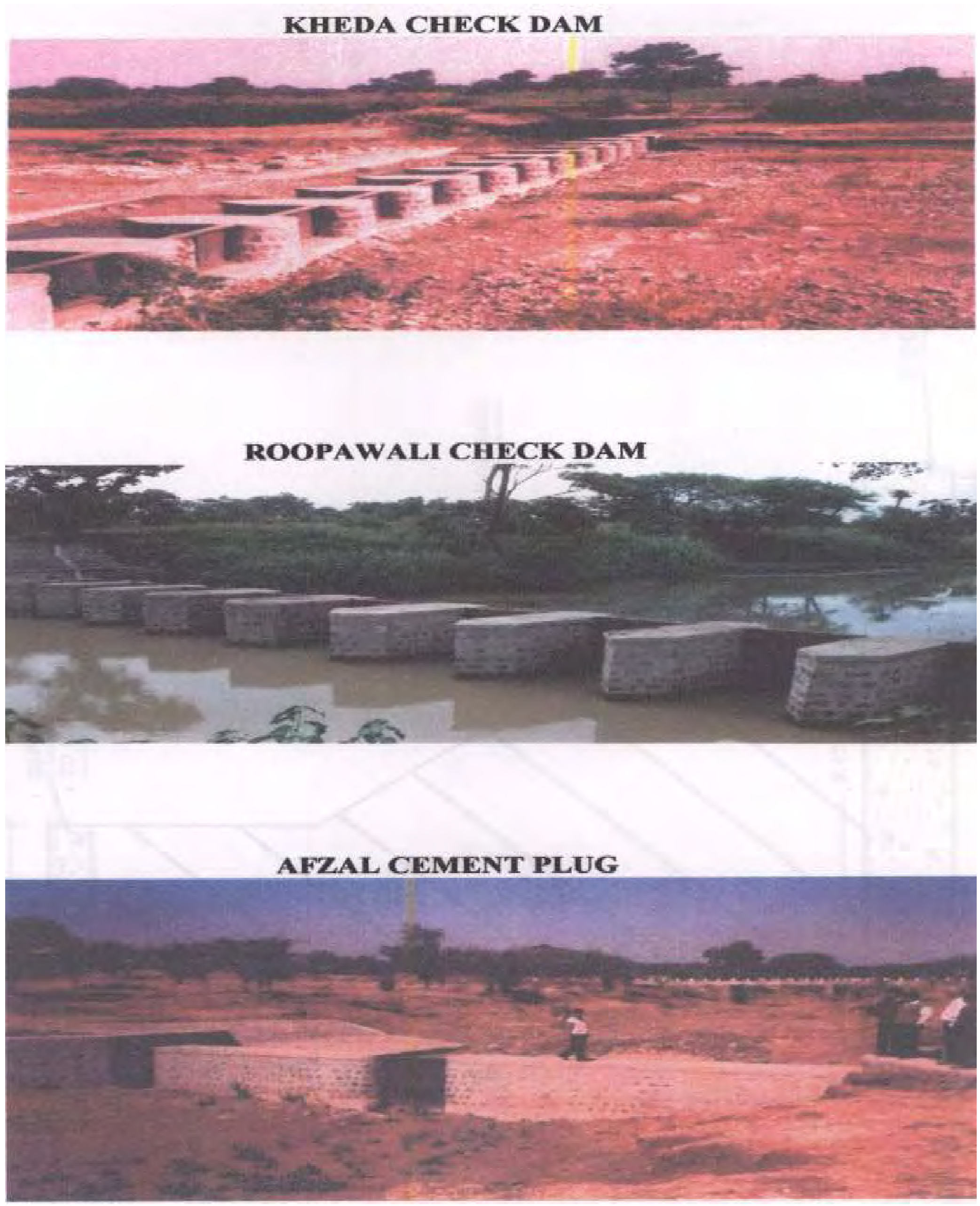


Figure.29 AR Structures constructed at Kheda, Roopawali, Afzal villages

8. Roof Top Rain Water Harvesting Studies in Dewas City, Dewas district

Location	:	Dewas City, Dewas district, M.P
Structures	:	One Thousand On-line filters
Expenditure	:	Rs. 6.0 lakhs
Implementing Agency	:	Collector, Dewas
Year of completion	:	2000
Geology	:	Basalt

Dewas city, located in the Malwa region of M.P., is one of the highly water scarce area. In the past, water was even brought by special trains. To overcome this situation, a people's movement, 'Bhujal Samvardhan Mission', was launched under the leader ship of the Collector. A low cost filter, for roof top rainwater harvesting, was developed as per CPHEED specifications. CGWB agreed to subsidize the cost of 1000 filters provided that the beneficiaries registered their ground water abstraction structure with CGWA.

After the installation of these water filters, there was a marked increase in the discharge of tube wells and an improvement in quality was also noticed.

9. Artificial Recharge Structures (Recharge Shafts) in Dewas district, M.P.

Location	:	5 village tanks in Dewas and Tonkkhurd blocks,
District	:	Dewas
Structures	:	Recharge shafts
Expenditure	:	Rs. 9.15 lakhs
Implementing Agency	:	Water Resources Department, Govt. of M.P.
Geology	:	Basalt

At some places in Dewas district it was found that dug wells in the vicinity of the village tanks were either dry or had very deep water levels due to heavy siltation. Alternatively, when the tanks were de-silted before the onset of monsoon, no surface storage could be created for longer period of time as these tanks served as good percolation tanks. Hence, it was decided that recharge shafts should be constructed in these tanks keeping the top of the recharge shaft at 50% R.L of the tank so that there should be recharge to ground water as well as storage water for 'Nistar' purposes.

Figure.30 Recharge Shaft at Mendkichak District Dewas

After the construction of theses recharge shafts (Figure.30), the water levels in the dug wells have show a rise in water levels.

10. Roof Top Rain Water Harvesting in PHED Colony, Musakhedi, Indore city

Location	:	PHED Colony, Musakhedi, Indore city, M.P
Structures	:	Roof Top Rain Water Harvesting
Expenditure	:	Rs. 6.94 lakhs
Implementing Agency	:	Public Health Engineering Department, Govt. of M.P.
Geology	:	Basalt

Indore city is highly urbanized and developed with high percentage of paved area resulting in reduction of natural ground water recharge, increase in runoff, decline in water level and decrease in yield of ground water abstraction structures. In PHED colony, Musakhedi, a total roof area of 2710 sq. m was utilized for roof top rain water harvesting. The roof top rainwater was diverted to a recharging well through troughs into collection chambers and then through a filter chamber. A piezometer of 60 m depth was drilled and equipped through DWLR to assess the impact of roof top rainwater harvesting.

Studies conducted have shown that there is a rise in water level of almost 4 – 5 metres after the monsoon. Dry hand pumps in the Colony have started to yield water.

11. Roof Top Rain Water Harvesting in Dewas district Hospital, Dewas city

Location	:	District Hospital, Dewas district, M.P
Structures	:	Roof top rain Water Harvesting
Expenditure	:	Rs. 3.37 lakhs
Implementing Agency	:	Water Resources Department, Govt. of M.P.
Geology	:	Basalt

The purpose for construction of roof top rainwater harvesting structure was to recharge the ground water and to improve the water quality.

After the construction of the roof top rainwater harvesting structure, the nitrate content, in the borehole in hospital campus, which was earlier more than 100 mg/l had reduced to less than 45 mg/l.

12. Artificial Recharge Studies (Demonstrative Projects) in Choti Kali Sindh watershed, Sonkutch and Bagli blocks, Dewas district, M.P.

Location	:	Choti Kali Sindh watershed, Sonkutch and Bagli blocks, Dewas district, M.P
Structures	:	Percolation tank (1), Stop dams (11), Recharge shaft (1), Gabion structures (10), Roof top rain water harvesting (2), Subsurface dyke (1)
Sanctioned amount	:	Rs. 49.06 lakhs
Implementing Agency	:	Public Health Engineering Department, Govt. of M.P.
Amount of water likely to be harnessed (Estimated)	:	158.24 TCM (in one year)

Choti kalisindh Watershed in Dewas district (Figure.31) comprises an area of 294.9 Sq. Km and falls in Survey of India Topo Sheet No. 55A/8 and 55B/1,5, & 9 and is bounded between N Lat. 76º17'04'' and 76º32'04''; and E long: 22º43'08'' and 23º02'04''. The major area of this watershed falls in Sonkutch block and some parts of western Tonkkhurd block and northern part of Bagli block. The area exhibits broad, flat shallow valleys with lateral erosion. Kali sind river drains the area. The average annual rainfall is 1021 mm. Deccan Trap basalts occupy the area. Long-term water level study reveals a declining trend ranging between 0.40 and 0.60-m/ year. A total 127 number of villages located in the area are declared "Water Scarcity villages" by the state PHED . On the basis of field survey and local conditions, 26 Sites for artificial recharge structures and 15 sites for Piezometers (For monitoring water levels) were selected in consultation with implementing agency, PHED, Dewas as follows:

Figure.31. AR structures constructed in Choti Kalisindh, Dewas Watershed

Stop dam (Masonry) –6,Stop dam (Masonry Weir) –5

Gabion structure –10, Percolation tank-01, Sub-surface dyke – 01

Recharge shaft – 01, Roof top rain water harvesting – 02

Piezometers – 15

All the structures were constructed and at present impact assessment studies are going on. Initial observations indicate that hand pumps, which were dried up, have started yielding and water levels in Piezometers and key observation wells are showing rising trend ranging between 5.00 and 12.00 m in pre monsoon period (2007, pre monsoon to 2008, pre monsoon).

F. MAHARASHTRA

Maharashtra covers an area 3,07,713 km^2. Average annual rainfall in the state is about 1433 mm. About 85% of the state is covered by Deccan basalts whereas the rest of the state is covered by Quaternary alluvium, Gondwanas, Cuddapahs, Kaladgis, Vindhyans, Dharwars and Archaeans. Based on the hydrogeological properties of different rock formations, the State can be divided into three major groups namely Unconsolidated, Semi-consolidated and Consolidated groups. The yield of dug wells in Deccan Trap varies from 0.2 to 30 m^3/hr whereas in Vindhyans, Cuddapahs and Kaladgi, it varies from 1.12-10 m^3/hr. In Archaean, yield is just 3-4 m^3/hr. In the semi consolidated formations, which consists of coastal Sedimentaries, Intra-trapeans and Gondwanas, the dugwells yield between 6-12m^3/hr. In unconsolidated formations, the dug wells yield between 0.5-20m^3/hr.

The annual replenishable groundwater resource of the state is 32.96 bcm with a net annual groundwater availability of 31.21 bcm. Ground water draft (as on 31st march 2004) is 15.09 bcm with a stage of ground water development of 48%. Out of the 318 assessment units in the state, 07 have been categorised as over exploited and 01 have been categorised as critical from ground water development point of view.

Artificial recharge structures suitable in the state

Geologically, the area is occupied by Deccan traps with an undulating topography. Contour bunding along the slopes and check dam/ nalla plugs and gully plugs are the suitable artificial recharge structures. Percolation ponds/tanks are ideally suited for the plain regions. In the alluvial deposit recharge pits, recharge shaft and trenches are suitable. For the urban areas it is the Roof top Rainwater harvesting and artificial recharge structures like the recharge shafts and recharge pits with/without tubewells are suitable.

The implementation of rain water harvesting and artificial recharge to ground water through watershed development programmes has been carried out in drought prone areas of Ahmednagar district by various Gram Panchayat, village communities and NGO's. The main aim of these programmes was to control soil erosion, conserve sub surface outflow, enhance soil moisture condition and augment the ground water resources through simple artificial recharge techniques. Benefits of such projects are as follows:-

A. Ahmadnagar District

Hiware Bazaar

In the village of Hiware Bazaar, a rain shadow area with an annual rainfall of 400 mm, the village community has demonstrated the benefits of rainwater harvesting, artificial recharge to ground water, conservation and management of ground resources. The ridge to valley concept was adopted under watershed development programme. It involved construction of structures like gully plugging, loose boulder structure, gabion structure, nalla bunding, cement check dams etc. The cost involved in constructing cement check dams was prohibitive and hence Shri Hazare developed modified gabion structure with a core wall which reduced the cost considerably and was as effective as cement check dam. This novel approach is being followed elsewhere also. Similarly on the ridgeline where the CCT was not possible, shallow soak pits were dug in order to collect rain water so that through seepage the water would be available to surrounding plantation. This resulted in increase in plant survival and their vigorous growth. This was also a novelty of Ralegan Siddhi programme.

Under watershed development programme, number of soil and water conservation structures like contour bunding, nala bund, cement nala bund, van tale, percolation tank, loose boulder structure, earthen bund and storage bandhara in addition to CCT in private and Panchayat land were constructed by Shramdan of villagers till 2005. The details are given in Table-7 and location is given in Figure.-32.

Table 7: Details of soil and water conservation structures constructed

Sr.No	Type of work	Area/Nos.
1	Contour bunding	414 ha
2	Nalla bunding	51
3	Van Talao	2
4	Cement Nalla bunding	4
5	Afforestation	408 ha
6	Storage Bandhara	7
7	Tree Plantation on road side	6 km
8	Loose boulder construction	12
9	Earthern structure	2

Figure.32 Location of soil and water conservation structures constructed.

A large-scale tree plantation along the roadside and farm bunds was also taken up with the help of Forest Department and People Participation. The impact assessment analysis indicated that the number of wells for irrigation has increased from 97 to 231 (2.4 times), area under protected irrigation increased by 1.5 times and irrigation during summer increased by 8.5 times. Sustainability of ground water resources as compared to pre project period has increased considerably. The agriculture growth has increased to 63% and the cropping intensity to 34 %. Ground water levels have become shallow (4 to 6 m from ground surface) even during summer season. As a result, the socio-economic condition of the villagers has improved tremendously. The village Panchayat has been awarded with 'National award for "Bhujal Samvardhan Puraskar" for the year 2007 by the Ministry of Water Resources, Govt. of India. Due to availability of water for irrigation through wells and realizing the importance of water the villagers decided to form cooperative societies well-wise. This resulted in bringing more land under cultivation and developments like double cropping change of farming system, horticulture plantations, vegetable cultivation, dairy farming etc. could take place. All this resulted in substantial increase in per capita income of the farmers and the villagers through their cooperative efforts created facilities like school, hostel. Gymnasiums, credit societies renovation of temple etc. in the village.

Ralegan Siddhi

The watershed development programme has been implemented in an interactive manner in Ralegan Siddhi, Parner taluka, Ahmednagar district. The village lies in the drought prone area. An intensive watershed development work has been undertaken in the village. This work was taken up under Integrated Watershed Development Project in the village since 1975. The water conservation structures constructed were Percolation Tanks, Nala Bunding, Contour Bunding, K.T. weirs and Gabion structures. The impact assessment of watershed development programme was undertaken by Directorate of Irrigation Research Development (DIRD), Govt, of Maharashtra in 1989-92 indicated the positive effect of overall water resources availability and benefits to the activities/operations based on water resources utilization. Few photographs of various recharge structures are given in Figure.33

Contour Bunding

Series of Check Dams


Percolation Tank


Check Dam

Figure.33- Artificial Recharge Structures constructed at Ralegan Siddhi.

Wadgaon (Amli) This is a drought prone village in Parner taluka, Ahmednagar district. In this village, roof top rainwater harvesting has been implemented in about 60% of village houses for augmenting two existing dug wells in the village. The village Panchayat has also constructed 4 K.T. weirs, Gabion structures on local nalas.

2. Arificial Recharge & Rain water Harvesting implemented by state agencies with CGWB

Pilot artificial recharge studies in Maharashtra were taken up with objective to investigate the feasibility of various recharge techniques in the watersheds namely WR-2 in Amravati district and TE-11 and TE-17 in Jalgaon district having different hydrogeological settings i.e. hard rock and soft rock. The ground water development in these watersheds was quite intensive and decline in ground water levels was being witnessed.

Watershed WR-2, Amravati District

The watershed WR-2 covers an area of about 488.7 sq. kms and is located in Warud taluka of Amravati district. This watershed is underlain by basalts and represents a hard rock terrain. The watershed covers 96 villages. Due to over exploitation of ground water for orange cultivation, the water levels are declining trend @ 0.20 m/year. Three percolation tanks and 10 cement plugs have been constructed (1995 to 1998) and details are given in Table 8.

Table 8 Location of Recharge Structures Constructed in WR-2 Watershed, Warud Taluka, Amravati District

S. No	Name of the recharge structure	No. of recharge structures constructed	Location of recharge structures	Gross storage in Thousands Cubic Meters	Average benefited area by each structure in hectare	Effici-ency
1	Percolation tanks	3	Manikpur Benoda Bhimdi	220.6 198.0 71.0	50-100	78-91%
2	Cement Plugs (Nallah Bunds)	10	Temburkheda I Temburkheda II, Malkhed Loni I Loni II Sendurjanaghat I Sendurjanaghat II Alora Benoda Mamdapur	7.42 4.79 2.10 2.21 3.60 5.67 2.49 3.23 5.30 3.24	10	81-97.5%
3	Under Ground Bhandharas (UGB)	05	Peth Mangruli, Bhada, Nandgaon, Haturna I&II			

Percolation tanks: Three Percolation tanks at Manikpur (Figure.34a), Benoda (Figure.34b) and Bhimdi with gross storage capacity varying from 71 to 221 TCM have been constructed. The recharge to ground water from percolation tanks varied from 49 to 132 TCM during 1997-98. These tanks contained water for 180 to 252 days. Around 60 to 120 ha of area downstream of percolation tanks was benefited by the recharge from percolation tanks. Around 1-4m, 4-9m, and 6-10m rise in water levels was observed during 1997-98. A total of 298.4 TCM of additional recharge from these three percolation tanks is capable of bringing about 60 ha of additional land under assured irrigation during the year.

Cement Plugs: Ten cement plugs having a storage capacity of 2.1 to 7.42 TCM have been constructed. The efficiency of cement plugs varies from 81.1 to 97.5 %. In general 3 to 6 fillings are observed during the monsoon and capacity utilisation of cement plugs is at times up to 400 % of storage capacity. During 1997-98, ten cement plugs recharged around 58.7 TCM to ground water which can bring an additional area of 11.7 ha under assured irrigation.

Under Ground Bhandaras: Five UGBs have been constructed and their impact on ground water reservoir is monitored.

Fig.34a Percolation Tank at Manikpur

Fig.34b.Percolation Tank at Benoda

Case study of Watershed TE-17, Jalgaon District

The watershed TE-17 covers an area of about 235 sq.kms and is located in located in Yaval taluka of Jalgaon district. This watershed is underlain by alluvium and represents soft rock terrain. Due to extensive banana cultivation, the ground water declines @ 1m/year. A total of 10 recharge structures have been constructed (1995 to 1998) and the details are given in Table 9.

Table 9: Location of Recharge Structures Constructed in TE-17 Watershed, Yaval Taluka, Jalgaon District

S. No	Name of the recharge structure	No .of recharge structures constructed	Location of recharge structures	Storage Capacity in Thousands Cubic Meters	Average benefited area by each structure in hectare	Efficiency
1	Percolation Tank	3	Ichkeda Haripura Dongaon	45 12 11	200 to 300	95-97%
2	Conversion of VT into PT	2	Baghjira Haripura	6 22	100 to 200	95-97%
3	Nallah diversion to utilise existing capacity of PT	1	Nagadevi	350	300 to 400	95-97%
4	Injection well	1	Dambhurni	Intake Capacity 3000 to 5000 lph	1	95%
5	Recharge Shaft	2	Savkheda Nagjhira	1440 lph 480 lph (Recharge Capacity)	3	95%
6	Dug well recharge	1	Giradgaon	(Volume recharged) 60,000- 70,000 lph	3	95%

It was observed that the efficiency of percolation tanks is up to 97% and the capacity utilisation due to repetitive fillings in case of new percolation tanks constructed under this project is around 140 to 450%. The area benefited ranges from 100-400 ha. The two recharge shafts constructed at Savkheda and Nagjhira have augmented around 23.60 TCM during 1997. It is observed that percolation tanks are most suitable surface structures in Bazada zone and the recharge shafts are considered as most efficient schemes in deep water table mountain front area. In watershed TE-17, about 605 TCM can be conserved in surface structures benefiting more than 1000 hectares of land. Among the sub-surface structures, recharge shafts and dug well recharge techniques are cost affective. The injection well method of recharging aquifer is very expensive. Injection well constructed at Dambhurni, Watershed TE-17, Jalgaon District is presented in Figure.35

Figure.35 Injection well at Dambhurni, Watershed TE-17, Jalgaon District

Case Study of Watershed TE-11, Jalgaon District

The watershed TE-11 in Yaval tahsil of Jalgaon district covering 28 villages has an area of 371 Sq.kms and falls in Tapi river basin. The main water bearing formations are alluvium as well as Talus and Scree deposits. A total of 10 recharge structures have been constructed during 2001-02. and the details are given in Table 10.

Table 10: Location of Recharge Structures Constructed in TE-11 Watershed, Yaval Taluka, Jalgaon District

S. No	Name of the recharge structure	No. of recharge structures constructed	Location of recharge structures	Storage Capacity in Thousands Cubic Meters	Recharge to Ground Water in Cubic Meters
1	Percolation Tank	5	Wadri Sangvi Dongarda I Dongarda II DongardaIII	98 71 32 25 58	11230 33360 6580 8850 28083
2	Recharge Shaft	5	Borkheda (1 No.) Wadri (4 Nos.)	1440 480 (Recharge capacity)	3

Percolation tanks : Five Percolation tanks at Wadri, Sangvi and Dongarda with gross storage capacity varying from 71 to 98 Thousand Cubic Meter (TCM) have been constructedand being monitored during the first year of its completion. The catchment areas of individual tanks varies from 0.425 to 4.273 sq.km. The combined storage capacity of all five percolation tanks is 285.89 TCM. The recharge to ground water from percolation tanks varied from 6.580 to 28.083 TCM. The submergence areas of these tanks varies from 12.35 to 42.0 Thousand Sq m. The benefit- cost ratio of these tanks varies between 1.12 and 2.30.

Figure.36. AR structures shaft with recharge well.

Recharge Shafts : The water levels of 42 observation wells, located around the five recharge shafts (Figure.36), were monitored weekly from June to Dec. 01 and afterwards monitoring was taken monthly upto March 02. The water levels in these wells ranged between 23.20 and 100.00 m bgl. 21 wells have gone dry during March 2002. The period of water impounded were 79, 40 and 11 days for Borkheda R.S. Wadri Circular II and Wadri Square II recharge shafts respectively.

Case Study of Ramtek, Nagpur District

A demonstrative project of roof top rain water harvesting has been implemented in Kavikulguru Institute of Technology and Science (KITS), Ramtek, Nagpur district during 2001-02 (Figure 37). Roof-top area of 360 sq m of Information Technology building has been used to harvest rain water and divert the same to recharge ground water through an existing dug well in the premises of the Institute. Rainfall from the roof of the building was diverted through a system of pipes, silt settlement chamber with overflow arrangement, on-line sand filter, flow meter, control valve to the recharge well.

Analysis of water level data collected from the recharge well and an observation bore well has indicated a substantial improvement in water level as well as the well yields in the area. As per estimation, a total of 215.7 cu. m of rain was received on the roof of the building, out of which 19 cu. m was actually recharged into the ground water system through the dug well.
This project has been implemented to familiarize the Government, Public Sector organisations, Industries, NGOs, voluntary organisations, Academic Institutes, etc. with the field demonstration of benefit of harvesting rain water on the building roof-tops and helping in recharging the aquifers for meeting the ever increasing demand for ground water.

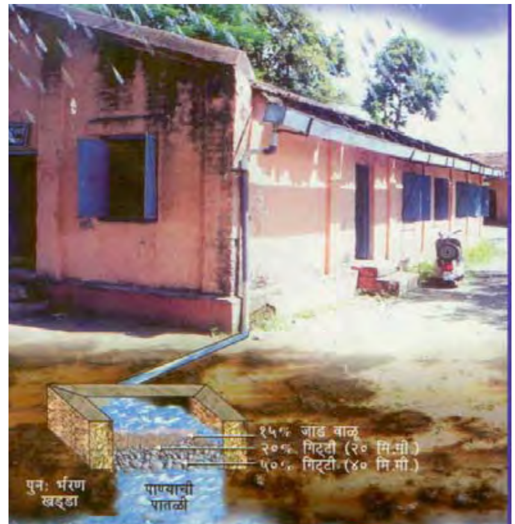


Figure.37.RTRWH & AR structures at Ramtek, Nagpur district

Case Study of Warud, Amravati District

A demonstrative project of roof top rain water harvesting has been implemented in Panchayat Samithi Office premises, Warud, Amravati district during 2002-03. Roof-top area of 500 sq m of Panchayat Samithi building has been used to harvest rain water and divert the same to recharge ground water through an existing dug well in the premises. Rainfall from the roof of the building was diverted through a system of pipes, silt settlement chamber with overflow arrangement, on-line sand filter, flow meter, control valve to the recharge well.

Analysis of water level data collected from the recharge well has indicated a substantial improvement in water level as well as the well yields in the area. As per estimation, a total of 311.30 cu. m of rain was received on the roof of the building, out of which 280.17 cu. m (90 %) was actually recharged into the ground water system through the dug well. This project has been implemented to familiarize the Government, Public Sector organisations, Industries, NGOs, voluntary organisations, Academic Institutes, etc. with the field demonstration of benefit of harvesting rain water on the building roof-tops and helping in recharging the aquifers for meeting the ever increasing demand for ground water.

G. NORTH EASTERN STATES

North Eastern region, though endowed with high rainfall, suffers from water shortage during the dry months particularly in hilly areas and urban areas. Rainwater is considered to be a viable means to augment the water supply for domestic water needs. The number of structures constructed state-wise is depicted Table 11.

Table 11 State wise Rooftop Rainwater Harvesting Structures

State	Total Structures	Cost (in lakhs)
Assam	13	23.22
Nagaland	42	116.43
Arunachal Pradesh	5	20.0
Meghalaya	6	20.32
Mizoram	35	28.0
Total	101	207.97

Arunachal Pradesh

Arunachal Pradesh is occupied mostly by hills (about 85% of the total geographical area) and 15% valley areas. Though it is heavily rain fed area, acute water scarcity is felt during lean period. To augment during lean period Roof Top Rain Water harvesting Scheme was selected the Ruksin Sub division of East Siang district. The details of schemes are given below in table 12.

Table 12: Rooftop Rainwater Harvesting Structures constructed in Arunachal Pradesh

Sl. No.	Scheme	Total fund allocated (Lakhs)	Implementing Agency	Impact Assessment
1.	Roof Top Rain Water harvesting in Ruksin Sub division in East Siang district	20	IFCD Govt. of Arunachal Pradesh	Water Tank capacity of each structure is 30,000 ltrs

Assam State

12 structures was constructed in Kamrup District. Hajo and Sonapur towns in Kamrup District have been selected for roof top rainwater harvesting schemes. 12 schools have been selected in two towns i.e. 6 in each town. The district is bestowed with abundant rainfall of over 2,000 mm

spread over 7 months in a year. The salient features of rain water harvesting schemes are furnished in Table.13 given below.

Table 13. Salient features of rain water harvesting in Kamrup District, Assam

S.No.	Site	Total Roof Top Area (sq. km.)	Roof Top Area Considered (sq. km.)	Average Rain Fall (m)	80% of Average Rain Fall (m)	Volume of water available annually (cu. m)	Number of Tanks provided	Storage Capacity Created (cu. m)	Rainfall required for filling Tanks (mm)
I.	HAJO								
1.	S.B.S.K.higher Secondary School	773.8	773.8	2.127	1.7016	1316.7	4	12	15
2.	Adarsh Vidyapith High School	741.89	300.00	2.127	1.7016	510.5	2	6	20
3.	Ganestola Prathamik Vidyalaya	116.61	70.00	2.127	1.7016	119.1	1	3	42
4.	Fakirtola Prathamik Vidyalaya	159.39	95.22	2.127	1.7016	162.0	1	3	32
5.	Fakirtola Madrassa High School	87.86	87.86	2.127	1.7016	149.5	2	6	68
6.	Devalaya Prathamik Vidyalaya	247.76	247.76	2.127	1.7016	421.6	2	6	24
II.	SONAPUR								
1.	Kamarkuchi M.E. School	745.00	745.00	2.127	1.7016	1267.7	2	6	8.0
2.	Kamarkuchi L.P. School	206.00	206.00	2.127	1.7016	350.5	1	3	15.0
3.	Ural L.P. School	140.50	140.50	2.127	1.7016	239.1	1	3	21.0
4.	Borkhat L.P. School (No.-1)	268.25	268.00	2.127	1.7016	456.0	1	3	11.0
5.	Borkhat L.P. School (No.-2)	157.70	157.70	2.127	1.7016	268.3	1	3	19.0
6.	Borkhat Janajatia M.E. School	176.00	150.00	2.127	1.7016	255.2	1	3	20.0

Out of 12 structures, one structure i.e. Devalaya Prathamik Vidyalaya in Hajo was executed by CGWB, NER at the cost of Rs 84,252/-. However, other structures were executed by WAPCOS under overall supervision of CGWB, NER.

Meghalaya state

Meghalaya is predominantly a hilly terrain with limited valley areas at places. The average annual rainfall in the state is around 2,050 mm. Though, the state is endowed with the plenty of rainfall, it experiences shortage of drinking water during the summer. This may be due to high surface run off, as the area is hilly with steep slopes. The main water supply is dependent on spring, streams and waterfalls. To augment water supply, Central Ground Water Board has provided technical guidance for construction of six roof top rainwater harvesting structures in East Khasi Hills district. Out of these six, three schemes are in schools and three schemes in Govt. buildings. The details of schemes are given below in table 14.

Table.14 Roof Top Rain Water Harvesting schemes in Meghalaya

Sl.No	Location of Schemes	Total Roof Area (sq. m)	Total fund allocated (Lakhs)	Implementing Agency	Water Harvested (cu. m)	Persons benefitted	Purposes
1.	State Guest House	186.2	20.32	WAPCOS	357	-	Washing & cleaning
2.	Circuit House	137.6			264.19	-	Gardening & washing
3.	State Central Library	1103.2			2118.4	15	Drinking, washing & cleaning
4.	Auxilium Convent	520.5			999.36	2000	laboratories, drinking, gardening & washing
5.	Pine Mount School	973.3			1868.73	1500	Laboratories & drinking
6.	All Saints Diocesan H.S. School	613.4			1177.73	2100	Laboratories

Mizoram state

The state constitutes a mountainous terrain with rugged topography represented by high longitudinal, parallel to sub parallel trending North South hills with moderate to steep slopes and narrow valleys. The hills are steep and separated by rivers creating deep gorges.

The average annual rainfall in the states is 2200 mm. The major part of rainfall is lost as surface run-off. In spite of good rainfall in state there is acute shortage of water especially during the summer. Considering the physiography, rainfall, some suitable structures like check dams can be constructed for harvesting the surface run off. The present water resources of Mizoram can be augmented through development of springs and by constructing rain water harvesting structures. The Central Ground Water Board has provided funds for construction of Rain Water harvesting structures of 35 selected sites in Aizawl district, Mizoram. The details of allocation of funds and schemes are given below in table 15.

Table.15 Roof Top Rain Water Harvesting schemes in Mizoram

Sl. No	Scheme	Total fund allocated (Lakhs)	Implementing Agency	Total Schemes	Impact Assessment
1	Roof Top Rain Water harvesting in Mizoram	28	Directorate of Rural Development, Mizoram.	35 schemes completed.	Total 5,53,000 ltrs. Harvested. 59,153 persons benefited.

Nagaland

Nagaland is basically hilly terrain with small-elongated valleys constituting about only 6 percent of total geographical area. Acute scarcity of drinking water occurs during the lean period mainly in hilly areas, which comprise about 94 % of total area of the state. In order to augment water supply, construction of rainwater harvesting structures in 47 sites covering Kohima and Mokokchung districts have been done. The details are given in table 16 & 17.

Table.16 Details of Rain Water Harvesting Structures in Nagaland

Sl. No.	Schemes	Total fund allocated (Lakh)	Implementing Agency	Completed Schemes	Households Benefitted in use for drinking & domestic purposes
1.	RTRWH in Kohima, Mokokchung district, Nagaland	55	Soil & Water Conservation Deptt. Nagaland	33 Structures completed (15 in Kohima, 18 in Mokokchung district)	551
2.	RTRWH in Rengma area, Nagaland	10.96	Soil & Water Conservation Deptt. Nagaland	4 Structures completed	60
3.	RTRWH in Mokokchung district, Nagaland	50.47	IFCD	11 Structures completed	378

Table.17 : Details of Roof Top Rain Water Harvesting Structures Implemented by the Soil & Conservation Department, Rengma, Nagaland

Sl.No.	Location	Estimated Cost Rs. P	Storage capacity (Litres)	No. of persons benefited
1.	Tsosisenyu	2,83,000	24,580	109
2.	Sendenyu	2,69,000	70,687	315
3.	Nsunyu	2,73,000	24,580	109
4.	Tesophenyu	2,71,000	34,622	154
TOTAL		10,96,000	1,54,469	687

ALL SAINTS SCHOOL, IGP, SHILLONG

CIRCUIT HOUSE, LABAN, SHILLONG

Figure.38 RTRWH and AR structure constructed in Shillong

Demonstration of Rain Water Harvesting from Rooftops of Govt. Rural Schools located in remote area for Collection of Rainwater by Constructing Storage Tank for Drinking and Use in Two Toilets for Girls in Govt. Schools in Rural Areas

In North Eastern Region, 36 Govt. schools have been covered in 4 states i.e. Assam, Manipur, Meghalaya and Nagaland in Phase-I. In Phase-II, 45 Govt. schools have been covered in those states. The details are summarized in Table 18.

Table.18 Details of Roof Top Rain Water Harvesting Structures Implemented by NGO

Name of State	Name of NGO	No. of Schools covered				No. of students benefited
		Phase-1	District	Phase-11	District	
Assam	Bosco Reach out, Guwahati, Kamrup	5	N.C. Hills	___	___	NA
	Centre for Youth & Rural Development, Chirang.	6	Chirang/ Udalguri	___	___	NA
	Subungni Najanai, Kokrajhar	5	Kokrajhar	15	Kokrajhar	NA
Manipur	Volunteers for village development, Ukhrul	5	Ukhrul	10	Ukhrul	772
Meghalaya	Bethany Society, Laitumkhrah, Shillong	6	East Khasi Hills	2 1 1	West Garo Hills East Garo South Garo	836
Nagaland	Prodigals Home, Dimapur	5	Dimapur	10	Dimapur/Peren	2068
	Naga Mothers Association, Kohima	5	Kohima	10	Kohima	NA
Total		37		49		3676

Bhoomual Samvardhan Puruskar – 2007

Bethany Society, Meghalaya was the only recipient of 'Bhoomijal Samvardhan Puraskar 2007 in North Eastern States. Ten Rooftop Rain Water Harvesting Tanks have been constructed in ten schools located in the East Khasi Hills, East, West and South Garo Hills district, Meghalaya. Twenty low cost toilets have been constructed, two in each school. There are separate toilets for girl students.

Benefits accrued

- A total of 3,00,000 litres rainwater has been conserved in 10 tanks.
- 20 low cost toilets, 2 in each school.
- 836 students are availing of safe drinking water and sanitation facilities in the 10 schools.

DISTRICT LIBRARY, IGP, SHILLONG

AUXILIUM CONVENT, NONGTHYMMAI, SHILLONG

Figure.39 RTRWH and AR structure constructed in Shillong

- Village community came together to solve an urgent problem, Village community was trained to implement all aspects of a programme such as planning, purchase of materials, payment to workers, monitoring, social auditing, maintenance of records, share benefits according to norms set by the community.
- Awareness levels regarding water and sanitation were raised and community is demanding such services from their local representatives.

- Village community and school community were motivated to take charge of the programme and ensure its sustainability.

Type of innovative methodology/technology adopted

- Involvement of the community for the total implementation of the project.
- Gender sensitivity in formation of village level implementation committees.
- Transparency in all monetary transactions.
- Demonstration of both underground and above ground rainwater harvesting tanks.
- Use of rooftop rainwater harvesting technology.
- Use of two-pit low cost sanitation toilets.
- Use of social audit for monitoring.
- Collaboration among Ministry of Water Resources, CGWB, National Level NGO, Local NGO and local community to implement the programme.
- The scheme is under the direct charge of the Headmaster and Managing Committee of the respective school.

Benefit-cost ratio

- Approximately Rs. 80,000/- was spent on the construction of the tanks. Hence, the cost of per litre of water conserved has been worked out to be Rs. 2.66.
- The maintenance cost is almost negligible.

Sustainability

- The tanks have a life of 20 years and the only maintenance required is to ensure that the channels from the rooftops are well maintained and the tanks are cleaned and necessary chemicals are used for purification. The school and village communities were made the primary stakeholders.

Awareness Generated

- Awareness has been generated in all the ten villages and also some of the neighbouring villages on the value of rainwater harvesting, importance of portable drinking water and sanitation.
- Bethany Society has been approached by many villages and local community groups to expand the programme.

The details of implementation by Bethani Society are depicted in Table.19:

Table.19 : Details of Implementation by Bethani Society, Meghalaya

S.No.	Name of School & Address	Block & District	Volume of Water Conserved (Litres)	No. students benefitted
1.	Rombagre Upper Primary School. Rombagre Village.	Rongram Block West Garo Hills	30,000	75
2.	Rongkhon Dilnigre Govt. L.P. School.. Dilnigre Village	Gambegre Block West Garo Hills	30,000	55
3.	Megapgre Govt. L.P. School Village Mepagre	Samanda Block East Garo Hills	30,000	150
4.	Dagal Songittal L. P. School. Village Khakiza	Chokpot Block South Garo Hills	30,000	40
5.	Mawlyngad Presbyterian L.P. School Village Mawlyngad	Mawryngkneng Block East Khasi Hills	30,000	140
6.	Laitkseh Govt. L.P. School. Village Laitkseh	Mawryengkneng Block. East Khasi Hills	30,000	64
7.	R C L.P. School Village Madan Thangsning	Mawkynrew Block' East Khasi Hills	30,000	45
8.	Kong BaiT Secondary School. Kharang Village	Mawkynrew Block East Khasi Hills	30,000	163
9.	Sohrarim Presbyterian L.P. School. Village Sohrarim	Laitkroh Block East Khasi Hills	30,000	63
10.	Khutmadan RC Govt. Aided School. Village Khutmadan	Sheila Bholagunj Block. East Khasi Hills	30,000	41

Laitkseh Govt. L.P. School, Mawryngkneng Block, East Khasi Hills
School Building has been extended over the tank

RC LP School, Madan Thangsning, Mawkynrew, East Khasi Hills

Figure.40 RTRWH & AR structure constructed at East Khasi hills

H. ORISSA

Orissa state covers an area of 1,55,707 km^2. There are five prominent physiographic features, they are coastal plains, northern uplands, southwestern hilly region, erossional plains of Mahanadi valley and subdued plateaus. The average annual rainfall of the state is about 1502 mm. The State is underlain by diverse rock types ranging in age from Archaean to Recent. The State can be hydrogeologically sub divided into consolidated, semi-consolidated & unconsolidated formations. The consolidated formations include hard crystallines and compact sedimentary rocks whereas semi-consolidated formations include weathered and friable Gondwana sedimentaries and loosely cemented Baripada beds. The unconsolidated formations include laterites and recent alluvium. The yield of tubewells tapping granite gneisse ranges between 10-35 m^3/hr whereas other consolidated formations, it ranges between 5-18 m^3/hr. The yield of tubewells in semi-consolidated formations range between 20-115 m^3/hr.

The annual replenishable groundwater resource of the state is 23.09 bcm with a net annual groundwater availability of 21.01 bcm. Ground water draft (as on 31st march 2004) is 3.85 bcm with a stage of ground water development of 18%. Out of the 314 assessment units in the state, 308 blocks has been categorised as safe from ground water development point of view. The remaining 6 blocks are saline.

Artificial recharge structures suitable for the state

The Orissa state has diversified geological features, from the archeans to the recent formation. Check dams/nalla plugs/ gully plugs and percolation ponds are suited for the consolidated formations. Recharge pits and recharge shafts with/without tubewells are ideally suited for the semiconsolidated and unconsolidated formations.

For the urban areas Roof top rainwater harvesting and artificial recharge structures with recharge shafts and recharge pits with/without tubewells are feasible.

Few case studies taken up in the state along with the impact analysis of these structures are listed below:

1. RAINWATER HARVESTING AND ARTIFICIAL RECHARGE TO GROUND WATER IN THE RAJ BHAWAN PREMISES, BHUBANESWAR, ORISSA.

Athgarh Sandstone of Upper Jurassic age occupies the whole Raj Bhawan premises with little or no lateritic cover. The phreatic aquifer, which contributes to the dug wells are poor and non yielding during summer. However the deeper aquifers in the form of fracture zones are highly potential and hence are extensively exploited in the Raj Bhawan and its surroundings. Long duration pumping through 8 to 10 Nos. of deep bore wells in the vicinities of Raj Bhawan and 4 such in the premises by PHE &D has already put enormous stress on the deeper ground water regime. The pre monsoonal (May) depth to water level was around 28.5 mbgl and the post monsoonal (November) was not improving beyond 18 to 20 mbgl. Raj Bhawan having a vast area of around 18.70 hectares felt capable building area for generating sufficient rain run-off due to the topography and was chosen for implementing pilot artificial recharge project in association with state govt. as implementing agency.

About 7.40 hectares of Raj Bhawan was sub divided into 3 sectors on the basis of land slope to treat the run-off separately. In each sector, the surface run-off was collected in a trench system. The phreatic aquifer gets recharged by seepage through side weep holes and base of the trench. Once sufficient surface run-off is harvested in the trench system, it flows through an array of pipes to the filtration chamber, where a fine sand filter removes all the fines from the water to make it ready for recharge. A primary filter (coarse sand) was also constructed in each trench to make the filtration more effective. A deep bore well at the end of each sector guides the harvested water to the deeper aquifer; thereby augmenting the deeper ground water resource by artificial means. To safeguard the deeper aquifer against pollution, arrangement of gate valve is made, which should be opened after 2 to 3 early monsoon showers, to deny entry of the pollutants, mainly nitrate, into the system. The Salient features of the Project are given below:

1.	Project Area	:	7.0 Hectares.	
2.	Normal Annual Rainfall	:	1520 mm.	
3.	Number of Rainy Days	:	86.	
4.	Annual Surface Run off	:	26,000 m^3.	
5.	Geology	:	Athgarh Sandstone of Upper Gondwana age. 6.	
6.	Hydrogeology	:	i.	Phreatic Aquifer is devoid of sufficient ground water.
		:	ii	Fracture zones form deeper aquifers, which are highly potential and are extensively exploited.
		:	iii	Pre monsoonal (April) depth to water level Phreatic - 7.60mbgl ; Deeper 28.50mbgl.
		:	iv	Post monsoonal (November) depth to water level Phreatic - 5.20mbgl ; Deeper - 20.00mbgl.
7.	Rain water harvested by	:	525m long trench system with lined wall, and 75m long open trench system.	
8.	Recharge bore wells	:	80m deep (3 Nos.).	
9.	Annual recharge to phreatic aquifer	:	1155 m^3.	
10.	Annual recharge to deeper aquifer	:	23670 m^3.	
11.	Ground water monitoring by	:	90m deep (1 piezometer) fitted with Automatic water Level Recorder.	
12.	Project cost	:	Rs. 14.17 Lakhs.	

HYDROGEOLOGICAL SETUP

Upper Gondwana formation represented by Athgarh sandstones consisting of fine to coarse grained, white to gray feldspathic sandstones, occur in major part of the area (Figure. 40). These are at times pebbly, conglomeratic to gritty and ferruginous layers of grayish white to pinkish clay, carbonaceous shale and Kaolin are intercalated with these sandstones. Un-consolidated formations are consisted of a sequence of sand, gravel, clay and silt layers. Laterites generally occur as capping over the Sandstones. The alluvium consists of sand, gravel and clay occurs mainly in the eastern part of the city.

A number of prominent lineaments have been identified by Remote sensing studies in the study area, which facilitate the ground water movement.

The depressions of the city follows East-West trending lineaments. Springs namely at Kedar Gouri and Baramunda are seen in this depression. These structural features are significant from hydrogeological point of view. Intersection of lineaments constitute potential zones for ground water development.

Ground Water Conditions

The city area is occupied by weathered, compact, friable and fractured sandstones. The laterites / weathered sandstones form phreatic aquifers tapped by dug wells. The dug wells range in depth from 1.70 to 15.61m. The pre and post monsoon depth to water level varies from 1.46 to 10.55 and 0.40 to 7.53 mbgl. respectively. The water table fluctuation range between 0.54 to 3.79 m and the yield varies from 1 to 3 m^3/hr. Dug wells located in topographic depressions have high yields.

The fractured and friable Athagarh sandstones form the deeper aquifers under semi-confined to confined conditions. The depth of the wells drilled in Bhubaneswar city area, ranges from 44 to 151m. Most of these wells are cased down to 15 to 25m. depth depending upon loose formation encountered. The Static Water Level in tube wells ranges from 7 to 24 mbgl. The yield of these wells ranges from 3 to 115m^3/hr. In the North-western parts of the city around Chandrasekharpur the wells sustain yield of 115m^3/hr (depth 100m), which reduces to less than 10m^3/hr in the Southern and South-western parts of the city around the Bhubaneswar air port and adjoining areas. The transmissivity values of the wells tested at CRPF (depth 150.7m) and Central Poultry Breeding Farm (depth 98.70m) are 258 and 94 m^2/day respectively. The basement is not encountered in both the bore holes. However at Aiginia area, the records of PHED bore hole indicate sharp reduction in the thickness of Athgarh sandstones and basement encountered at 25m depth only, with reduced yield of the bore wells. The bore holes were drilled by Central Ground water Board at Kapilaprasad and Khondalite basement was encountered at 51m depth.

The data indicated that fractured and friable Athgarh sandstones form the deeper aquifers. The laterites formed due to weathering of sandstones are vesicular, ferruginous and highly porous, which support a large number of dug wells.

The Unconsolidated formations consisting sequence of sand, gravel, clay and silt layers. The sand and gravel form the main repository of ground water. The Ground water in shallow aquifers occurs under phreatic conditions, while the deeper aquifers occur under confined conditions. The depth of the tube wells in this formation are generally less than 40m, tapping 10 to 15 m of aquifer thickness and the yield of the wells is about 10 lps.

Pre-monsoon water levels	:	The depth to water level during pre monsoon ranges from 1.46 to 10.55 mbgl. The deeper water levels i.e. more than 8 m, generally occur in Northwest, and western part of the city.
Post-Monsoon Water Level	:	The depth to water level ranges from 0.40 to 7.53 mbgl. The depth to water level between 2 and 4 m. occurs in eastern part of the city. The depth to water level map for post-monsoon period has been presented in Plate-3.
Water Level Fluctuation	:	The water level fluctuation varies from 0.28 to 3.79 m. The maximum fluctuation (>3m.) has been observed in Kapilprasad, Nuagaon, Jagannath prasad and Mancheswar occur in western part of the city, while the fluctuation less than 1m has been recorded in Bargarh, Koradakatta, Jharapada, OUAT Farm, RBI colony and Sahid Nagar.

Long Term Water Level Trend of National Hydrograph Stations in Bhubaneswar city

For recording long term water level trend within the city area, 5 nos. national hydrograph network stations had been established and monitored four times in a year. The long term trend of water levels indicate marginal decline in water level in the city. The main source of Ground water recharge is precipitation, which is further augmented by recharge from surface water bodies present in the area The construction of new buildings have reduced the recharge to ground water , which in turn have increased the storm runoff. The annual replenishable Ground water resource in the Bhubaneswar master plan area has been estimated to be 27.97 MCM. The hydrogeological situation prevailing in the Bhubaneswar city area is favourable for developing the ground water resource and the decline in ground water level at present is marginal. However in due course of time i.e. by 2020, the Ground water levels may further decline due to excess withdrawal of water by fast urbanisation and industrial development. To augment the ground water resource for facing any unforeseen situation in the long term, the artificial recharge techniques like, roof top rain water harvesting, surface runoff rain water Harvesting and renovation of existing tanks may be adopted

The ground water samples from shallow aquifers (Dug wells) in general have lower dissolved mineral content as all the water samples have E.C. values less than 750 micro siemens/cm at 25 ^{0} C. The electrical conductivity was found varying from 42 to 523 micro siemens/cm at 25^0 C during the pre monsoon and from 40 to 638 micro siemens / cm at 25^0 C during the post monsoon. Hence the ground water is quite fresh in Bhubaneswar. Ground Water from shallow aquifer has been found to be slightly acidic in nature. In pre monsoon, the pH ranges from 4.68 to 7.075 and in post-monsoon it ranges from 3.92 to 6.93. The chloride content of ground water in the shallow aquifers ranges from 7.1 to 80 mg/l during pre monsoon and from 3.5 to 85 mg/l during post monsoon studies. The highest value of 85 mg/l was recorded at Rasulgarh. Pre monsoon chemical quality of shallow ground water with respect to Nitrate content varies in different localities of the Bhubaneswar city. Only two wells, at Bargarh (50 mg/l) and Bapuji Nagar (55 mg/l) were found to have Nitrate more than the permissible limit of 45 mg/l (BIS 1993). In post monsoon, more wells have been found to fall under high nitrate concentration (> 45 mg/l) . The wells at Ashok Nagar, Bargarh , Kedargouri temple, Khandagiri, Delta Colony and Ganga nagar were found containing Nitrate more than 45 mg/l.

In shallow ground water of the Bhubaneswar city, the fluoride contents are within the permissible limit of 1.5 mg/l. The Total Hardness is within desirable limit of 300 mg/l as $CaCO_3$

(BIS -1993). In pre monsoon studies the hardness values ranges between 18 to 125 mg/l and in post monsoon it ranges from 14 to 200 mg/l.The iron content in phreatic aquifer is well within the permissible limit (1.0 mg/l) except in two places Damana Chhak (pre monsoon, 1.4 mg/l) and Jharpada (post monsoon ,1.4 mg/l). The existence of iron is mainly due to the iron rich lateritic formation in the area.

The ground water sample from deeper aquifers (semi/confined) have on the whole lower dissolved mineral content, as around 92 % water samples, having E.C. values less than 500 micro siemens / cm during pre monsoon studies with highest value of 561 micro siemens / cm at Lingipur hand pump. The Electrical conductance ranges between 42 and 823 micro siemens/cm at 25°c .The pH varies from 3.88 to 6.70 in the area which shows acidic nature of the water. This may be inferred due to progressive leaching action in laterite. Other chemical constituents are within the permissible limit.

2. ARTIFICIAL RECHARGE TECHNIQUES:

The Project area considered for implementing Rainwater harvesting within the Raj Bhawan premises in about 18.70 ha, which is situated on a low mound having radial slope. The Raj Bhawan main building is located centrally in the project area. Roof top rain water harvesting is planned for the main building, whereas, the open areas such as approach roads, lawns, garden areas and secretariat blocks are considered for harvesting surface run-off (Figure. 41). Based on rainfall data of Bhubaneswar IMD station, rainfall of 100mm per day is considered as the expected maximum daily rainfall of the city. Therefore the maximum amount of rainwater expected to harvest from these open areas are calculated to 2800 m^3 per day. However it was not possible to harvest all the water for the recharge work due to various hydrological/ hydrogeological factors such as, topography of project area, land forms/use, slopping pattern, shape of the project area, and the lateritic soil cover on Athagarh sandstone.

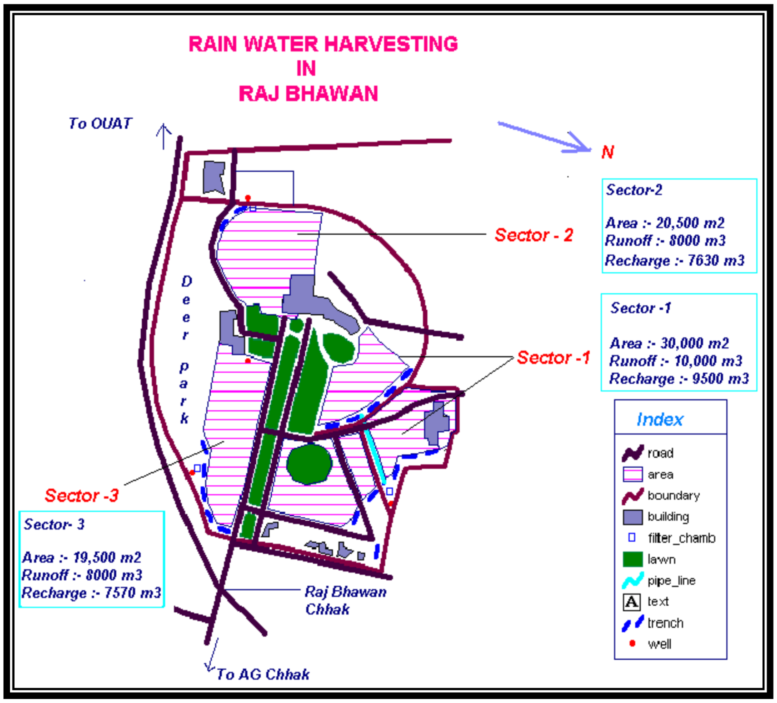


Figure 41. Layout of Rainwater Harvesting and Artificial Recharge Structure in Raj Bhawan premises, Bhubaneswar

The run-off co-efficient for calculating the maximum rainfall run-off is considered to be 15 percent in a day during peak rainy day. Based on the site conditions, recharge trench is designed as artificial recharge structure for accommodating the run-off from the open areas. The project area is divided into 4 major sectors. The details of run-off generated from different sectors, necessary structures required for and the quantity of rainwater expected to reach the groundwater regime have been given in the following table.20

Table.20 Details of Sectors, Raj Bhawan premises, Bhubaneswar

Sectors	Area in Sq.m	Potential Run-off generated by a peak shower of 100mm/day (Col.2*0.1* 0.15) cum/day	Length of 1mx1m size Trench required (Col.3/1.09) in mts.	Length of Boundary wall already existing (Suitable for Trenching) in mts.	Length of Trench to be constructed inside the sector areas in mts	Approximate amount of recharge to the GW regime cum/day.
1	2	3	4	5	6	7
Sector-I	43545	653	600	523	77	54
Sector-II	44927	674	618	400	218	56
Sector-III	20000	300	275	-	275	25
Sector-IV	52270	784	720	500	220	65
Total	160742	2411	2213	1423	790	200

* The trench recharge is taken as 3 haM/day/10^6 Sq .m of wetted perimeter

Initially, the Recharge trench of size 1m width and 1m depth was constructed adjacent to the existing 1423 m length of boundary wall all along in order to give maximum wetted area per cubic meter of trench thereby allowing optimum recharge. Further another 790 m length of recharge trench was excavated inside the garden/ lawn area in order to harvest the additional run-off generated from the areas. Iron mesh of 1.5m width was be provided over the top of the trench so as to avoid any mishaps. This recharge structure was designed to accommodate around 2400 cum of water and can sustain the maximum rainfall of 100mm per day. These artificial recharge structures are capable of adding 200 cum per day to groundwater regime from the surface run-off. Since the annual normal rainfall of Bhubaneswar is around 1520mm, these artificial recharge structures are capable of augmenting additional recharge of around 30000 cum annually to the groundwater regime considering 85% efficiency of structures. The details of sector wise structures is given in figure 42 (A-E) and table 21, 22, 23 (a-b).


A : Honeycomb Structures


B : Trench with Iron Mesh cover


C : Lined Trench with Gravel Beds


D : Filter Chamber with Recharge Bore


E : Top View of Filter Chamber

Figure 42 (A-E) : Civil Structures for Rain Water Harvesting & Artificial Recharge constructed in Raj Bhawan Premises, Bhubaneswar

Table.21 Sector wise details of structures, Raj Bhawan premises, Bhubaneswar

Sectors	Catchment area (m^2)	Expected Annual run-off (m^3)	Length of Trench (m)	Estimated Annual recharge to phreatic aquifer (m^3)	Estimated Annual recharge to deeper aquifer (m^3)
Sector –I (Police barrack)	30,000	10,000	292 (lined) 73 (unlined)	480	9,020
Sector-II (Children's park)	20,500	8,000	48 (lined) 2 (unlined)	290	7,340
Sector-III (Deer park)	19,500	8,000	155 (lined)	260	7,310
Near Garrage	4,000	1,800	30 (lined)	125	-
Total	74,000	27,800	525 (lined) 75 (unlined)	1,155	23,670

Table 22: Construction Details of Recharge Borewells

Recharge Well site (RW)	Depth of Well (mbgl)	Fracture Zones (mbgl)	Individual Discharge (LPS)	Cumulative Discharge (LPS)	Static Water level as on 07-01-02 (mbgl)
RW-I (Police Barrack)	85	35.0 47.0-51.55 78.8-83.0	2.0 5.0 4.0	11.0	25.33
RW-II (Children's park)	80	34.0 53.0 57.3-59.6 73.3-77.8	2.0 2.0 3.0 5.0	12.0	20.54
RW-III (Deer park)	80	32.4-34.7 52.85-55.15	2.0 5.0	7.0	22.24

Table 23a: Construction Details of Trenches

Sector	Location	Catchment Area Planned (Sqm)	Size of Trench L x B x H (m)	
			(Lined)	(Unlined)
Sector –I	Police barrack	11,000	106 x 1.0 x 1.2	-
	Ring side	14,000	143 x 1.0 x 1.2	32 x 1.0 x 1.00
	Coconut area	5,000	43 x 1.0 x 1.3 30 x 1.0 x 1.5	41 x 0.45 x 0.5
Sector –II	Children's Park	20500	48 x 2.0 x 0.6	2 x 2.0 x 0.3
Sector –III	Deer's Park	19500	155 x 1.0 x 1.2	-

Table 23b: Construction Details of Filter Chambers

ITEM	Location	Size of Filter L x B x H (m)	Material used
Primary filter	In the end/middle of each trench	1.0 x 1.0 x1.2	Course sand with Pebbles of 10-20 mm size, 10cm thick at top and bottom
Main filter (Filtration Chamber)	At every Recharge bore well	5.0 x 2.0 x 1.5	Fine sand (0.6 - 1 mm) with Pebbles of 10-20mm size, 10cm thick at top and 30 cm at bottom

CALCULATION PROCEDURE APPLIED FOR ARTIFICIAL RECHARGE

Considering 10% of rainfall as interception and evaporation, the rain water generated on the roof is given in table 24.

Table 24. Details of rainwater collected in roof

Amount of rain fall in mm	Rainwater collected over the roof area in mm
50	45
100	90
150	135
200	180
250	225
300	270

II. The intake capacity of the proposed borewell to be 160 cum per day.

III. As the maximum intensity of shower is around 15 mm/hr, 160 cum of roof top water can be collected in 12 hrs. in exceptional cases. While the bore well can accommodate only 80 cum of water, a trench of size 1m x 2m x 40m long is to be constructed for storing the rest. The trench is to be divided into two compartments, of which the first chamber is to be filled with cobbles and pebbles of 30 cm thick to avoid turbidity of incoming harvested water. A fine sand filter of 4 m length with multiple compartment is to be constructed to make the water free from sediments. The filtered clear water is then routed to the recharge bore well by an outlet pipe through a sieve of 0.5mm to 1mm size.

IV. The structure thus designed can accommodate maximum of 220 cum of water in a day, that is equivalent to 250 mm of rainfall. As the trench can recharge 5 cum/day to the phreatic aquifer, the dead storage in the trench will thrive only for 12 to 15 days after a peak rainfall.

V. Addition of rainwater into the deeper aquifer through the recharge well produces a cone of influence around it. It's radius is independent of the amount of harvested water added (Q) and is governed by the following formula,

$$R = \sqrt{\frac{2.25Tt}{S}}$$

So, a heavy rainfall of around 250mm with moderate intensity can recharge the aquifer 700m away from the recharge well, while the same rain with low intensity can recharge upto 1000m. The addition to the groundwater reservoir is calculated as 100 cum in both the ways.

Since the rainfall ranges from drizzles to heavy downpour, the amount of annual recharge to the deeper aquifer can vary from 1000 cum to 600 cum respectively, whereas the annual recharge to the phreatic aquifer is around 350 cum. Thus the structure can recharge an additional quantity of 1200 cum of water annually on an average to the ground water regime (Table 25).

Table.25 Estimated Recharge to Phreatic and Deeper Aquifers by Rain Water Harvesting

Recharge well	Sectors Covered	Catchment Area Planned (Sqm)	Annual Run-off generation capability (Cum)	Size of Trench L x B x H (m)	Estimated Annual Recharge to Phreatic aquifer (Cum)	Estimated Annual Recharge to Deeper Aquifer (Cum)
RW-I	Sector - I	11,000	10,000	107 x 1.0 x 1.2	480.0	9020
	Sector - II	14,000		133 x 1.0 x 1.2		
	Sector - III	5,000		44 x 1.0 x 1.3		
RW-II	Sector - IV	19,500	8,000	155 x 1.0 x 1.2	260.0	7340
RW-III	Sector - V	20,500	8,000	75 x 2.0 x 0.6	290.0	7310
Total		70,000	26,000		1030.0	23670

IMPACT ASSESSMENT

In order to get the necessary feedback about the structure, an Automatic Water Level Recorder was lowered in the Piezometer. The Piezometer is centrally located with reference to the Recharge Borewells and Pumping Borewells in order to get good reflection of recharge and withdrawal impact on the ground water regime. The Automatic Water Level Recorder is capable of recording ground water level data hourly and can be set at any multiple of hour. The data and its analysis are presented in Figure. 43, 44 & 45.

Pumping impact on the ground water regime is clearly observed in the Hydrograph (Figure. 45). The daily water level fluctuation is in the tune of 0.7 meter, which can't be attributed by the diurnal fluctuation of ground water level. Each day there is a peak representing recovery during night and a trough representing pumping during daytime by the three pumping stations present in the campus. Small sharp peaks at trough center represents stoppage of pumping in some pumping stations between 12 noon to 3 P.M.

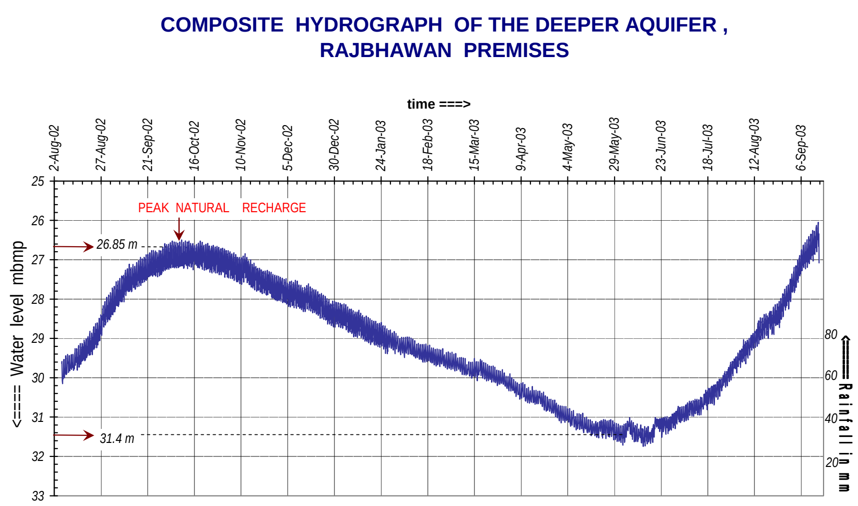


Figure 43 : Composite Hydrograph of Deeper Aquifer, Raj Bhawan Premises, Bhubaneswar

The water bearing fractures are present approximately at 35, 57 & 79 meter below ground level and are confined in nature. In phreatic aquifer the impact of rain on ground water is immediate, while in case of confined aquifer it takes few hours to few days depending on the distance of the recharge zone from the observed location. So sudden rise of water level during rain is caused by the direct recharge of the aquifer at the recharge well site thus indicating artificial recharge. Early monsoonal showers clearly depict this pattern where as the impact of late showers are being marred by the natural ground water recharge.

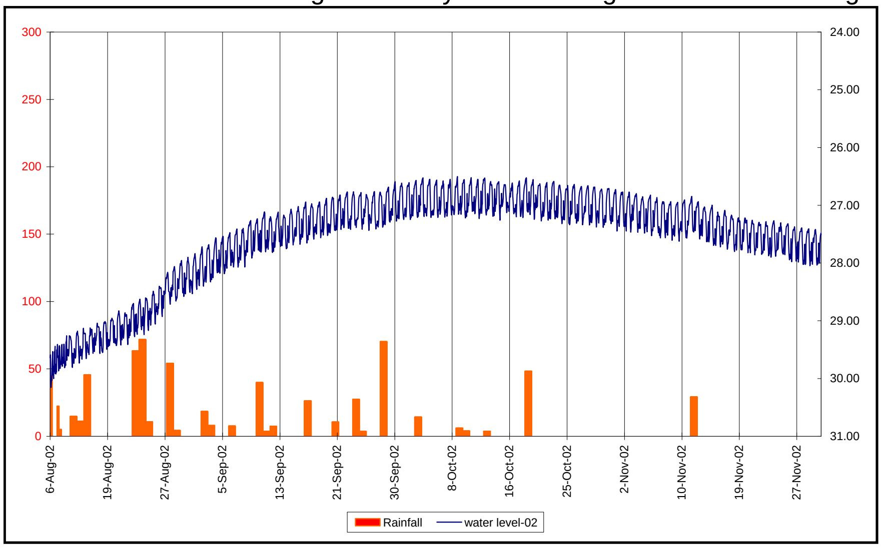


Figure 44 : Effect of Rainfall on the Deeper Aquifer

Comparison of water level data from early August to Mid September shows a rise of around 1 meter in the ground water regime (Figure. 46). The cumulative monsoonal rainfall from May onwards, show less rainfall in 2003 than that of the year 2002. Therefore the rise is clearly attributed to the artificial recharge. The natural monsoonal recharge is around 4.55 meter as depicted in Fig-47. A rise of 1.0 meter of water level thus, contributes to 22% of ground water resource augmentation due to artificial recharge.

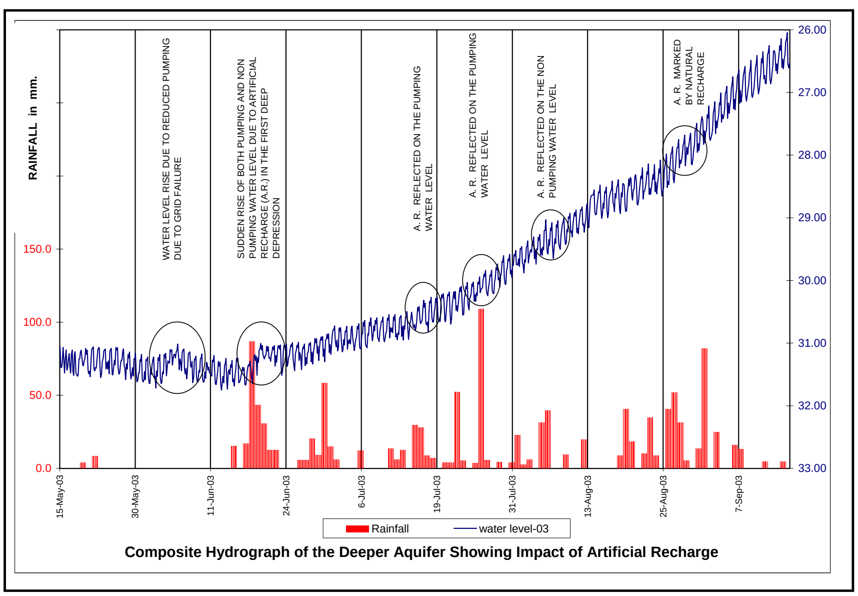


Figure 45 : Impact of Artificial Recharge on Deeper Aquifer

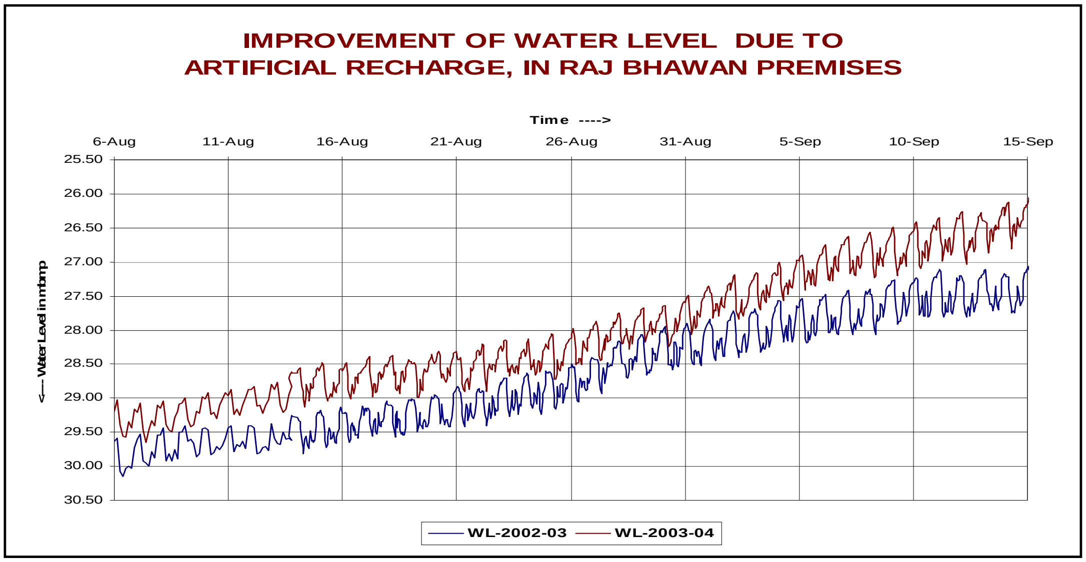


Figure 46. Improvement of Water Level Due to Artificial Recharge, Raj Bhawan Premises, Bhubaneswar

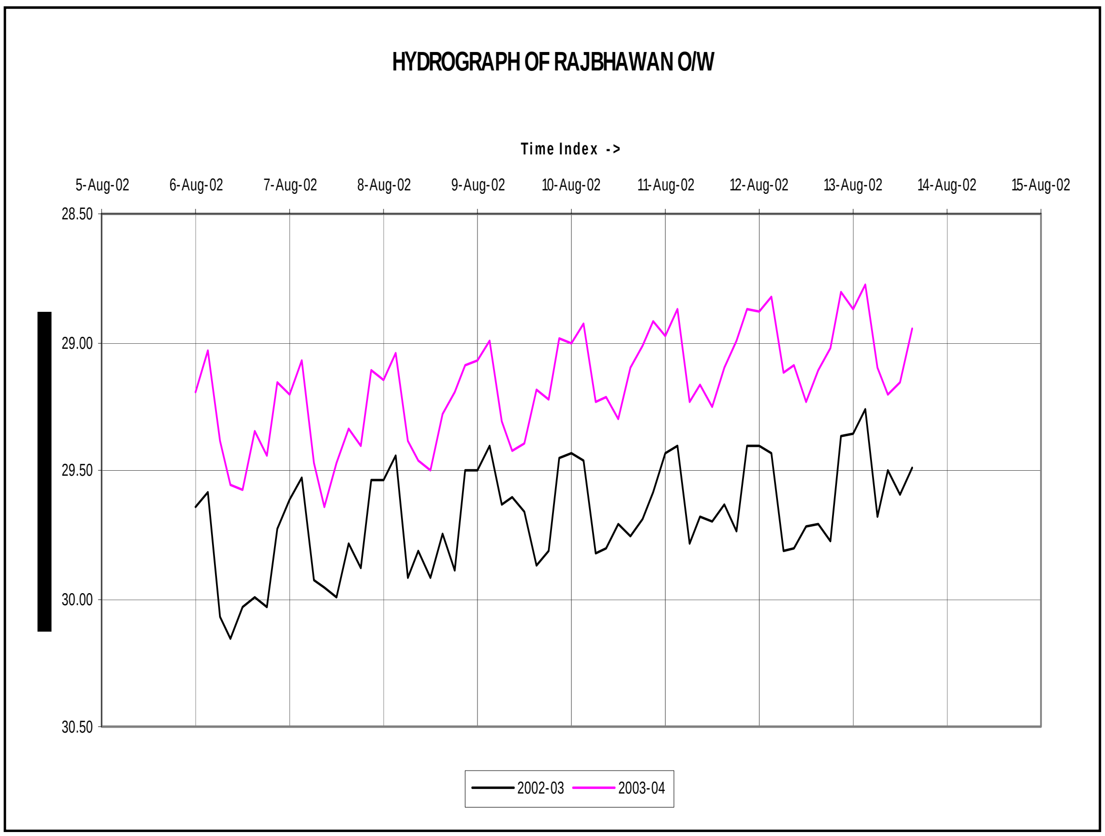


Figure 47 : Hydrograph of Observation well, Rajbhawan Premises showing Impact of Artificial recharge

Pilot Study on Arresting Salinity Ingress & Artificial Recharge to Ground Water through creeks

A number of projects have been taken up in coastal saline hazard areas utilizing the minor creeks and nalas for storing the fresh water for irrigation and side by side injecting the fresh water into saline water bearing shallow aquifers so that the salinity of water can be reduced and make it useful for irrigation and other purpose. The second part of the project i.e. injection of fresh water into saline water bearing aquifer has been taken up purely on pilot basis. The salient information on the projects is as below:

Feasibility study was undertaken by Central Ground Water Board in 2001 to work out a project with a view to control salinity ingress in the surface flow of creeks as well as recharge to the saline water aquifer to change the quality and availability for its subsequent use. The following observations were made at the onset.

i. The creeks and sub creeks are required to be desilted
ii. Suitable outlet should be provided to increase irrigation intensity.
iii. Sluice gates are required to be maintained properly and should be strengthened.
iv. Inflow and outflow of fresh/tide water should be monitored.
v. Salt resistant paddy should be grown.

With a view to above suggestions, the work was taken up by the C.G.W.B under the Central Sector Scheme of water harvesting and recharging to ground water. Seven pilot schemes in parts of Bhadrak, Kendrapara and Puri districts were taken up for this purpose (figure – 48).

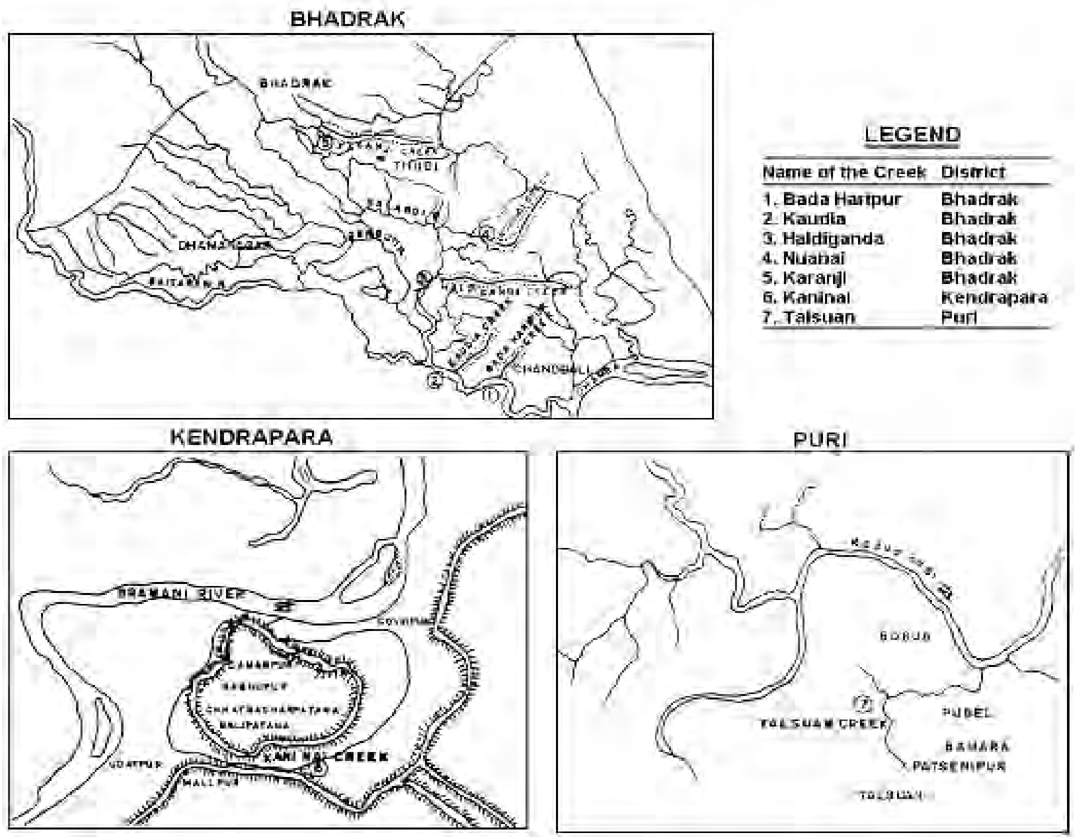


Figure 48 Creeks identified for Arresting Salinity Ingress in Bhadrak, Kendrapara & Puri District, Orissa

There were two components of these schemes.

The work of construction of shallow piezometers to monitor ground water build up and improvement in water quality due to water spreading in creeks and work shall be carried out by Central Ground Water Board.

The work of strengthening and provisioning of sluice gates / tidal regulators on creeks as well as other related civil works shall be done by WAPCOS and Govt. of Orissa.
The people of these areas mainly depend on agriculture and irrigation, which mainly depends on the availability of water in creek and sub creeks. During drought and scattered rainfall years, Kharif paddy gets damaged and Rabi crops could not be raised due to lack of irrigation facilities. On implementation of these schemes, the impounded sweet water in the creek can easily be utilised by the farmers through indigenous devices. The following creeks were studied and proposed for work.

i. Haldiganda Creek, Chandabali block, Bhadrak district.
ii. Kaudia creek, Chandabali block, Bhadrak district.
iii. Nuanai creek, Chandabali block, Bhadrak district.
iv. Karanji creek, Tihidi block, Bhadrak district.
v. Bada Haripur creek, Chandabali block, Bhadrak district.
vi. Kani creek, Rajnagar block, Kendrapara district.
vii. Talsuan creek, Kakatpur block, Puri district.

The brief descriptions of the above creeks are given below.

3.1 Haldiganda Creek

The Haldiganda (Nunajore) is a drainage channel, which off takes from the river Salandi near the village Hengupati and out falls to the river Matei, which is 2 km down stream of Bansada ferry ghat. The length of the channel is 19.74 km and drains out from an area of 9000 ha in the Chandbali block of Bhadrak district through 34 numbers of sub creeks. The total length of these sub creeks is 79.26 km.

The Haldiganda creek receives sweet / fresh water flow from Salandi river upto mid of March. One sluice gate has been provided near village Hengupati across this creek to impound sweet/fresh water. Another sluice gate has been provided near Matei river side to prevent ingress of saline water from the Sea. At present creek and sub creeks are silted up, which retards the easy flow of water.

However, a small part in the area is being irrigated in the proposed project area. People are utilizing this water for irrigation (mainly Summer Paddy and Wheat) and other selective cash crops. The sluice which has been damaged during last super cyclone, needs repair.

The water flowing from Salandi river is found to be sweet/fresh up to mid of March which can be impounded in Haldiganda creek and sub creeks through sluice gates at Hengupati and Biswanathpur. The impounded water in the creek and sub creeks can easily be utilized by the farmers through indigenous devices. This will cater to irrigate 1103 hectares in Rabi and selective cash crops could be raised along this creek. There are 23 villages to be benefited through this scheme. The main creek will also provide inland transportation of agricultural products of locality as it was in practice earlier. It may also provide connectivity to the villages, through water ways if needed.

3.2 Kaudia Creek

The Kaudiajore off takes from the river Salandi and out falls in the river Baitarani near Chandbali. The length of the jore is 11.85 kms. There are 28 numbers of sub creeks which join the Kaudia jore and the total length of sub creeks is 33.5 kms. The water enters into the main creek and sub creeks and remains fresh/sweet upto 1st week of March which can be utilised for irrigation purpose by the framers through indigenous devices. One sluice gate has been provided across Kaudiajore near Chandbali to prevent ingress of tidal water from the Sea. Creek and sub creeks are silted up which needs renovation. One sluice gate is suggested at suitable point where Kaudiajore meets Salandi.

The impounded fresh/sweet water in the creek and sub creeks on full implementation of scheme could be utilised for irrigation by the farmers especially in Rabi season and Supplement in Kharif during dry spell. This will create an irrigation potential of 1120 ha. in Kharif season and 400 ha. in Rabi season.

3.3 Nuanai Creek

The Nuanai Creek off takes from the river Matei near village Baliapal and ultimately joins to another creek “Terjodia” Nallah. The length of the main creek is 7 Km and sub creeks 21.35 Kms. The creeks are silted up as a result of which flow of water is obstructed.

One sluice gate if provided at Baliapal at Nuanai and Matei confluence it will facilitate flow and prevention of tidal water into Nuanai. The fresh/sweet water may be allowed to impound in the creek/sub creeks and impounded water may be utilised for irrigation during Rabi and Kharif seasons. The main creek and sub creeks may be renovated which not only help in irrigation but also in quick discharge of accumulated water. The drainage congestion can also be relieved through the drainage after renovation.

3.4 Karanji Creek

The Karanji nala originates from the escape channel of Dasmeriza canal (Salandi irrigation canal). Near Baruni village it bifurcates into Karanji nala and Kundi nala. The catchment of Kundi nala and Karanji nala is 755 ha and 1195 ha respectively. The nalas are situated in the flooded area without any protection embankment. The nalas have joined at a distance of 1 Km down stream of the existing sluice site and flowing for length of 6 Km in the name of Dholi nala which fells into Matei river. The total length of 4 numbers main creeks is 7.10 Kms and 4 numbers of sub creeks is of 6.8 kms. The creeks and sub creeks are silted up. There are two sluice gates at Kundi and Karanji which are badly damaged. Strengthening of the gates may be ensured for impounding of fresh water and preventing saline water. Provision for construction of additional drainage outlets may be considered. Creeks and sub creeks are to be renovated for proper drainage and impounding fresh water. The irrigation potential likely to be created is around 810 ha in Kharif and 442 ha in Rabi. The agricultural activity in the area will boost the socio-economic condition of the people.

3.5 Bada Haripur Creek

The Bada Haripur creek which is a drainage channel and takes off from the left bank of Baitarani river near the village Bada Haripur extends for a length of 5 Km. It drains out an area of 1500 ha. There are 12 numbers of sub creeks having total length of 20.16 Kms. Due to tidal effect, sweet water is pushed into these creeks which is used for irrigation. Presently creeks and sub creeks are siltedup and as a result of which the entry of sweet water from river Baitarani into the creeks has been blocked up. Existing drainage sluice a Badaharipur is to be strengthened to regulate sweet flow from Baitarani river and prevent tidal ingress. Renovation of drainage channels, creeks and sub creeks for impounding fresh water and provision of outlet will facilitate recharge to ground water regime.

3.6 Kani Creek

The lengths of the Kani creek and sub creeks are 13km and 20 km respectively. It covers drainage area of 1000 ha. There is no regulatory provision for movement of sweet water and prevention of tidal water into the creeks. Presently creeks and sub creeks are silted up with the construction of 3 nos. of sluice gates, renovation of creeks and sub creeks etc, drainage congestion will be relieved and ingress of saline water through control sluice could be checked.

3.7 Talasuan Creek

The length of the Talasuan creek is 3.5km and sub creeks are 7.0 km. The total drainage area is 500 ha. There is no regulatory provisions for movement of sweet water and preventing ingress of saline water in the creeks. Presently creeks and sub creeks are silted up.

It was proposed to construct sluice gate to regulate the flow of sweet/fresh water and renovation of creek and sub creeks of estimated cost of Rs.0.2 crores. With this, drainage congestion will be relieved and ingress of saline water can be checked through sluice gate.

Execution / Construction Activity

The following works were done for arresting saline ingress

- Desiltation and renovation of the creeks by excavation
- Remodelling of old sluices and construction of new ones
- Construction of 15 small(VRB) bridges and one high level bridge across Bhadrak-Chandbali road over the creeks

The details of renovation work carried out in the creeks are given in table 26

Table 26 Details of Renovation Work Done

Sl No	Name of Creek	Number of			Excavation	
		Creeks	Sub-Creeks	Total	Estimated Quantity	Executed Quantity
					CuM	CuM
1	Haladiganda	1	31	32	3,31,000	3,30,800
2	Kaudia	1	28	29	1,01,440	1,01,140
3	Badaharipur	1	14	15	93,340	93,340
4	Nuanai	1	24	25	2,16,465	2,12,983
5	Karanji	1	6	7	2,45,685	2,45,685
	Total	5	103	108	9,87,930	9,83,908

Impact Assessment

After renovation of creeks and remodelling of sluices, the fresh water has been impounded in the year of 2002 – 03. The amount of fresh water impounded in the creeks is given in table 27. There has been a remarkable increase in water availability and irrigation potential after implementation of the project. The irrigation potentiality was 30 % during 2002 – 03 and it increased to 60 % during 2003 – 04. The photographic glimpses of the structures constructed have been given in figure 48 (A-H) and the impact assessment details are given in table 28. The details of Kharif and Rabi ayacut and under creek are given in table 29a& b

Table 27. Fresh Water Impounded in the Creeks(2002-03)

Sl No	Creek Name	Fresh Water Impounded
		CuM
1	Haladiganda	4,65,000
2	Kaudia	1,20,000
3	Badaharipur	1,70,000
4	Nuanai	1,60,000
5	Karanji	1,96,000

Table 28. Impact Assessment of Arresting Salinity Ingress
(Under Central Sector Scheme)

Sl. No.	Name of Creek	Water Availability		Increase in Irrigation Potential
		Pre - Execution	Post - Execution	
		m^3	m^3	m^3
1	Haladiganda	10,46,88.40	5,63,115.80	4,58,478
2	Badaharipur	22,660	1,15,640	93,000
3	Nuanai	14,960.25	1,186,380	1,70,000
4	Kaudia	1,23,150	2,84,246	1,60,000
5	Karanji	3,00,00	810,000	5,10,000

Table 29 a : Impact Assessment – Details of Ayacut Covered under Creek Irrigation

Sl No	Creek Name	Ayacut in Target (Ha)		Ayacut Achieved 2002 - 03 (Ha)		Ayacut Achieved 2003 - 04 (Ha)	
		Kharif	Rabi	Kharif	Rabi	Kharif	Rabi
1	Haladiganda	1367	2708	410	812	820	1825
2	Badaharipur	1200	424	360	30	720	255
3	Nuanai	1456	742	437	225	875	445
4	Kaudia	1120	1429	336	430	675	860
5	Karanji	810	142	245	150	500	100
	Total	5953	5445	1788	1647	3590	3285

A. Ricket Chattara Creek – Excavation in progress

B. Ricket Chattara Creek – After Completion of Excavation

C. Sashikadeipur Creek – Excavation in Progress

D. Kalidaspur Sluice – Reinforcement Details

E. Kuhali-Baupokhari Sluice – Reinforcement Details

F. View of Andola Sluice after Completion

G. View of Gahamnali Sluice after Completion

H. View of Karanjadia Sluice after Completion

Figure 49 (A – H). Civil Construction Structures in the Creek Areas of Bhadrak District

Table 29 b : Impact Assessment Details under Creek Irrigation

Creeks / Effects		Haldiganda	Badaharipur	Nuanai	Kaudia	Karanji
Salinity Ingress Check		Completely Checked and Multiple usage of creek water done	Completely Checked and Multiple usage of creek water done	Completely Checked and Multiple usage of creek water done	Completely Checked and Multiple usage of creek water done	From Mantei river completely checked. 1950 Ha made free of Salinity & Water Logging. Multiple usage of creek water done
Impounding Capacity (CuM)		4,65,000	1,20,000	1,70,000	1,60,000	1,96,875
Ayacut Irrigated (Ha)	Khariff	367	1200	1456	1120	810
	Rabi	2708	424	742	1429	142
Increased Irrigation Potential (HaM)		460	93	170	160	810
Ground Water Recharge		All along the Creek network	All along the Creek network	All along the Creek network	All along the Creek network	17.5 Km Tract Recharged

Case Study on arresting Salinity Ingress & Artificial Recharge to Ground Water in parts of Basudevpur & Chandbali Blocks of Bhadrak District, Orissa

PROJECT AT A GLANCE

I. General Particulars
- (a) Location : 20^{0}55' and 21^{0}15' North Latitude; 86^{0}45' and 86^{0}55' East Longitude
- (b) Project Area : 830 Km^{2} (Appx.)
- (c) District Head quarters : Bhadrak
- (d) Subdivision : Bhadrak
- (e) Blocks : 1.Basudevpur (Part); 2. Chandbali (Part)

II Climatology :
- (a) Average annual rainfall : 1528 mm
- (b) Maximum temperature : 36°C (May)
- (c) Minimum temperature : 14°C (December)

III Name of the scheme — "Arresting Salinity Ingress & Artificial Recharge to Ground Water in parts of Basudevpur & Chandbali Blocks of Bhadrak District, Orissa".

V Financial outlay of the project
- Initial Estimated outlay of the Scheme — Rs. 647 lakhs
- Actual expenditure — Rs. 549.25 lakhs

V Date of Launching of the project — 09.01.2002
- Duration of the project — 2002-2004

VI Funding Agency — Ministry of Water Resources, Govt. of India

VII Implementing Agencies

	State Water Resources Department, Govt. of Orissa.	(Civil and structural works)
	WAPCOS India Ltd.	(Consultancy and supervision charges)
	CGWB, Govt. of India	(Construction of recharge wells and allied structures etc)
VIII	Details of Creeks/ sub creeks renovated	
	No. of creeks and sub creeks identified for renovation	27
	Total quantity of earth work carried out for desiltation of creeks	12,27,876 cum
	No. of sluices	6 Kalidaspur Gadala, Kuhaliboupukhari, Andola jhor, Karanjadia, Gahama nala Baliapada
	No. of foot bridges constructed	27
	Total length of creeks/sub creeks renovated	76.60 km
IX	Impact Assessment after construction of sluices and renovation of creeks/sub creeks	
	Quantity of fresh water impounded in 27 creeks/sub-creeks	798119.29 cum
	Irrigation potential created	5500 Ha in Rabi 5500 Ha in Kharif
X	Hydrogeological investigation and construction of recharge structures etc.	
	Geological formation	Alluvium
	Major geomorphic features	Coastal plain, Tidal flat, Marshy land, Estuaries, palaeo-dunes and creeks.
	No. of recharge well constructed	22
	No. of piezometers constructed	15
	Occurrence of fresh/brackish water zones	0-10 fresh, 10-180 saline, 180-246 fresh, >246 saline
	Zones tapped	15-45 m bgl
	Yield of the wells	15-32 lps
	Transmissivity	274-1798 m^2/day
	Specific capacity	2.6-13.3 lps/m
	Static water level of shallow piezometers	1.02-2.10 m bgl
	EC in μs/cm at 25^0 C	777- 30525
XI	Findings on Impact Assessment studies	
	Intake capacity of recharge wells	5,37,192 cum
	Post project observations and data analysis.	Improvement in water quality with passage of time and fresh water lense / ridge created over brackish water to arrest salinity ingress.

AIM OF THE PROJECT

The area represents the zone where land and sea meet and comprise a variety of geomorphic features like estuaries, marshes, palaeo-dunes, tidal flats and tidal channels /creeks The creeks are tidal in nature and salinity ingress is a regular phenomenon in the area. The project aims at arresting salinity ingress and improving irrigation facilities in the area through the development of creeks/sub creeks, which were silted up over space and time. Moreover, an attempt has been made for improving the ground water quality by injecting the fresh surface water impounded in the creeks/sub creeks to the saline aquifer system by adopting artificial recharge techniques.

BENEFITS FROM THE PROJECT

Improvement of Irrigation facilities Renovation of the creek system and Sluice and Check weirs have been constructed to regulate sea water ingress and to impound the fresh water in the creeks through tidal influx. Proper sluice arrangement was made at the end of each creek. During full moon and new moon days sluice gate is opened for entry of fresh water into the creeks and once the creek gets filled up, the sluice gate is closed. The fresh water thus impounded is being used for irrigation through indigenous devices. Rabi crops like wheat and mustard, green vegetables are cultivated in the area after these constructions. Now it is observed that people have started double cropping pattern since the implementation of this project. Quantity of fresh water which will be impounded in the 27 creeks/sub-creeks (figure – 50) has been estimated as 798119.29 cum and irrigation potential of 5500 ha in Rabi and 5500 ha during Kharif has been created from the project.

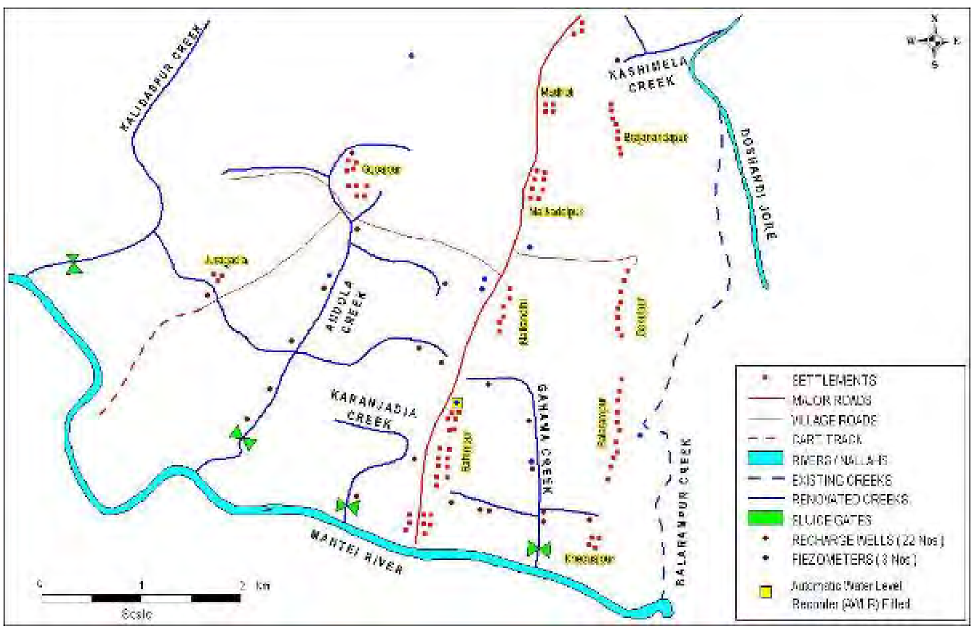


Figure 50 : Artificial Recharge Structures in Basudevpur and Chandbali Blocks of Bhadrak District, Orissa

ARTIFICIAL RECHARGE STRUCTURES

Based on the prevailing hydrogeological conditions of the area, 22 numbers of recharge wells of 152mm diameter has been constructed by means of Water Jet Technique, which is similar to Rotary Drilling. The brackish water zones existing between 15m to 45 meter below ground level were tapped by lowering suitable well assembly. As the water level in the recharge well is around 0.5 to 1 meter below that of the canal water level, a pressure head of around the same is planned to be maintained by siphoning the excess creek water in to the brackish aquifer system.

The excess fresh water is directed to the recharge well by overflow pipes of (2½" dia) with regulatory valve arrangements. A coarse sand filter is constructed to filter effectively the creek water before entering into the recharge well. To check and monitor the recharge, a gate valve and water meter arrangement has been made to each recharge well.

IMPACT ASSESSMENT

As the canal water head is around 0.5 meter above the water level of the recharge well, thus ideally the well can accept water at the rate of half of the Specific Capacity. However the intake capacity of wells seldom matches with that of pumping capacity due to a lot of factors like siltation of the aquifer, air entrapped in the recharged water, clogging of the well screen by bacterial activities and flocculation by mixing of two different type of water (Todd et.al, pp 467-468). Hence 75% of intake capacity is taken into consideration for recharge calculation.

Taking in to consideration of the Specific capacity of the recharge wells as well as the factors described above, the total intake capacity works out to be 36.16 lps for 21 number of recharge wells. The total quantity of water that can be recharged for 250 operational days comes to 716256 m^3. Hence, the 75% of this quantity i.e. 537192 m^3 (716256*0.75) may be taken as total quantity for recharge.

Generally, the river (Matei) water remains fresh up to March and gets brackish to saline during summer i.e. April to June. However, heavy late monsoon showers in 2003, which continued up to December 2003, had led to the availability of fresh water during the full summer. So as the recharge wells were made operational during April 2004, sufficient fresh water had entered into the aquifer system. Thus a floating fresh water lense is detected at the piezometer constructed at Rahimpur village. This floating fresh water has variation of quality downwards. The water sample collected from 4 m bgl on 4.6.2004 has shown EC of 760 μs/cm at 25^0C while that collected from 13 m bgl has given EC of 2288μs/cm at 25^0 C. The formation water is found out to be 36000 μs/cm at 25^0 C.

The AWLR having the provision of EC measurement was lowered in the above-mentioned piezometer and was programmed for 2 hourly data acquisition. The continuous data on the fresh floating water lense for 7 days from 4.6.2004 to 10.6.2004 is summarised in the figure-51. The EC has improved continuously in stepwise manner from 2288 to 1727 μs/cm at 25^0 C. Though the ground water level is on a decline trend due to summer season, the improvement of ground water quality indicates that artificial recharge is on progress.

An interesting correlation is observed between the EC and the temperature of the ground water. Sudden rise of ground water temperature coincides with the steps where ground water improves its quality. This can be explained by the differences of temperature between the surface water harvested in the creeks and the ground water existing in the aquifer. During summer seasons the surface water temperature used to be around 31^0C, which is more than that of the ground water. Thus when large volume of fresh surface water is recharging the aquifer, its reflection on the ground water temperature is imminent (figure. 52).

Monsoonal rain generally starts from mid June and thus creeks and canals got filled up with rainwater as well as from the fresh river water. Artificial recharge during the whole monsoonal period has improved the quality still further as the EC has reached 1500 μs/cm at 25^0 C during October 2004.

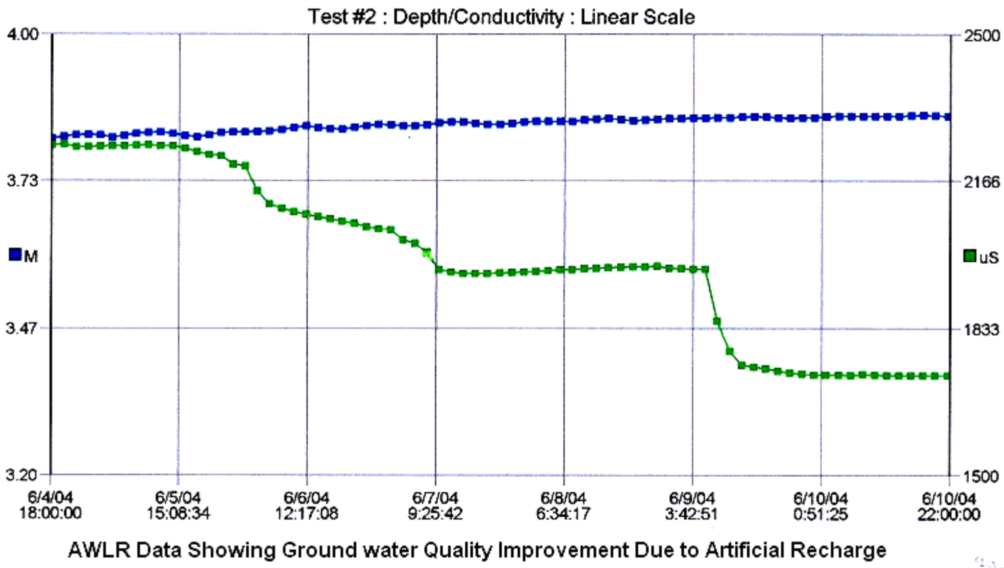


Figure. 51 : Improvement of Ground Water Quality due to Artificial Recharge (Depth Vs Conductivity)

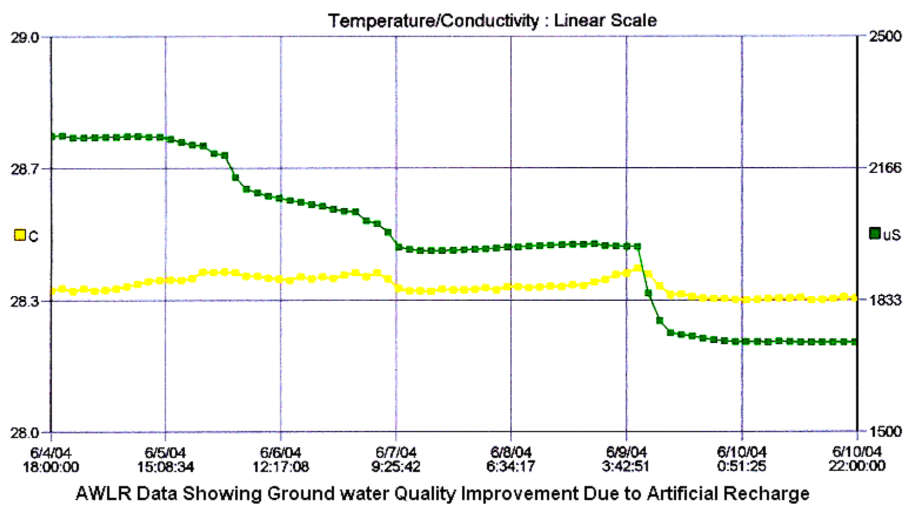


Figure. 52 Improvement of Ground Water Quality due to Artificial Recharge (Temperature vs Conductivity)

To determine the utility of the fresh water lense floating over the brackish / saline zone a pumping test was carried out on piezometer. The water quality was found to be fresh up to 5 minutes of pumping with EC of around 2683 μs/cm at 25^0 C. The water is of Na (Cl + HCO_3) type with the concentration of Chloride is twice that of the Bicarbonate (Table – 3). This can be explained by the fact that the floating fresh water-bearing zone develops on the saline aquifer by replacing the saline water. Thus when the NaCl type of water is getting replaced by Ca $(HCO_3)_2$ type of water, Ion exchange results in the formation of Na(Cl + HCO_3) type of water. If the undisturbed fresh water of the floating zone could have been collected, then it could have been of Na HCO_3 type.

Once pumping was stopped, the water level start recouping by gushing of fresh water from all around. Hence EC started improving from 46000 to 8504 µs/cm at 25^0 C between 11 days. However the improvement is not uniform and sudden jump of EC from 45290 to 16622 µs/cm at 25^0 C within 12 hours was conspicuous (figure. 53).

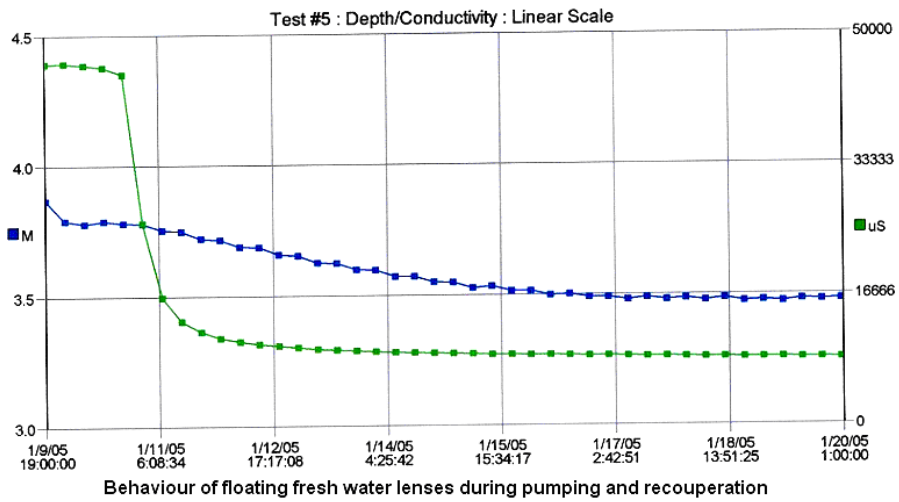


Figure – 53. Behaviour of floating fresh water lenses during pumping & recouperation

The pilot project is one of its maiden attempts taken up by Central ground Water Board in the coastal creek areas of Orissa. On successful implementation of the project and based on pre- post project data gathered from field studies, it was observed that there is a remarkable change in water quality with passage of time. Further, the project had accrued many benefits in terms of higher agricultural production through double cropping and has encouraged the local people to adopt cash crops especially during rabi season. Also, the areas, which were prone to drainage congestion and flooding, are now free from such water logging and heavy inundation. Foot bridges have helped the local farmers in transporting their agricultural produces and crossing of castles. The areas that were unapproachable have now become easily accessible.

The recharge wells near to the sluices need frequent maintenance, as the tidal water is muddy and is choking the filter bed. The pipe which is connecting the canal to the recharge structure also require maintenance against the entry of wooden pieces, dead aquatic animals, etc which are responsible for choking the pipe. Hence the following are some of the feedbacks received from this study:

Around 15% of the project fund can be earmarked for such types of schemes towards the maintenance of the A.R structures, which is vital for its continued operation.

Recharge structures near sluices are to be avoided as the effect of heavy influx of saline water during high tides may affect the recharge well.

In future, such structures are to be constructed in the creek / canal itself to avoid use of pipes and gate valves etc. which need constant maintenance.

The floating fresh water lense can be utilised by deploying low capacity pumps. The drawdown should be kept as low as possible (less than 0.3 meter) as one meter of drawdown can lead to 40 meter rise of fresh-saline water interface (Ghyben – Herzberg Principle).

To get optimum recharge, the creeks / canals are to be filled up frequently as the recharge amount depends on the differences between the canal level and ground water head. To achieve this, sluice gates require to be properly regulated in time.

Artificial Recharge to Ground Water by GWS&I, Govt of Orissa

The Directorate of Ground Water Survey & Investigation (GWS&I), Govt of Orissa had taken up some pilot projects on artificial recharge to ground water in Orissa under the Central Sector Scheme, funded by the Govt. of India, for popularizing the artificial recharge techniques in the State (Table 30). These includes the following four districts:

- Artificial Recharge to Ground Water in Kalajhore Watershed, Khallikote Block, Ganjam District
- Artificial Recharge to Ground Water in Tamkajodi Watershed, Saharpada Block, Keonjhar District
- Artificial Recharge to Ground Water in Barkatia Watershed, Athgarh Block, Cuttack District
- Roof Top Rain Water Harvesting at Hydrology Project Administrative Building, Bhubaneswar

Pilot of Artificial Recharge to Ground Water in Kalajhore Watershed, Khallikote Block, Ganjam District

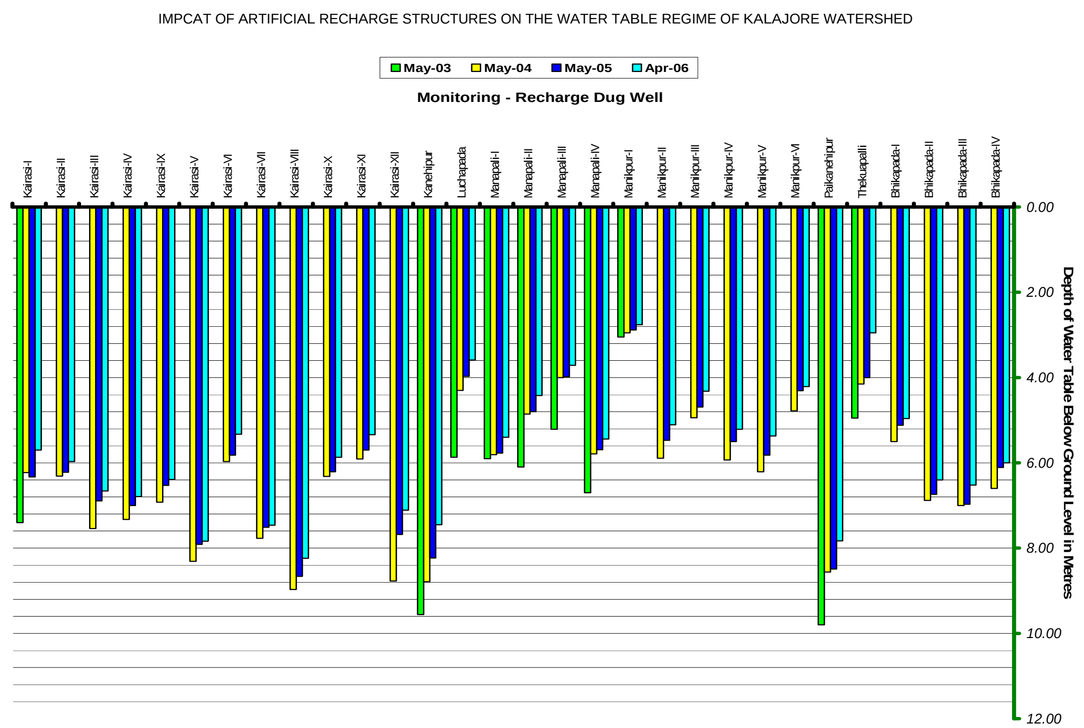
Watershed	:	Kalajhore
Block	:	Khallikote
District	:	Ganjam, Orissa
Approximate Project Area	:	17 Sq. Km.
Number of villages covered	:	09 (Manapali, Kairasi, Thekuapali, Manikpur, Luchapada, Kanehipur, Bhikapada, Kandigaon)
Total rainfall	:	1290 mm
Project Execution by	:	GWS &I Division, Berhampur
Total amount spent	:	Rs. 33.32 Lakhs
Total volume of Recharge	:	$1.04 \times 10^5 m^3$
Rise in water table	:	0.90m

Table 30. Recharge Structures constructed, Kalajore Watershed, Ganjam.

Sl No	Location	Recharge Dug Well	Gully Plug	Recharge Pit	Recharge Tank	Renovation of Tank
1.	Manapali	4	20	3	1	-
2.	Kairasi	12		9	1	-
3.	Thekuapali	1	-	3		-
4.	Manikpur	6	-	-	1	1
5.	Luchapada	1	-	2	-	-
6.	Kanehipur	1	-	3	-	-
7.	Paikanehipur	1	-	-	-	-
8.	Bhikapada	4	-	-	-	-
9.	Kandigaon	-	-	-	-	1
	Total	30	20	20	3	2

Impact Assessment

In total, 30 recharge dug wells, 3 recharge tanks and renovation of 2 tanks had been executed in the project area in two phases. All these structures were completed by end of March 2004. The ground water table was monitored periodically in all recharge dug wells and few domestic dug wells in the project area from the benchmarked month of May 2003 up to May 2006. Monitoring of depth to water level indicate the tremendous impact of the recharge structures on the ground water regime of the region (figure. 54). On an average, the impact has resulted in increase of summer water table by 0.90 Meters in domestic dug wells. This ecological impact in the project area has also lead to improvement of soil moisture and created a verdant landscape in summer. People are quite happy to find water in their wells during the worst part of the summer (April-May). They have been eagerly explaining the positive effect of the project to all visiting teams of officers representing Govt. of India / Govt. of Orissa with a hope to increase the density of these artificial recharge structures in the watershed so that they can harvest more water to meet their farming requirements. The ground water resource of the project area has been impacted due to augmented recharge during monsoon season. The pre-project assessment of ground water resource was made based on the rainfall infiltration factor. It was estimated to be 127 Hectare Meters (HM). During post-project period, the summer water table has been raised on an average 0.90 M, which is equivalent to additional 10.44 HM of ground water resource over and above 127 HM. Hence the present ground water resource of the project area is assed to be 137.44 HM based on the water table fluctuation.



B: Recharge Wells

Figure 54. Impact Assessment – Improvement in Depth to Water level, Kalajore Watershed, Ganjam District

Artificial Recharge to Ground Water in Tamkajodi Watershed, Saharpada Block, Keonjhar District

Watershed	:	Tamkajodi
Block	:	Saharapada
District	:	Keonjhar, Orissa
Approximate Project Area	:	15 Sq. Km.
Number of villages covered	:	07 (Danuatangarpada, Daspada, Gandabeda,

		Telipada, Sandhanurjaypur, Ghuntanalli, Jamunalli)
Total rainfall	:	990.78 mm
Project Execution by	:	GWS &I Division, Baripada
Total amount spent	:	Rs. 49.75 Lakhs
Total volume of Recharge	:	$8.10X10^6 m^3$
Rise in water table	:	0.69-1.54 m (premonsoon) 0.38-2.35 (postmonsoon)

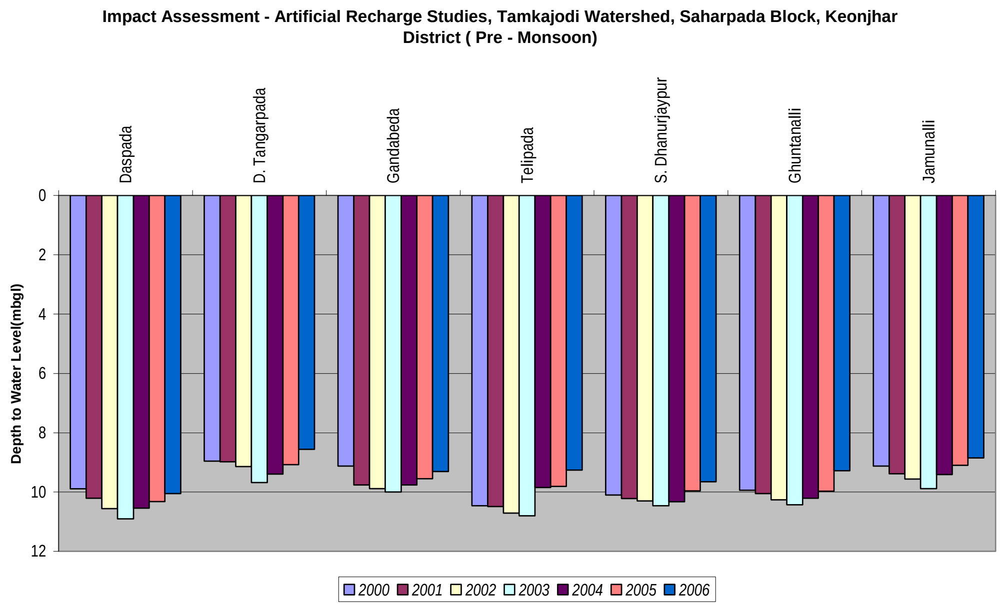
Table 31 Recharge structures constructed in the different location of the study area

Sl No	Location	Recharge Dug Well	Recharge of Existing Tank	Recharge Tank	Recharge Pit	Percolation Tank	Check Dam
1	Daspada	2	2	2	7	-	1
2	D. Tangarpada	4	2	1	5	-	2
3	Gandabeda	2	1	2	5	-	-
4	Telipada	1	1	2	5	1	-
5	S.Dhanurjaypur	2	1	1	3	-	-
6	Ghuntanalli	2	1	1	2	-	-
7	Jamunalli	2	-	1	3	-	-
	TOTAL	15	8	10	30	1	3

Impact Assessment

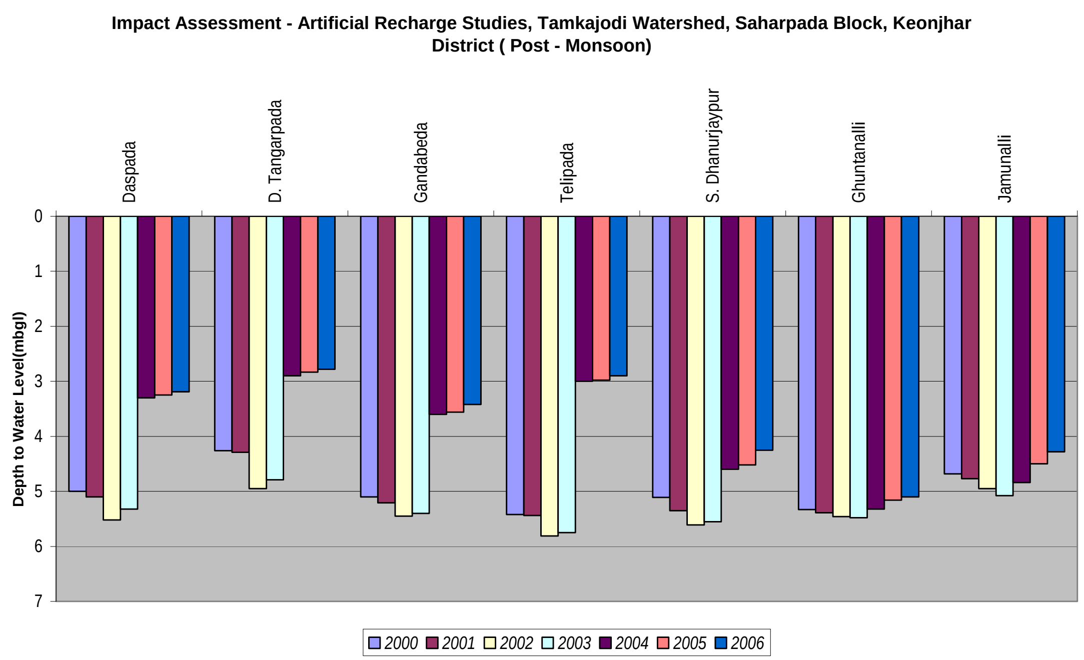
After execution of the artificial recharge structures which includes renovation of 8 existing ponds and excavation of 10 recharge tanks and 1 percolation tank, 15 recharge dug wells, construction of 3 check dams, ground water recharge was greatly enhanced (Table.31).

The impact of this recharge were monitored regularly (Figure. 55 & 56). Artificial recharge structures, Tamkajodi Watershed, Saharpada Block, Keonjhar District is presented in figure. 56(A-D). The quantum of recharge was found to be around 64 % of the total run-off (8.10×10^6 m^3). Lateritic soil and sandy cover seen in many parts of the project area results in increased infiltration and percolation rate for enhanced ground water recharge.



A.

Pre - Monsoon



B. Post – Monsoon

Figure 55 (A&B) : Depth to Water level in Metres below ground level

A. Tamakjodi Watershed – Check Dam during Construction Phase

B. Tamakjodi Watershed – Check Dam After Completion

C. Tamakjodi Watershed – Percolation Tank during Construction

D. Recharge Well At Daspada

Figure 56 (A-D) : Artificial recharge structures, Tamkajodi Watershed, Saharpada Block, Keonjhar District

Artificial Recharge to Ground Water in Barkatia Watershed, Athgarh Block, Cuttack District

Watershed	:	Barkatianalla
Block	:	Athagarh
District	:	Cuttack
Approximate Project Area	:	20.00 Sq. Km.
Numbers and names of the Villages covered	:	20(Jemadeipur, Kapusingh, Sarkoli, Oranda, Gurudijhatia, Kotar, Pithakhia, Bali, Baula, Chotiambmba, Sitarampur, Khamarnuagaon, Kaduanuagaon, Chhagaon, Sauria, Gobara, Belda, Danduria, Kolalathapangi, Moharitaila)
Project Execution by	:	HP Division, Bhubaneswar
Total expenditure	:	Rs. 54.76 lakhs
Total volume Recharge	:	13 x 106 m^3

Table 32. Artificial Recharge Structures (ARS) constructed in the Barakatianalla

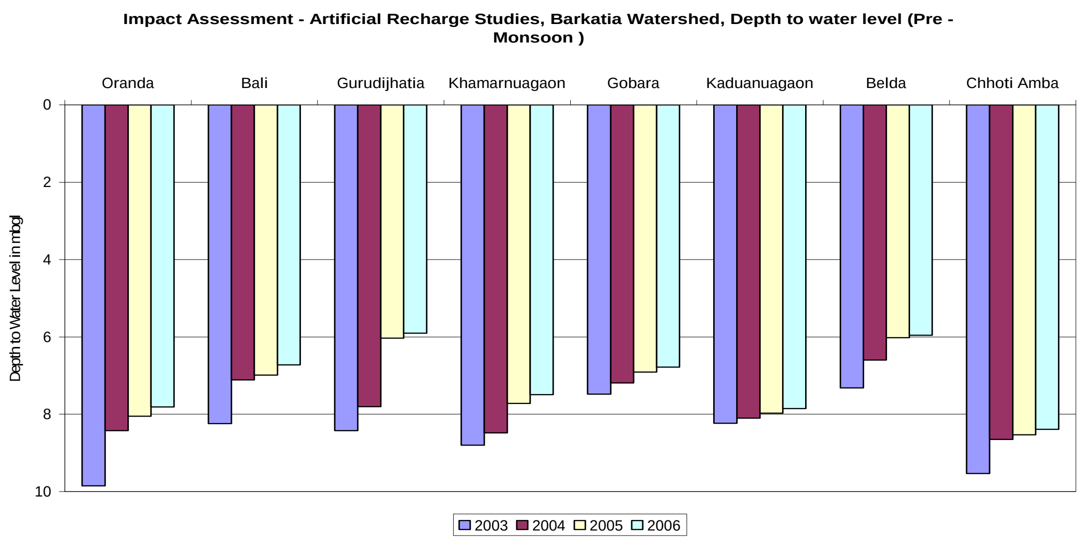
Sl. No	Location (Village)	Recharge Dug Well	Recharge BW	Recharge TW	Recharge Pit	Recharge Tank	Renovation of Tank	Check Dam
1	Sitarampur	1	-	1	1	-	-	-
2	Oranda	1	1	-	1	-	1	1
3	Bali	1	-	-	1	2	1	-
4	Jemadeipur	1	-	-	-	1	-	-
5	Sarkoli	1	1	-	1	2	1	-
6	Baula	-	-	-	-	-	1	-
7	Kapursingh	-	1	-	-	-	1	-
8	Kolathapangi	-	1	-	-	3	-	-
9	Souria	-	1	-	-	3	-	-
10	Pithakhia	-	-	1	-	-	-	-
11	Belda	1	-	-	1	3	-	-
12	Khamarnuagaon	1	-	-	1	-	1	-
13	Chotiamba	1	-	-	1	3	1	-
14	Gurudijhatia	3	-	-	3	-	1	-
15	Kotar	1	-	-	1	-	1	-
16	Danduria	2	-	-	2	-	1	-
17	Kaduanuagaon	2	-	-	2	-	-	-
18	Moharitaila	1	-	-	1	3	-	-
19	Gobara	2	-	-	2	-	-	-
20	Chhagaon	1			1		-	-
	Total	20	5	2	20	20	10	1

Impact Assessment

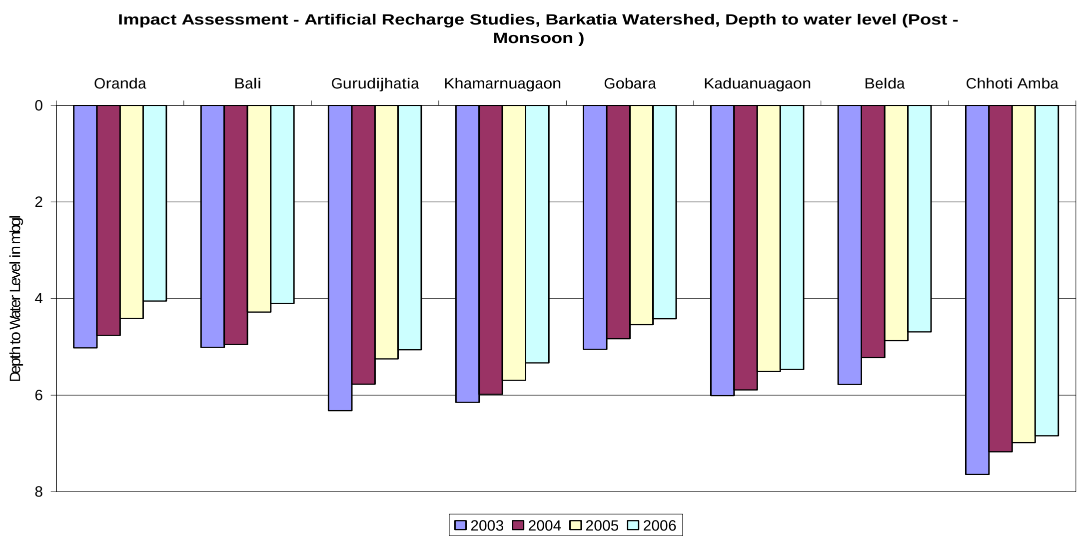
After execution of the above mentioned structures for artificial recharge, the impact of recharge through renovation of existing pond, recharge tanks, rooftop rainwater harvesting structures, check dam established in the command areas as well as the catchments in the project area were monitored regularly. From the monitoring it was observed that on an average there is a rise of 1 – 2.40 m of water level in the pre-monsoon and 0.6 – 1.07 m in the post-monsoon period (figure.57 A&B). depth to water level during pre & post monsoon is given in Table.33. The quantum of recharge being around 55% of the total run off (13 X 10^6 m^3). Artificial recharge structures constructed in the Barkatia block, Athgarh block, Cuttack district, Orissa is presented in figure 58 A-D.

Table 33. Impact Assessment – Depth to water level in metres below ground level (in Dug Wells)Barkatia Watershed, Athgarh Block, Cuttack District.

Sl No	Location	2003		2004		2005		2006	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	Oranda	9.85	5.02	8.42	4.76	8.05	4.41	7.81	4.05
2	Bali	8.24	5.01	7.11	4.95	6.99	4.28	6.72	4.1
3	Gurudijhatia	8.42	6.32	7.80	5.77	6.03	5.25	5.9	5.06
4	Khamarnuagaon	8.80	6.15	8.48	5.98	7.72	5.69	7.49	5.33
5	Gobara	7.48	5.05	7.19	4.83	6.91	4.54	6.78	4.42
6	Kaduanuagaon	8.23	6.01	8.10	5.89	7.97	5.51	7.85	5.47
7	Belda	7.32	5.78	6.60	5.22	6.02	4.87	5.96	4.69
8	Chhoti Amba	9.53	7.64	8.65	7.17	8.53	6.98	8.39	6.84



A . Pre-Monsoon



B. Post Monsoon

Figure 57 (A-B): Impact of Artificial Recharge – Depth to Water level(mbgl)
Barkatia Watershed, Athgarh Block, Cuttack District, Orissa

A. Barkatia Water Shed – Percolation Tank

B. Barkatia Watershed – Recharge Pit with Bore Well

C. Barkatia Watershed – Recharge Bore

D. Barkatia Watershed - Trench with recharge Bore

Figure 58 (A-D): Artificial Recharge Structures, Barkatia Watershed, Athgarh Block, Cuttack District

Roof Top Rain Water Harvesting at Hydrology Project

Administrative Building, Bhubaneswar

Location	:	HP BUILDING,BHUBANESWAR
District	:	Khurda, Orissa
Year of construction	:	2004
Total rainfall	:	1691.07 mm
Total sanctioned cost of the Project	:	Rs. 8.13 Lakhs
Total amount spent	:	Rs. 8.56 Lakhs
Total volume of Recharge	:	2174.23 m^3
Rise in water table	:	0.70m (premonsoon) 2.04 m (post monsoon)
Formation	:	Sandstone.
Recharge Structures constructed	:	Recharge dug well (dia-6m) with three shafts of 125 mm dia.

Ground water is the only source of water in the campus of the Hydrology Project Administrative Building, Bhubaneswar. There are two bore wells in the campus and one additional bore well is for depth to water level monitoring which is fitted with DWLR. One dug well is excavated for recharge purpose.

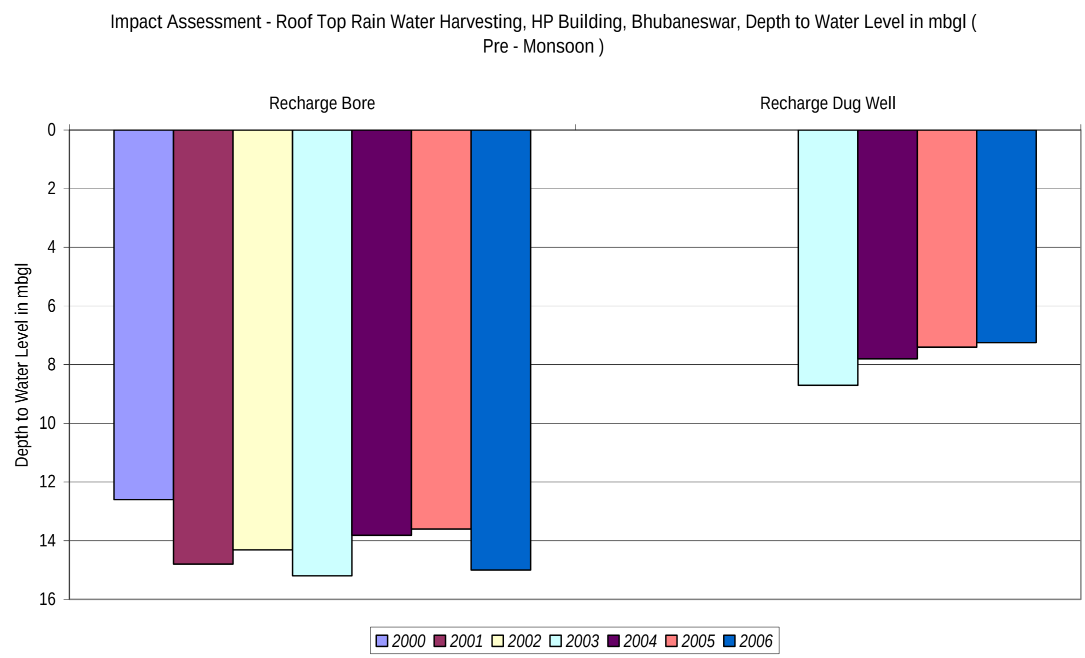
HP administrative building is having a roof top area of 1000 sq. m and that of OWPO quarters is 800 sq. m. nearby Rengali Liason Office is 450 sq. m. The total Roof top area of the project is 2250 sq. m. 15 rainwater outlets at the roof top were connected to 15 number of PVC pipes of 100 mm diameter to bring down rain water to the collection and a first flush device too is installed. The collection chambers are half filled with gravels for rainwater filtration. The chambers are connected with 150 mm diameter PVC pipes with the excavated dug well at the backward of the building. The silt settling tank, filter chambers are properly arranged and the roof tops were maintained and cleaned regularly.

Impact Assessment

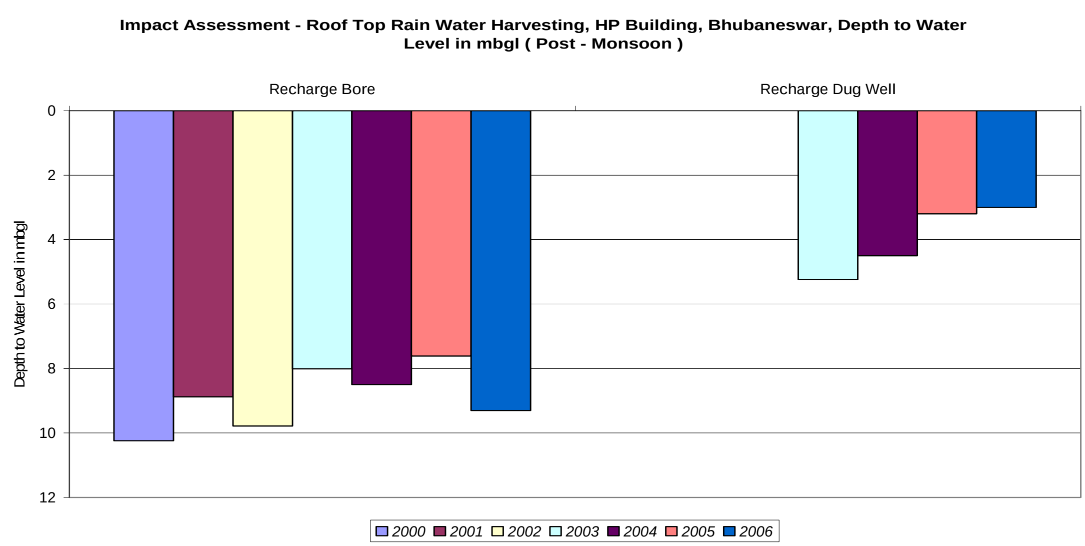
The project was monitored weekly and rainfall data, depth to water level and water quality data was collected on a regular periodicity. The monitoring records shows instant response of rain water harvesting in the dug well with a 1.5 – 2 m rise in water level from October 2003 to that of 2006 (Figure.59 A&B). The comparison of water levels in the bore well and that in the dug wells are given below in table 34. However, in the year 2006 due to excessive pumping the water levels showed a pseudo decline.

Table 34. Impact Assessment – Depth to Water Level, HP Building, Bhubaneswar

Year	Bore Well		Dug Well		Rainfall	Rainwater Harvested
	Pre	Post	Pre	Post	(mm)	(m^3)
2000	12.60	10.24	-	-		
2001	14.80	8.88	-	-		
2002	14.31	9.79	-	-		
2003	15.20	8.01	8.70	5.24		
2004	13.82	8.50	7.80	4.50	1096	2096
2005	13.60	7.61	7.40	3.20	1579	2566.86
2006	15.00	9.30	7.25	3.00	1881	2174.23



A. Pre – Monsoon



B. Post – Monsoon

Figure 59 (A-B) : Impact Assessment – Roof Top Rain Water Harvesting, HP Administrative Building, Bhubaneswar

I. HARYANA & PUNJAB

Haryana state covers an area of 44,212 km^2. The state has an average annaual rainfall of 612 mm. Major part of the state is occupied by alluvium. The southern part of the state is underlain by consolidated formations of the Delhi system and northern part is underlain by Siwaliks. Based on yield potential characteristics of aquifers, the State can be divided into three zones. The first one comprises of 26,090 sq.km in parts of Sirsa, Hissar, Bhiwani, Mahendergarh & Jind districts, where tubewells can yield 50 m3/hr. The second one falls in parts of Hissar, Kurukshetra, Karnal, Bhiwani and Gurgaon districts, covering an area of 7100 sq.km tubewells in this zone, can yield between 50-150m3/hr. The third one extends by 9200 sq.km in parts of Ambala, Kuruskshetra, Karnal and Sonepat districts, where the yield varies between 150-200 m^3/hr. An area of 1660 sq.km in parts of Gurgaon, Bhiwani and Mahendergarh districts is underlain by consolidated formations, where the yield prospects of aquifers are limited.

The main cause of ground water depletion is over exploitation of ground water resources to meet the increasing demand of various sector including agriculture, industry and domestic in Punjab and Haryana states. Extensive paddy cultivations, especially during summer months has effected the available ground water resources adversely due to declining water table, the tubewells have to be deepened and farmers are shifting to the use of submersible pumps in place of centrifugal pumps being used by them till now, resulting in additional expenditure and extra power consumption. This has adversely affected the socio- economic conditions of the small farmers. This declining water table trends, if not checked, would assume an alarming situation in near future affecting agriculture production and thus economy of the state and the country.

The annual replenishable groundwater resource of the Haryana and Punjab state are 9.31 bcm & 23.78 bcm respectively. The net annual groundwater availability of Haryana and Punjab state are 8.63 bcm & 21.44 bcm respectively. Ground water draft (as on 31st march 2004) of Haryana state is 9.45 bcm with a stage of ground water development of 109%. Out of the 113 assessment units in the Haryana state, 55 blocks has been categorised as over exploited and 11 blocks as critical from ground water development point of view. Groundwater draft (as on 31st march 2004) of Punjab state is 31.16 bcm with a stage of ground water development of 145%. Out of the 137 assessment units in the Punjab state, 103 blocks has been categorised as over exploited and 05 blocks as critical from ground water development point of view.
Artificial recharge structures suitable for the state

Major portion of the state is occupied by alluvium. Surface spreading, Recharge pits and recharge shafts with tubewells are ideally suited for these unconsolidated formations. Induced recharge wells in favourable locations. Check dams/nalla plugs/ gully plugs and percolation ponds are suited for the consolidated formations. For the urban areas Roof top rainwater harvesting and artificial recharge structures with recharge shafts and recharge pits with/without tubewells are feasible.

The impact on the ground water regime in terms of quality and quantity by implementing the artificial recharge and rain water harvesting studies in the State of Punjab and Haryana have been found very encouraging. Followings studies on artificial recharge and rain water harvesting have been carried out in the Haryana & Punjab State:

- Artificial recharge to ground water utilising canal and surplus pond water at village Channian Nakodar block, district Jalandhar, punjab

- Artificial recharge to ground water in golden temple complex, Amritsar city, Punjab
- Artificial recharge to ground water utilizing runoff generated in patiala nadi, block patiala, district patiala, Punjab
- Artificial recharge to ground water by utilizing surplus water of khanna distributary, at Bhattian canal colony, block Khanna, district Ludhiana, Punjab
- Rainwater harvesting at Kheti Bhawan, Amritsar, Punjab
- Roof top rain water harvesting at basic medical sciences block, Punjab University, Chandigarh.
- Artificial recharge to ground water utilizing run off generated in Miranpur choe , block Patiala , district Patiala , Punjab
- Artificial recharge to ground water utilizing surface runoff of dhuri drain, dhuri block, district Sangrur, Punjab
- Artificial recharge to ground water utilizing surface runoff of Dhuri link drain, dhuri block, district Sangrur, Punjab.
- Artificial recharge to ground water utilising runoff generated in bassian drain, block Nihalsisngh wala district Moga
- Artificial recharge to ground water utilizing waste water from Brahm Sarovar, Haryana

Artificial Recharge to Ground Water Utilising Canal and Surplus Pond Water at Village Channian Nakodar Block, District Jalandhar

Location: Village Channian Nakodar Block, District Jalandhar
Year of construction: 1999-2000
Implementing Agency: Ground Water Cell,Department of Agriculture, Punjab

Figure 60: Pond at Channian Nakodar Block, District Jalandhar

Type of Structures:

- A recharge well with observation wells
- Modification of abandoned dug well to recharge well.
- Utilization of the water of existing village pond for artificial recharge.

The results of the studies indicate that the recharged water is effective in arresting the rate of decline of water levels in the area. Due to artificial recharge from surplus pond water and natural recharge from rainfall, the falling water level trend was arrested from 1.31 m/month to 0.41m/month to 0.29m/month by October 2002. The results have also indicated that it is feasible to recharge unconfined aquifer by utilizing canal and pond water. For two years since the inception of the scheme, the back flow of waste water has stopped entering the streets. The abandoned dry dug wells can be put to best use again by converting them into dug cum recharge wells and these can be proved as effective recharge structures.

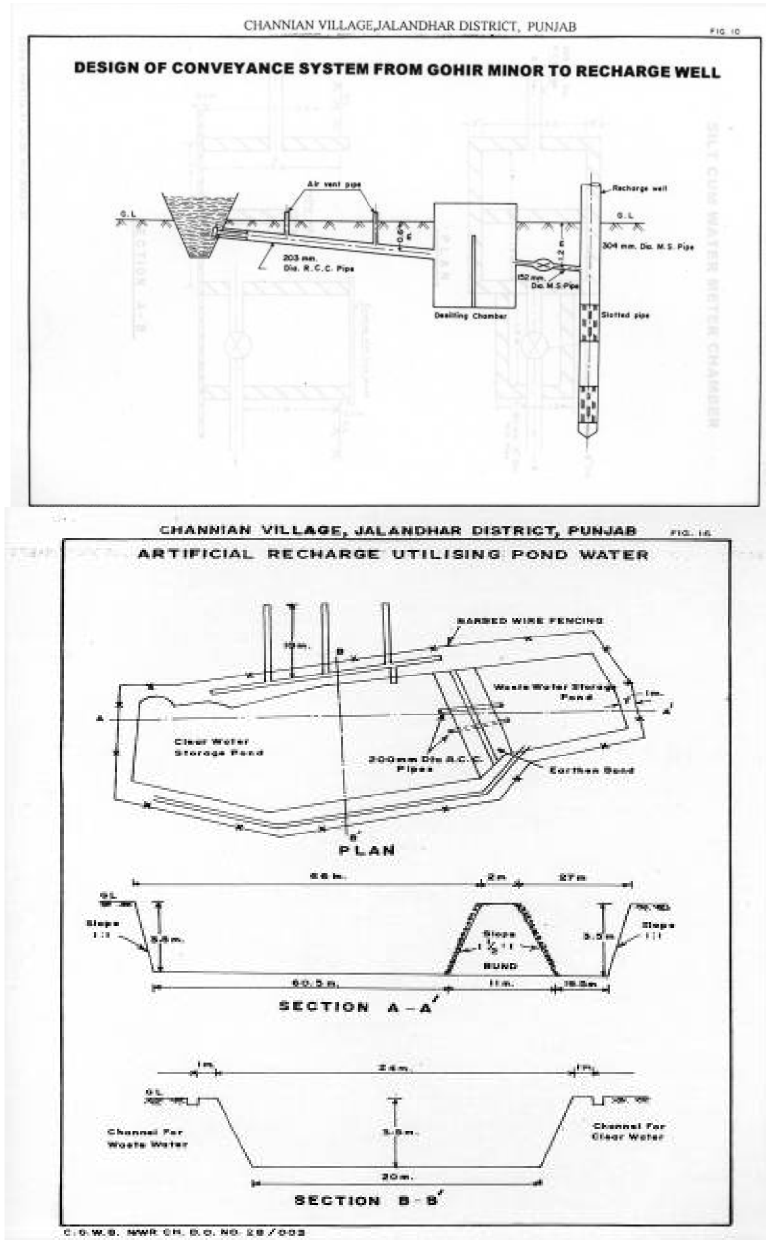


Figure 61: Artificial Recaharge Structure at Channian Nakodar Block, District Jalandhar

Artificial Recharge to Ground Water in Golden Temple Complex, Amritsar City, Punjab.

Location: Golden Temple Complex, Amritsar City
Type of Structure:
Two recharge wells have been constructed in the Galliara Area and 4,41,504 m^3 /year surplus water from Sarovar is recharged to the ground water. Similarily two recharge wells have been constructed in the open space opposite Dewan Hall and 51,100 m^3 /year water of washing of Parikrama area 23,652m^3/year from Charan Ganga and 7,145 m^3 /year of rooftop rain water is being used for recharging groundwater.

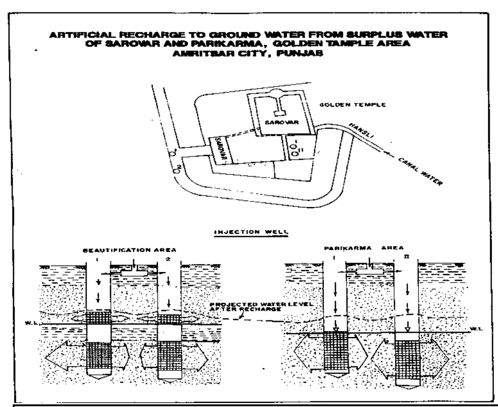


Figure 62: Artificial Recharge structure at Golden Temple Complex, Amritsar City

The first major benefit of the scheme is conservation of water and arresting fall in water levels, in turn resulting in saving of energy for lifting of water. Another advantage is the sustainability of the existing structures preventing them from going defunct due to fast decline in water levels. Artificial recharge by utilizing Sarovar water and swimming pools is feasible and is suitable for urban areas like Amritsar city.

Rainwater Harvesting at Kheti Bhawan, Amritsar, Punjab

Location: Kheti Bhawan, Amritsar
Year of Construction:
Implementing agency: Department of Agriculture, Punjab and funded by Central Ground Water Board under central sector scheme.
Cost of the Scheme: Rs.1.00 lakh
Type of Structure: Rain water from the roof top of Khetri Bhawan is being recharged to ground water through a recharge well.

The annual draft of ground water has exceeded the annual recharge, resulting in mining of static ground water reservoir in the area. This has resulted in decline in water level at an alarming rate.

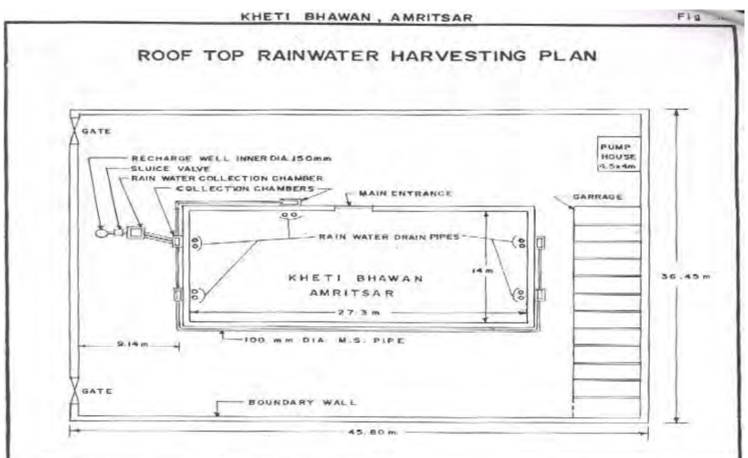


Figure 63: Artificial Recharge structure at Golden Temple Complex, Amritsar City

The scheme is a demonstrative scheme for popularizing the roof top rain water harvesting. The rate of recharge of the structures constructed works out to be 14 liters per second. The studies reveal that it is feasible to harvest the roof top rain water and can be used for recharging ground water. The scheme can be replicated in other buildings of the city.

Artificial Recharge to Ground Water utilizing runoff generated in Patiala Nadi, Block Patiala, District Patiala, Punjab

Location: Patiala Nadi, Block Patiala
Type of Structure:

Punjab has a dense network of drains which were constructed during early 70's to tackle the problems of water logging both surface as well as sub-surface These drains were very effective in getting rid of water logging problem. Due to declining water levels, these drains are not serving the purpose for which these were constructed. This resulted into the reduction of natural recharge to a greater extent. In case the bed of these drains is modified in a way to allow the surface runoff to percolate to recharge the ground water regime it can help to check the declining trend of water levels.

Along Patiala Nadi in Patiala block, Patiala district, the bed of the drain was modified by constructing one long trench and 20 small trenches and within long trench 10 recharge wells and one recharge well in each small trench were constructed, to enhance the rate of recharge to ground water. Maintenance of the recharge structures, involving clearing of weeds and grass from the bed of the modified drains and removal of accumulated silt is very important for overall efficiency during its lifetime.

Experiment has created awareness amongst the farmers of the area for augmenting the ground water recharge along the Nadi beds in depleting water level areas. By doing so, apart from the additional recharge to ground water, there will be marked reduction in runoff losses and flooding of land.

Observed rate of recharge in slice I & II with 20 recharge wells was 10.5 lps/well where as it is 8.96 lps/running meter length of trench in slice III with 5 recharge wells.

Artificial Recharge to Ground Water Utilizing Run off generated in Miranpur Choe, Block Patiala, District Patiala, Punjab

Location: Miranpur Choe, Block Patiala

Type of structure: The bed of the Miranpur drain was modified to construct 24 number recharge wells. Four number piezometers were also constructed to monitor the effect of recharge on ground water regime.

During monitoring period the recharge capacity of the recharge / injection wells has come out to be 2.22 lps. These results have been found to be encouraging in the experimental stage. These kind of schemes can be replicated in other areas for augmenting the ground water recharge by artificial means. The encouraging results could be sustained only if the structures are properly maintained. It involves clearing of weeds and grass from the bed of the modified drains and removal of accumulated silt on the filter media from time to time, which can be done at nominal cost.

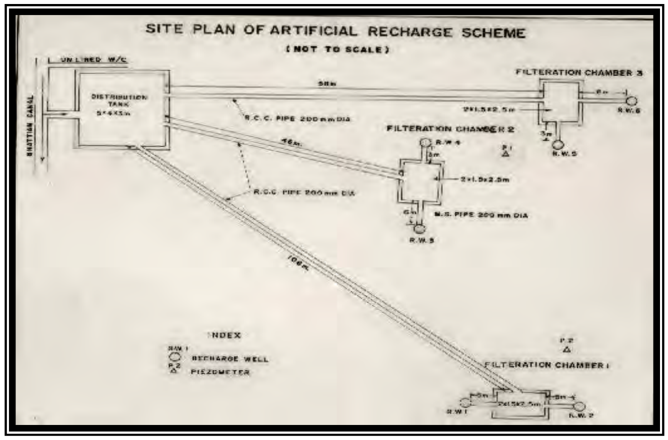


Figure 64: Artificial Recharge structure at Miranpur Choe, Block Patiala

Artificial Recharge to Ground Water by Utilizing Surplus Water Of Khanna Distributary, at Bhattian Canal Colony, Block Khanna, District Ludhiana, Punjab

Location: Bhattian Canal Colony, Block Khanna
Year of Construction: 2002
Implementing agency: Investigation division of Directorate Water Resources, Punjab
Cost of the scheme: Rs. 9.48 lakhs
Type of Structure:
The scheme utilized surplus canal water of Khanna distributary of Bhakra main line canal for ground water recharge. It was taken up to study the feasibility of augmenting ground water resources in the area. Six recharge tubewells were constructed for recharging canal water under gravity. A water distribution tank and three filtration chambers were also constructed.

The artificial recharge to ground water has helped in arresting the rate of decline from 16 cms/months to 4 cm/month rise. As per the information collected from local people, the discharge of the tubewells is not reduced at the time of pumping of ground water during sowing season of paddy although ground water draft is at its peak. The scheme has been found very effective in recharging surplus canal water and is cost effective. The recharge wells have to be cleared with compressed air once in 3 years so as to maintain their original recharge capacity.

Roof Top Rain Water Harvesting at Basic Medical Sciences Block, Punjab University, Chandigarh.

Location	:	Basic Medical Sciences Block, Panjab University, Chandigarh
Year of Construction	:	2001
Implementing agency	:	Engineering wing of Punjab University and funded by Central Ground Water Board under central sector scheme.

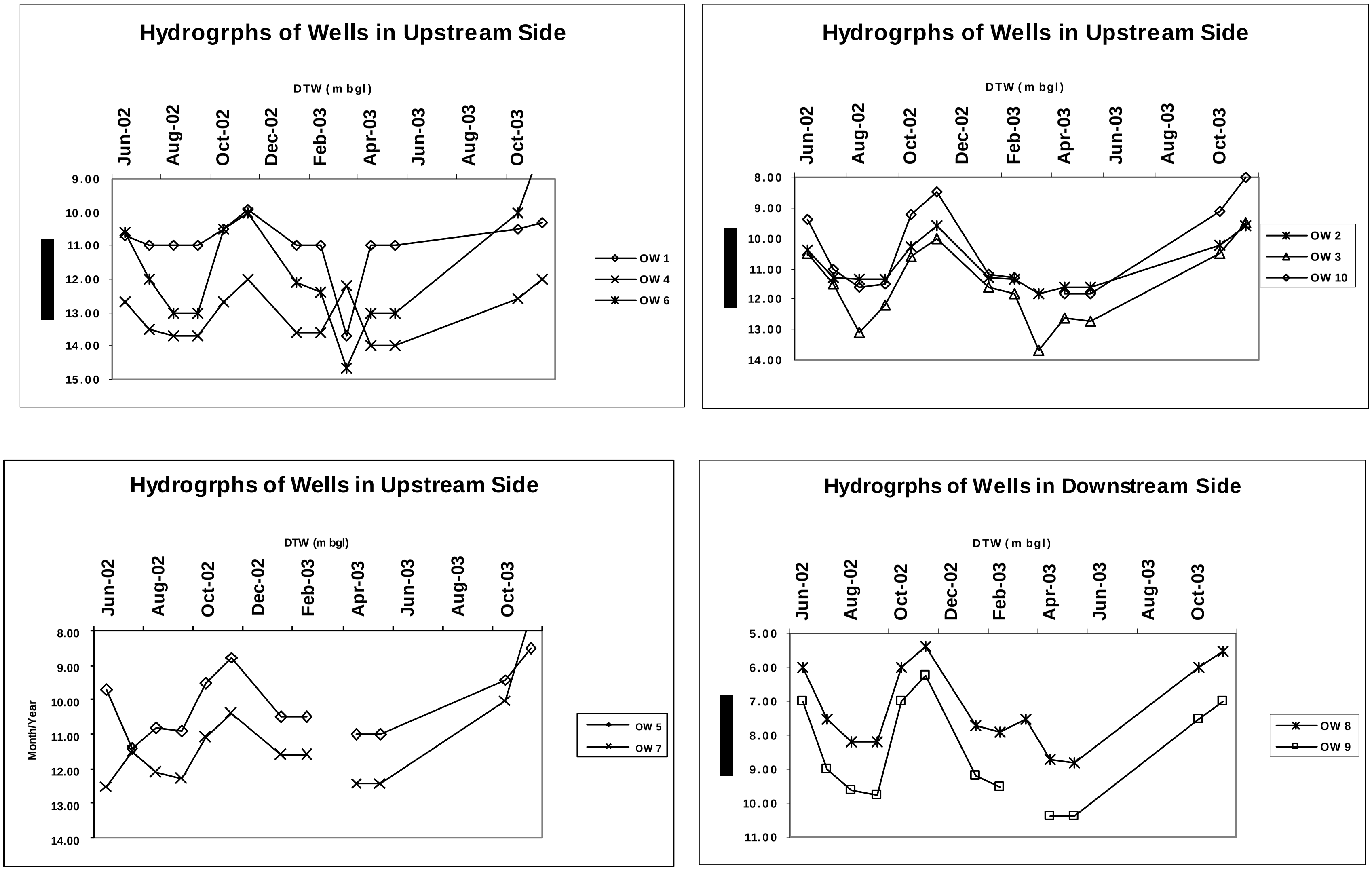


Figure 69. Hydrographs adjacent to Sub Surface Dyke in Avaravalli, Tiruchchirappalli District

Cost of the Scheme: Rs.2.56 Lakh

Type of structure:

Domestic water supply in the city is met from two sources, Bhakra canal and deep tubewells. The canal water supply is limited hence the additional burden of increased water demand is met by ground water through construction of additional tubewells. This puts more stress on ground water storage and decline in the water levels particularly of deeper aquifers, which sustain the tubewell discharge.

Water from surface runoff and rooftop rainwater can be utilized for augmenting ground water resources. The Basic Medical Sciences Block, Panjab University with rooftop area of 2100 m^2 was selected to study the feasibility of recharging ground water by harvesting roof top rain water.The total rainfall received during the study period is 1201 mm, resulting 2135m^3 of roof top surface runoff. Out of this, 1985m^3 of water is estimated to be recharged to the ground water reservoir, which is 93% of roof top runoff generated.The recharge results have indicated that it is possible to recharge the confined aquifer system occurring in the city and the experimental studies have proved to be very successful. Aquifer system, comprising of sand and gravel can easily accept water recharged through recharge wells. The scheme also helped in creating awareness amongst the students of various departments and institutions about roof top rainwater harvesting techniques. The teaching faculty members have also been trained in these artificial recharge methods.

Artificial Recharge to Ground Water Utilising Runoff generated in Bassian Drain , Block Nihalsisngh Wala, District Moga

Location: Bassian Drain , Block Nihalsisngh Wala

Type of Structure:

Two trenches each having 170m length were constructed with three recharge wells in each trench and 3 piezometers on both sides of the trench. Total quantity of water anticipated to be recharged annually through two trenches of 170m length is 5.58 MCM.

Scheme has helped to install 18 additional shallow tubewells in the area. In the area 108 shallow tubewells owned by the farmers have been benefited due to rise in water level. Total number of beneficiaries is 130 families. In an area of 11 sq km the rise in water level observed was 0.20m. The farmers of the area also reported that there is appreciable increase in discharge of their shallow tubewells due to artificial recharging of aquifer system of the area. Water level data reveals marginal increase in water levels around Bassian drain in spite of heavy pumping for paddy growth.

Artificial Recharge to Ground Water Utilizing Surface Runoff of Dhuri Drain , Dhuri Block, District Sangrur, Punjab

Location: Dhuri Drain , Dhuri Block

Year of Construction: 1999-2000

Cost of the Scheme: Rs. 39.10 lakhs

Implementing Agency: Executive Engineer, Investigation Division, Water Resources, Punjab and funded by CGWB

Type of Structure:

Artificial recharge to ground water through modified drain bed utilizing surface drain discharges from Dhuri Drain. The scheme envisages construction of 20 shafts of 3m dia and

10 shafts of 2m dia down to 6m in the drain bed. For direct recharge through drain bed, the bed was modified by constructing a trench of 295m length, 5m width at the top and 3m at the bottom and having 3.25m depth. Six recharge wells were constructed in the lateral trench to enhance the rate of recharge to dewatered unconfined aquifer. Twenty four piezometers were installed on both sides of the drain to study the behaviour of water level.

The study indicated that it is feasible to recharge the unconfined aquifer in the area by utilising the flow generated in the surface drains and recharging the same through shafts, trenches and recharge wells. However uncased recharge wells filled with gravel have not been found very effective in recharging ground water. The recharge test conducted on the trench and 4 shafts revealed that average rate of recharge is about 94 litres/sec. Apart from the additional recharge to ground water and arresting the declining trend of water level, there was marked reduction in runoff, water loses and flooding of land. The farmers of the area have reported that there was increase in discharge of their tubewells during testing of the recharge structures. On an average 0.25 m rise in water level was observed in an area of 30 sq.km. and about 200 families benefited.

Artificial Recharge to Ground Water Utilizing Surface Runoff of Dhuri Link Drain, Dhuri Block, District Sangrur, Punjab.

Location: Dhuri Link Drain, Dhuri Block

Year of Construction: 1999-2000

Cost of the Scheme: Rs. 34.20 lakhs

Implementing Agency: Executive Engineer, Investigation Division, Water Resources, Punjab and funded by CGWB

Type of Structure:

Recharge to ground water through modified drain bed utilising surface drain discharges from Dhuri Link Drain. The scheme envisages construction of 28 shafts of 3m dia in the drain bed, out of which 23 were constructed down to a depth of 6m and 5 to a depth of 11m, (upto water level). For direct recharge through drain bed, the bed was modified by constructing a trench of 250m length, 5m width at the top and 3m at the bottom and having 3m depth. Sixteen piezometers were also installed on both sides of the drain to study the behavior of water level due to artificial recharge. Three recharge wells were also installed within the trench to enhance the rate of recharge to unconfined aquifer.

The study indicates that it is feasible to recharge the unconfined aquifer in the area by utilising the flow generated in the surface drains and recharging the same through shafts, trenches and recharge wells.

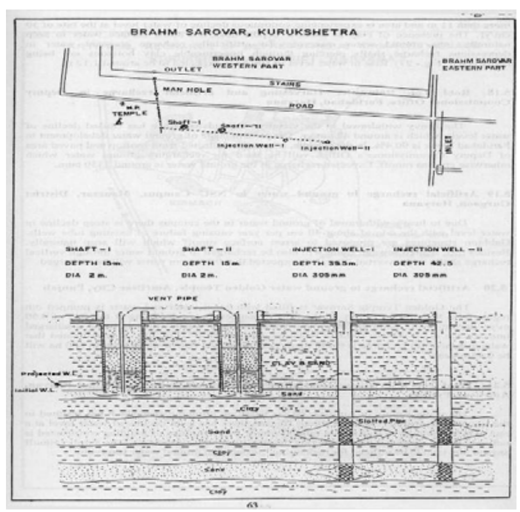


Figure 65: Artificial Recharge structure at Braham Sarovar, Kurukshetra city

Artificial Recharge to Ground Water Utilizing Waste Water from Braham Sarovar, Kurukshetra city, Haryana

Location: Braham Sarovar, Kurukshetra city

Type of Structure: The Braham Sarovar has an area of 0.418 sq.km. and storage capacity of 1.9 MCM of water. The Sarover is filled by water from Thaneswar Distributary by pumping and after few days 1.27 m column of water of the Sarover is drained out and the Sarovar is again filled with water to maintain desired water column. The scheme envisaged the recharge to ground water through injecting wastewater of Braham Sarovar by recharge structures such as recharge shafts and injection wells. Two recharge shafts and two injection wells were constructed in the south western part of the Braham Sarovar.

Total annual water available from leakage was estimated to be 0.063 MCM. The surplus water discharged from Sarovar is 0.2808 MCM. Hence, the total water available for recharge during one year from Sarovar was 0.3496 MCM.The analysis of water level data indicates that no rise of water level was observed in piezometer. However trend analysis of water level indicates that decline rate at nearest hydrograph network station at Kaulpur, tapping shallow aquifers was 1.175 m/year, where as average declining rate in the piezometers near artificial recharge structure was 0.2544 m/ year. The lesser rate of decline in piezometer might be an indication of positive impact of the structure.

J. TAMIL NADU

Tamil Nadu state covers an area of 1,30,058 km^2. The average annual rainfall of the state is about 995 mm. Nearly 73% of the total area of the State is occupied by a variety of hard & fissured crystalline rocks like charnockite, gneisses and granites. The depth of open wells varies from 6 to 30mbgl. While the depth of borewells generally varies from 30-100m. The sedimentary formations consist of sand stones, limestones and shales whereas Quaternary sediments in the State represented by Older alluvium and Recent alluvium and coastal sands. In the Cauvery delta of Thanjavur district, the artesian pressure head ranges between 4.5 m to 17 magl with free flow up to 270 m^3/hr. The yield of wells in the alluvium varies form 27 to 212 m^3/hr. The yield of wells in the fissured formations varies from 7 to 35 m^3/hr.

The annual replenishable groundwater resource of the state is 23.07 bcm with a net annual groundwater availability of 20.76 bcm. Ground water draft (as on 31st march 2004) is 17.65 bcm with a stage of ground water development of 85%. Out of the 385 assessment units in the state, 142 blocks has been categorised as overexploited and 33 blocks have been categorised as critical from ground water development point of view.
Artificial recharge structures suitable for the state

The Tamil Nadu state has diversified geological features, from the archeans to the recent formation with major portion occupied by consolidated formations. Check dams/nalla plugs/ gully plugs and percolation ponds are suited for these consolidated formations. Recharge pits and recharge shafts with tubewells are ideally suited for the semiconsolidated and unconsolidated formations. For urban areas roof top rainwater harvesting and artificial recharge structure like the recharge pit and recharge shafts with/without tubewells are feasible.

Some of the Pilot and Demonstrative Artificial Recharge studies to augment the groundwater resources executed by State Agencies and NGOs under technical and financial support of Central Ground Water Board are described briefly about the objectives of the study, the background information on the area, project formulation, execution and impact of the artificial recharge structures on the groundwater regime.

Under Central Sector Scheme, construction of sub-surface dykes on experimental/ operational basis was taken up at three locations in Tamil Nadu. The details of villages where these structures have been shown in Table-35

Table: 35 Details of villages in Tamil Nadu where subsurface dykes were constructed

S.No	District	Taluk	Block	Village
1	Dharmapuri	Pennagaram	Pennagaram	Madam
2	Namakkal	Rasipuram	Rasipuram	Kunavelampatti
3	Dharmapuri	Harur	Harur	Ellapudayampatti

Sub-surface dykes, also known as Ground water Dams or Underground Bandharas are basically water conservation structures and are effective in providing sustainability to ground water abstraction structures by arresting sub-surface flow. The main purpose of construction of a sub-surface dyke is to arrest the flow of ground water out of the watershed and to increase the storage within the aquifer, by which the de-saturated aquifers get replenished, resulting in rise of ground water in the upstream side of the structure.

Sub-surface dykes have the following advantages in comparison with other artificial recharge structures

- As water is stored within the aquifer, no land is lost due to submergence and the land above the reservoir can be utilized even after construction of the structure.
- No water is lost due to evaporation.
- There is no siltation and consequent reduction in storage capacity.
- There is no potential disaster like collapse as in the case of surface reservoirs.

Technical possibilities of constructing the dyke and achieving large storage reservoirs with suitable recharge conditions and low seepage losses are the main criteria for siting of sub-surface dykes. Valley shapes and gradients are used for site identification. Optimally, a valley should be well defined and wide with a very narrow outlet (bottle necked). This reduces the cost of the structure and makes it possible to have a comparatively large storage volume. This indicates that the gradient of the valley floor should not be high since that would reduce the storage volumes behind a dam of given height.

The limitations on depth of underground construction stipulate that the unconfined aquifer should be within a shallow to moderate depth (down to 10 m bgl) and have a well-defined impermeable base layer. Such situations occur in hard rock areas and shallow alluvial riverine deposits.

Salient features of the sub surface dykes constructed are given in Table 36.

Impact Assessment Study

The following methodologies have been adopted for assessing the impacts of the sub-surface dyke on the ground water regime in the area.

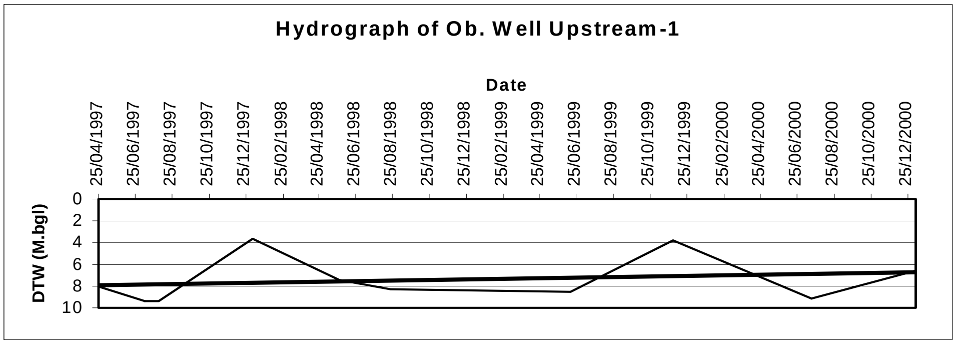
Observation wells established in the area were monitored on a regular basis to estimate the rise in water levels and to estimate the quantum of ground water recharge. However, as ground water extraction is taking place from the area together with its recharge, realistic assessment of the quantum of water recharged is considered difficult.

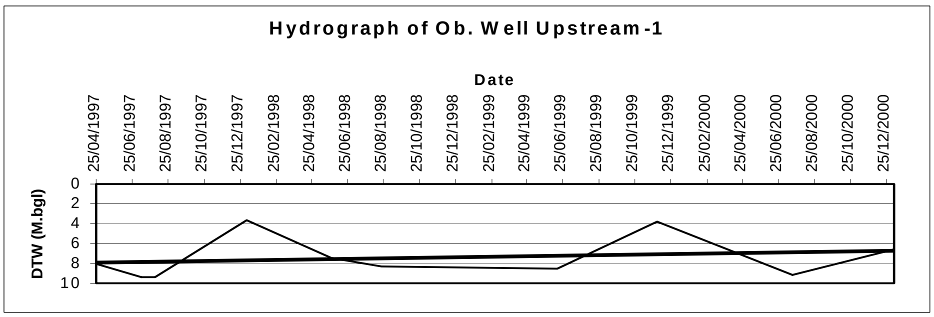
Data pertaining to Increase in the availability of water in the existing wells and the increase in the area cropped were collected from the farmers and this data was used to quantify the benefits due to construction of the structure.

Table 36. Salient features of the AR Structure subsurface dykes

Particulars	Madam Village, Pennagaram block, Dharmapuri District	Kunavelampatti village, Rasipuram block, Namakkal District	Ellapudayampatti village, Harur block, Dharmapuri District
Normal rainfall (mm)	857	862	850
Elevation (m. a msl)	510	240	350
Geology	Archaean Gneisses	Archaean Gneisses	Archaean Gneisses
Soil Type	Mixed Loams	Mixed Loams	Mixed Loams & gravelly to sandy soils
Crops Grown	Paddy, Jowar, Ground nut	Paddy, Ground nut, Vegetables	Paddy, Ground nut, Vegetables
Depth to water (m.bgl) Pre-monsoon Post-monsoon	 8 – 12 4 - 8	 8 – 12 4 - 8	 8 – 12 4 - 8
Length of structure (m)	175	100	120
Maximum Depth (m.bgl)	6.50	5.5	6.5
No. of Piezometers	4 Pairs	2 Pairs	-
Cost of Construction	Rs. 4.50 Lakhs.	Rs. 4.00 Lakhs.	Rs. 6.50 Lakhs.

Impacts on water levels have been presented below for each site.





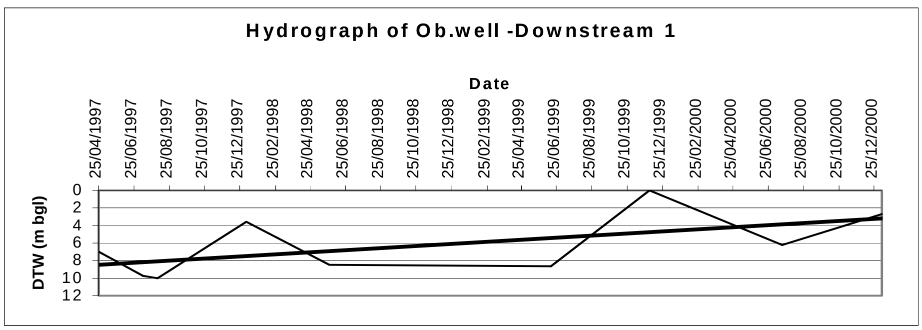
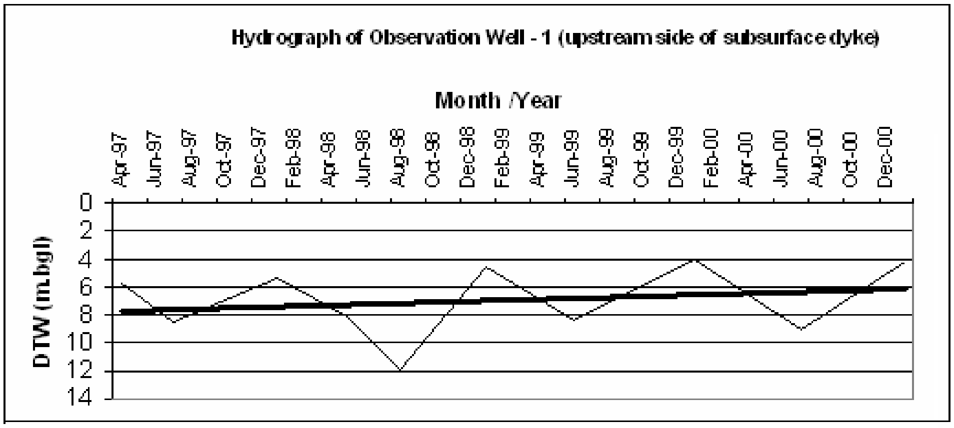


Figure 66: Hydrograph at Madam, Dharmapuri District



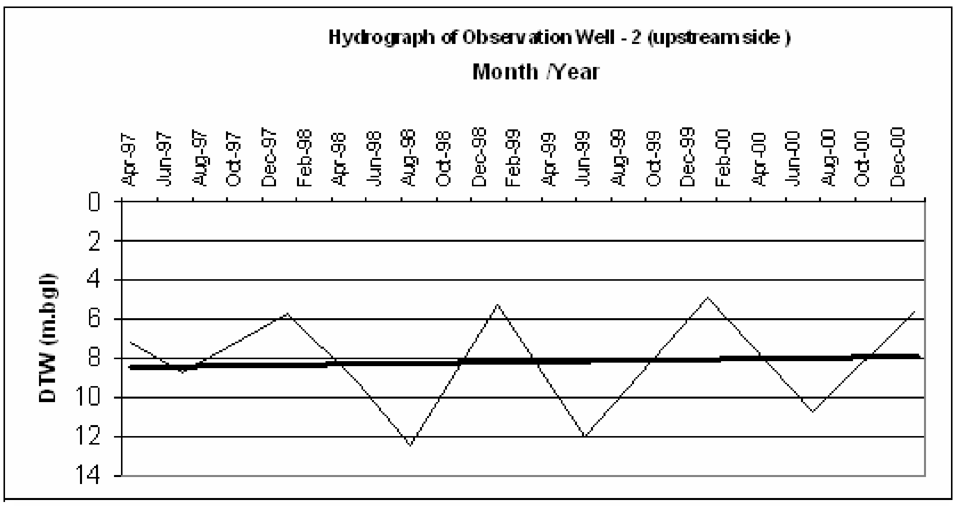


Figure 67: Impact Analysis- Kunavelampatti, Namakkal District

A summary of impact on the irrigation has been provided below (Table 37)

Table 37: Summary of Impact on irrigation

Particulars	Madam Dharmapuri district	Ellapudayampatti Dharmapuri District	Kunavelampatti Namakkal district
No. of farmers benefited	15	8	5
Total area benefited	10 Ha.	12 Ha.	7.5Ha.
Incremental income due to assured irrigation + additional area brought under irrigation (Rs/Yr/ha)	2500	2500	2500
Total incremental income due to increased production(Rs/Yr)	25,000	30,000	18,750
Cost of construction of the structure (Rs.)	4,50,000	6,50,000	4,00,000
Life of the structure (Years)	25	25	25
Annual investment for construction (Rs)	18,000	26,000	16,000
Interest on Annual expenditure @10% (Rs)	1800	2600	1600
Total Annual investment (Rs)	19,800	28,600	17,600
Cost-benefit ratio	1: 1.26	1: 1.052	1: 1.1

The construction of sub surface dykes for water conservation purposes has revealed the following.

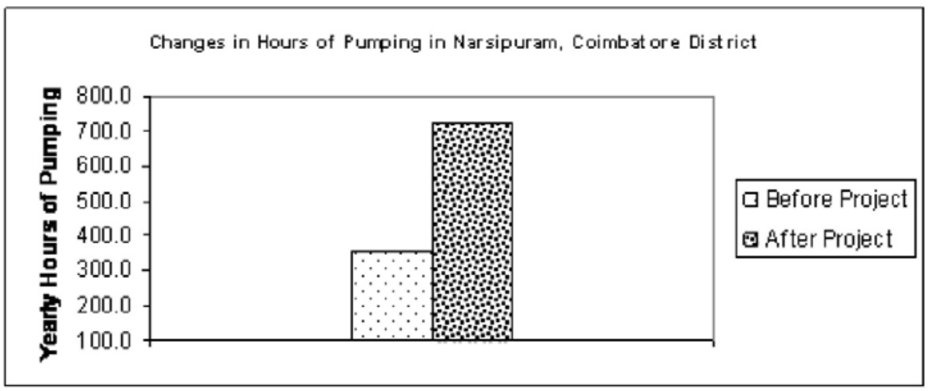
- Subsurface dykes constructed in Namakkal and Dharmapuri districts have been effective in conserving ground water on their upstream sides by arresting sub-surface flow of ground water.
- The construction of the structures has resulted in improved sustainability of irrigation wells in the command areas of the structures.
- No significant decline in water levels/reduction in yield has been observed in wells located downstream of the structures.
- The cost-benefit ratios computed for the schemes indicate that subsurface dykes, though economically viable, may not be the best structures suitable for conservation of groundwater for irrigation purposes, as the area benefited is normally small. However, subsurface dykes could be ideal structures for water conservation for community water supplies, when combined with an infiltration well on its upstream side. Further, the cost on operation and maintenance is nil, thus on a longer run, the structure will be highly cost effective.
- Realistic assessment of impacts of subsurface dyke is difficult due to the ground water extraction from the command area. The assessment of impacts, in such cases, is to be done based on reported data only. However, the actual beneficial impacts in the long run will be much higher when we consider the improvements in the socio-economic conditions of the farmers in the area.
- Subsurface dykes could be used effectively to conserve sub-surface flow, when constructed in combination with other recharge structures like check dams and percolation ponds, for a watershed/sub-basin as a whole.

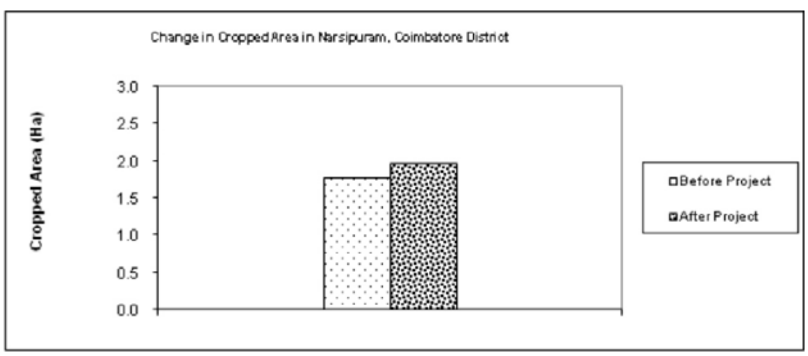
- During IX and X plans 13 schemes were executed by CGWB under Central Sector Scheme in the State of Tamil Nadu. The schemes have been executed by State Government agencies, viz., Agricultural Engineering Department, Tamil Nadu Water Supply & Drainage Board, Public Works Department, Auroville Water Service, a NGO etc.

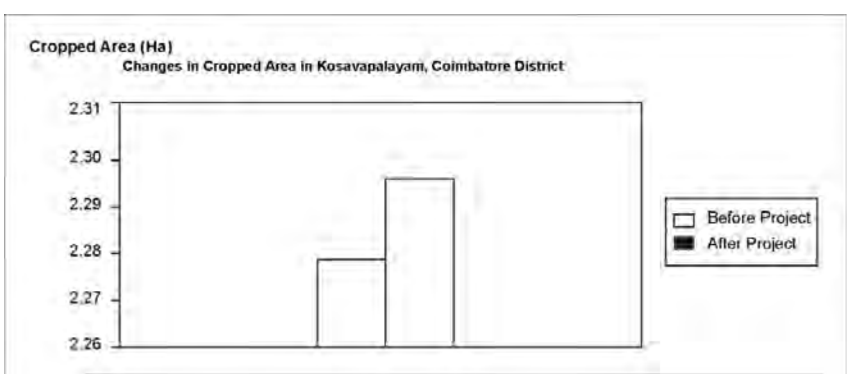
- Observation wells established in the area were monitored on a regular basis to estimate the rise in water levels and to estimate the quantum of ground water recharge. However, as ground water extraction is taking place from the area together with its recharge, realistic assessment of the quantum of water recharged is considered difficult. Data pertaining to increase in the availability of water in the existing wells and the increases in the area cropped were collected from the farmers and this data was used to quantify the benefits due to construction of the structure.

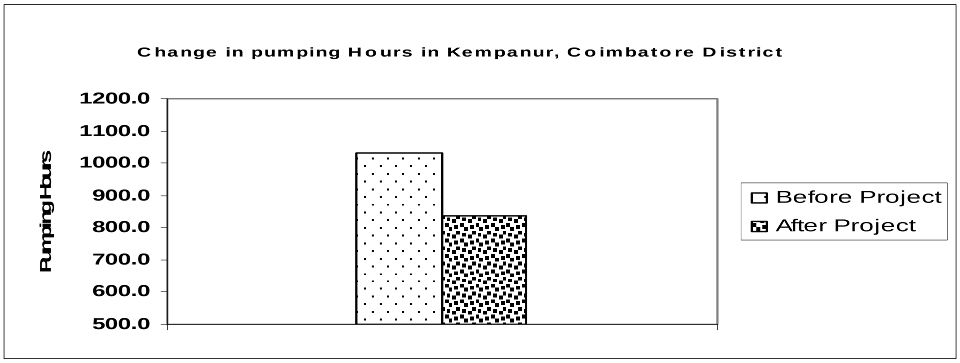
Impact Assessment Study

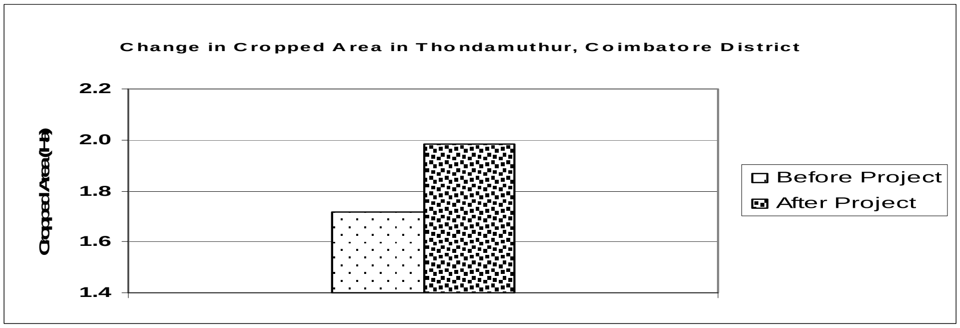
The impacts of different structures are enumerated below in figure 68.











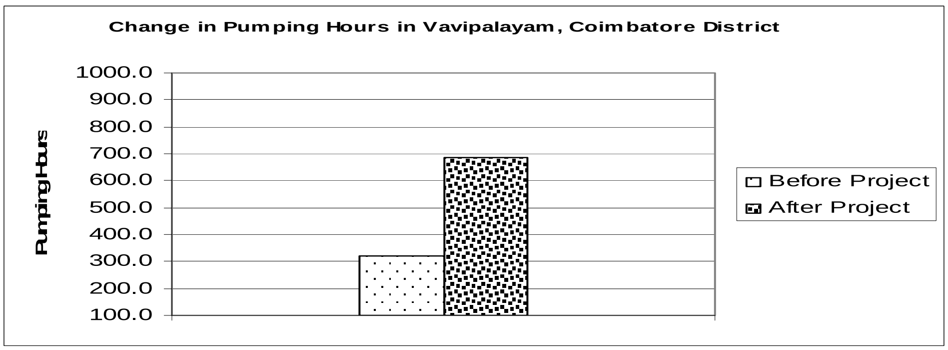


Figure 68: Impact of Percolation Ponds in Coimbatore District on pumping pattern

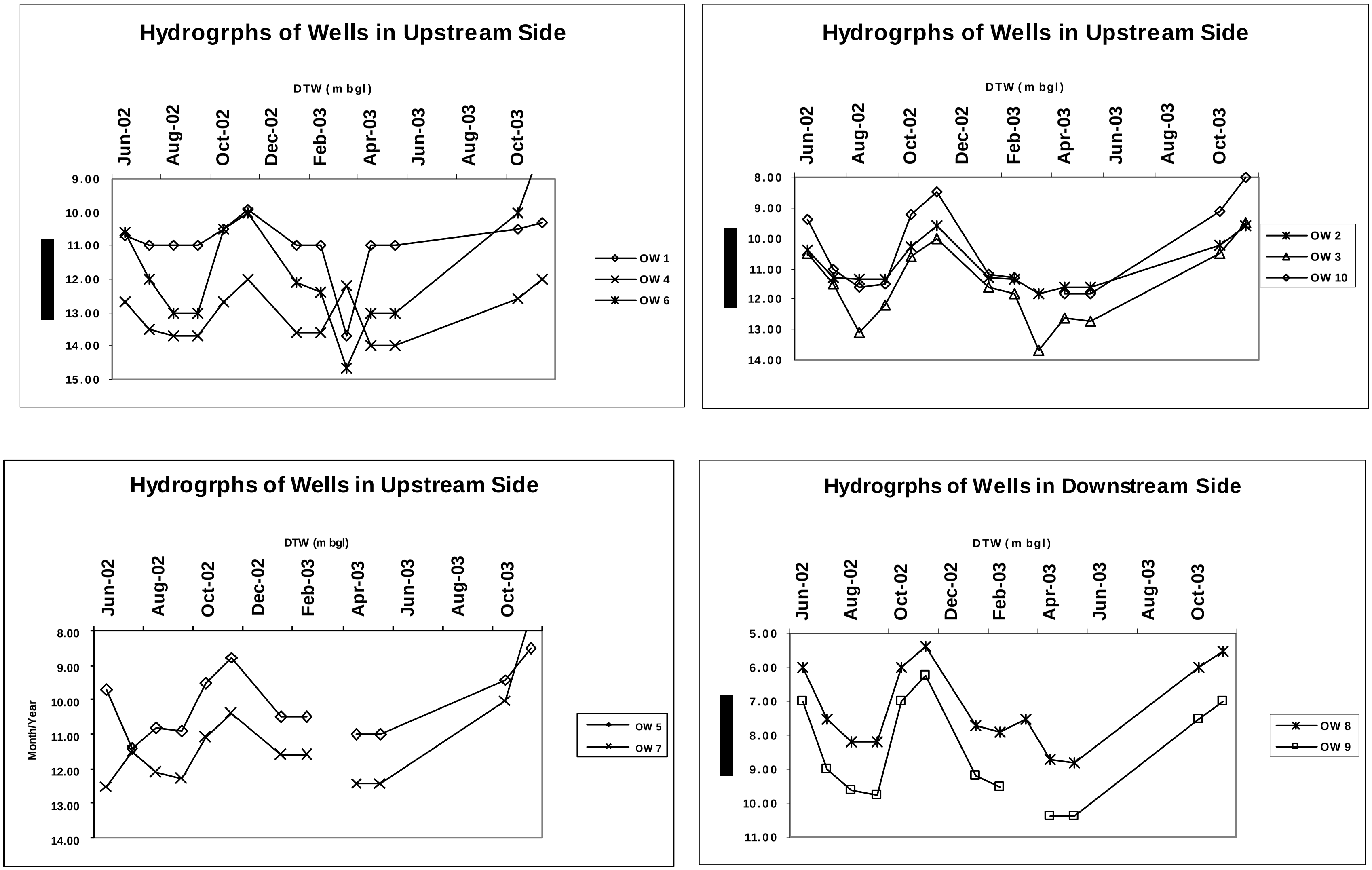
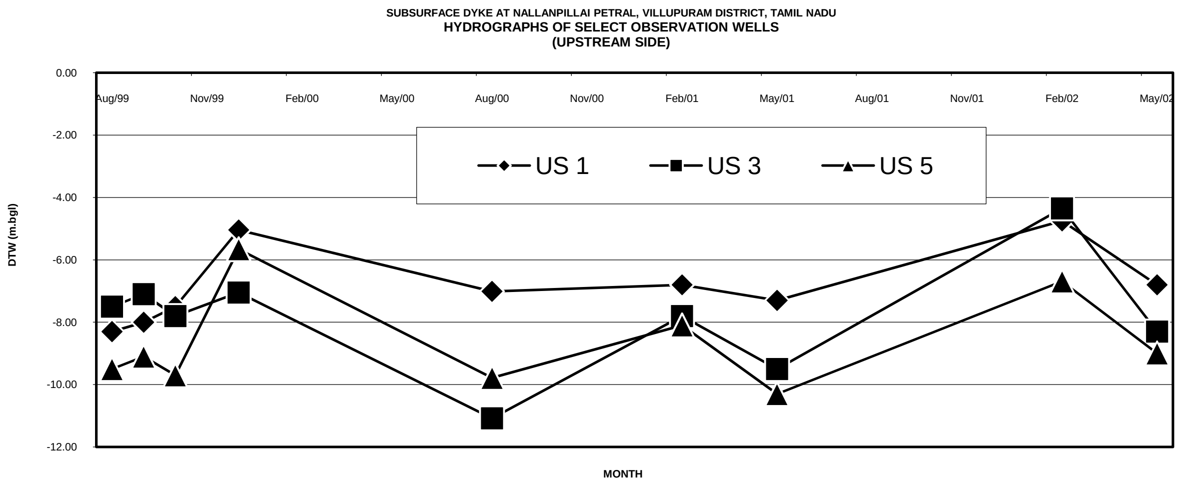


Figure 69. Hydrographs adjacent to Sub Surface Dyke in Avaravalli, Tiruchchirappalli District



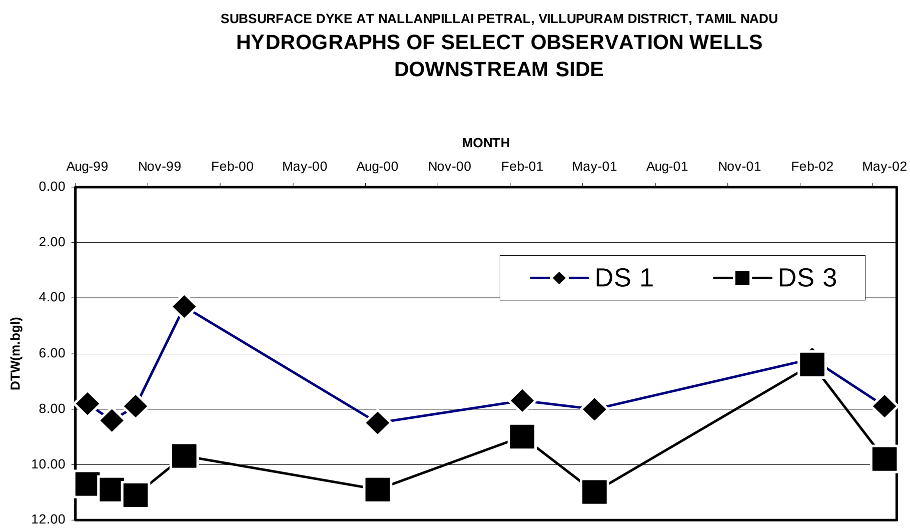


Figure 70: Hydrographs of OW on Upstream & downstream of dyke

Demonstrative Project on Artificial Recharge to Groundwater in Gangavalli Block

During X Plan, the Central Ground Water Board executed artificial recharge structures with cluster approach in Gangavalli Block, which has the highest groundwater development (221%) as per the computation of Dynamic resources of the State of Tamil Nadu as on 31.03.2004, to improve the overall groundwater situation for increased productivity of crops and sustainable rural water supply to the people. The scheme for artificial recharge was formulated with two-pronged approach, viz., augmenting the irrigation sources and drinking water sources. A reconnaissance survey was made and Tamil Nadu Water Supply and Drainage Board (TWAD Board) responsible for water supply in the State of Tamil Nadu was asked to submit a proposal for augmenting their sources in Gangavalli Block, while Agricultural Engineering Department (AED) responsible for assisting the farmers in "On Farm Development" activities and Public

Works Department (PWD) responsible for irrigation were asked to submit their proposals for augmenting the irrigation sources.

A summary of the project proposal giving details on the location, capacity, executing agency and the cost of the scheme are provided are provided as Figure 65. Impact of these structures are represent in figure 70 to 76.

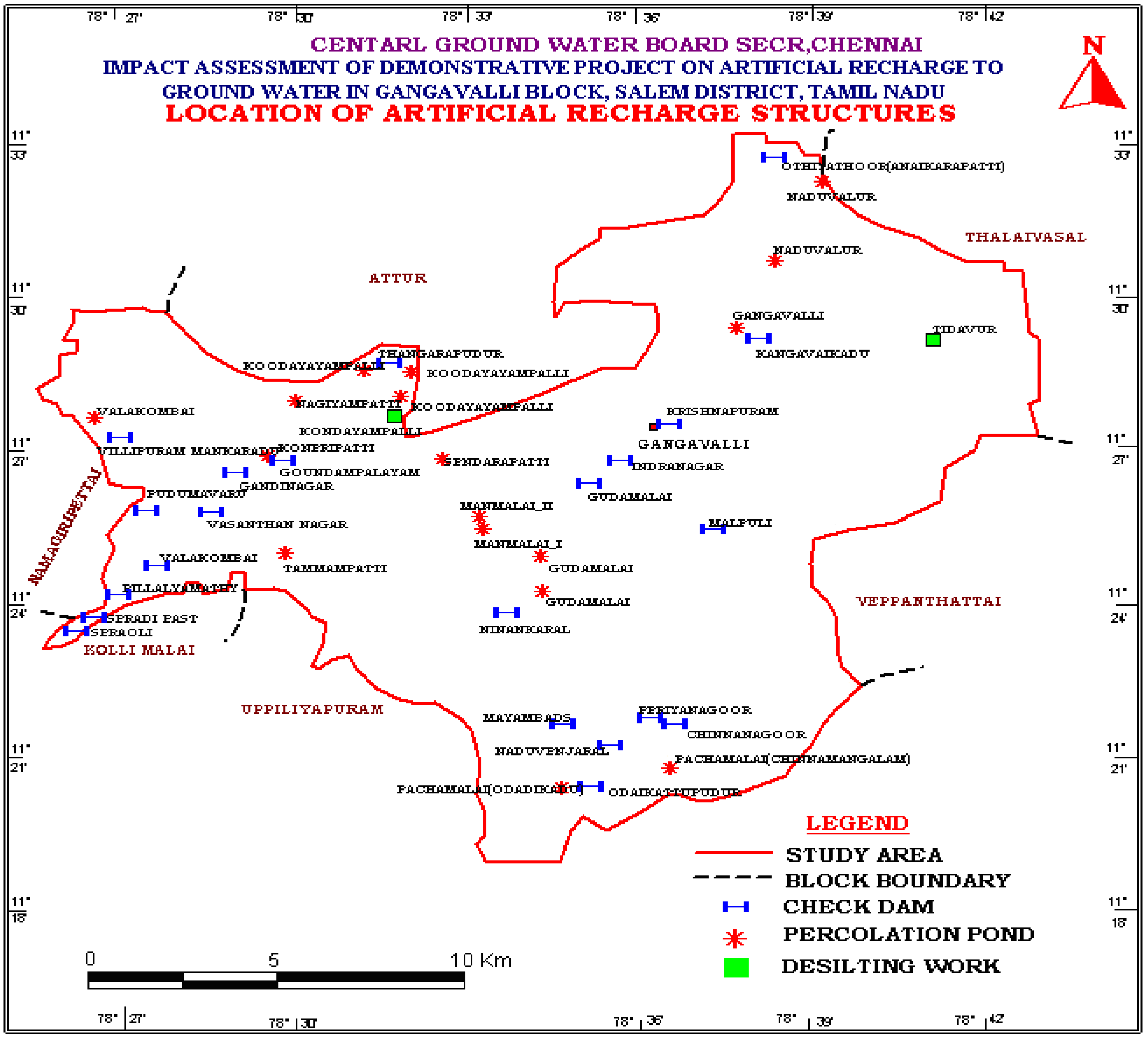


Figure 71. Details of the location of different AR structures in Gangavalli block, Tamilnadu.

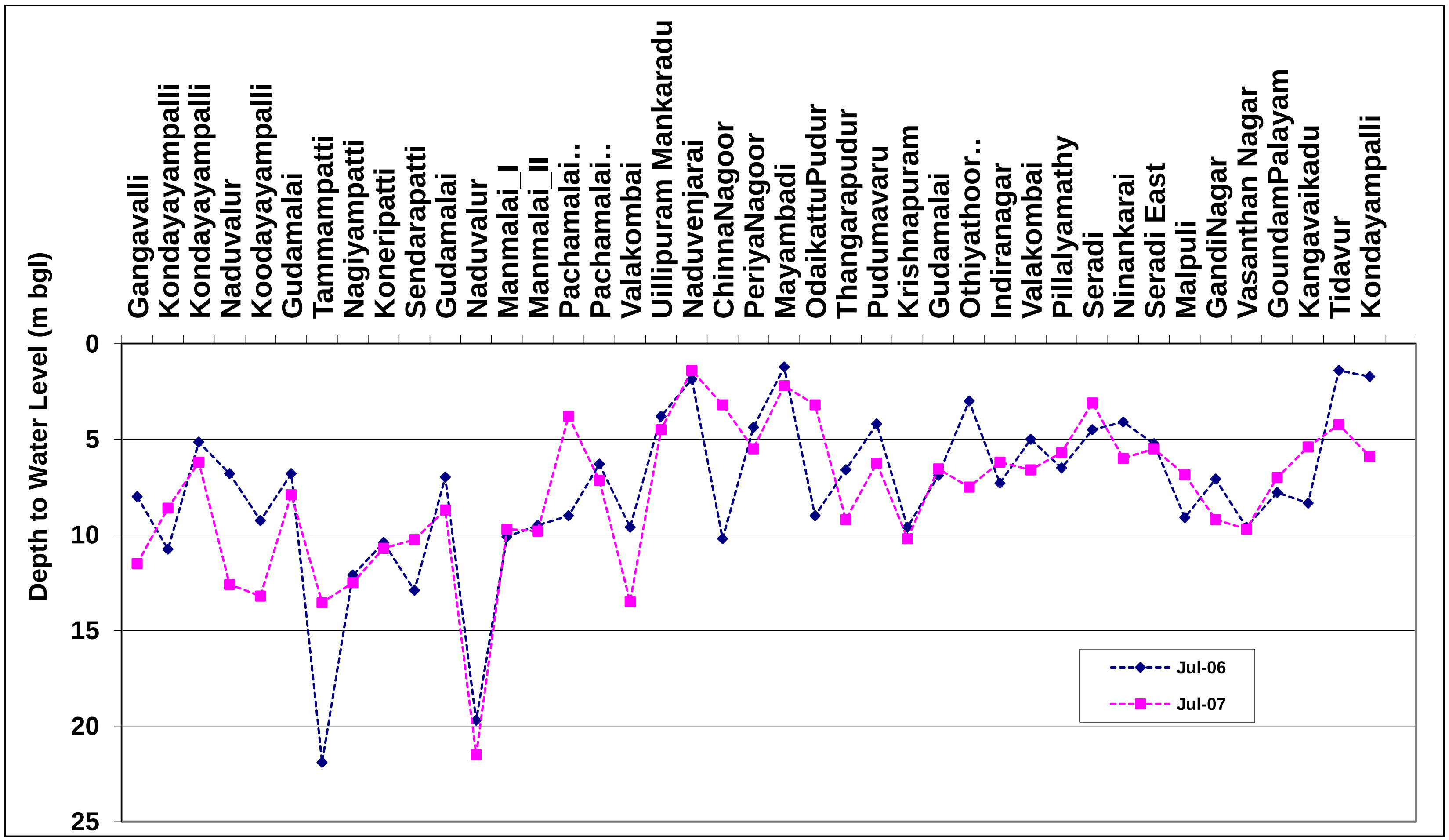


Figure 72. Impact on Water levels- premonsoon period

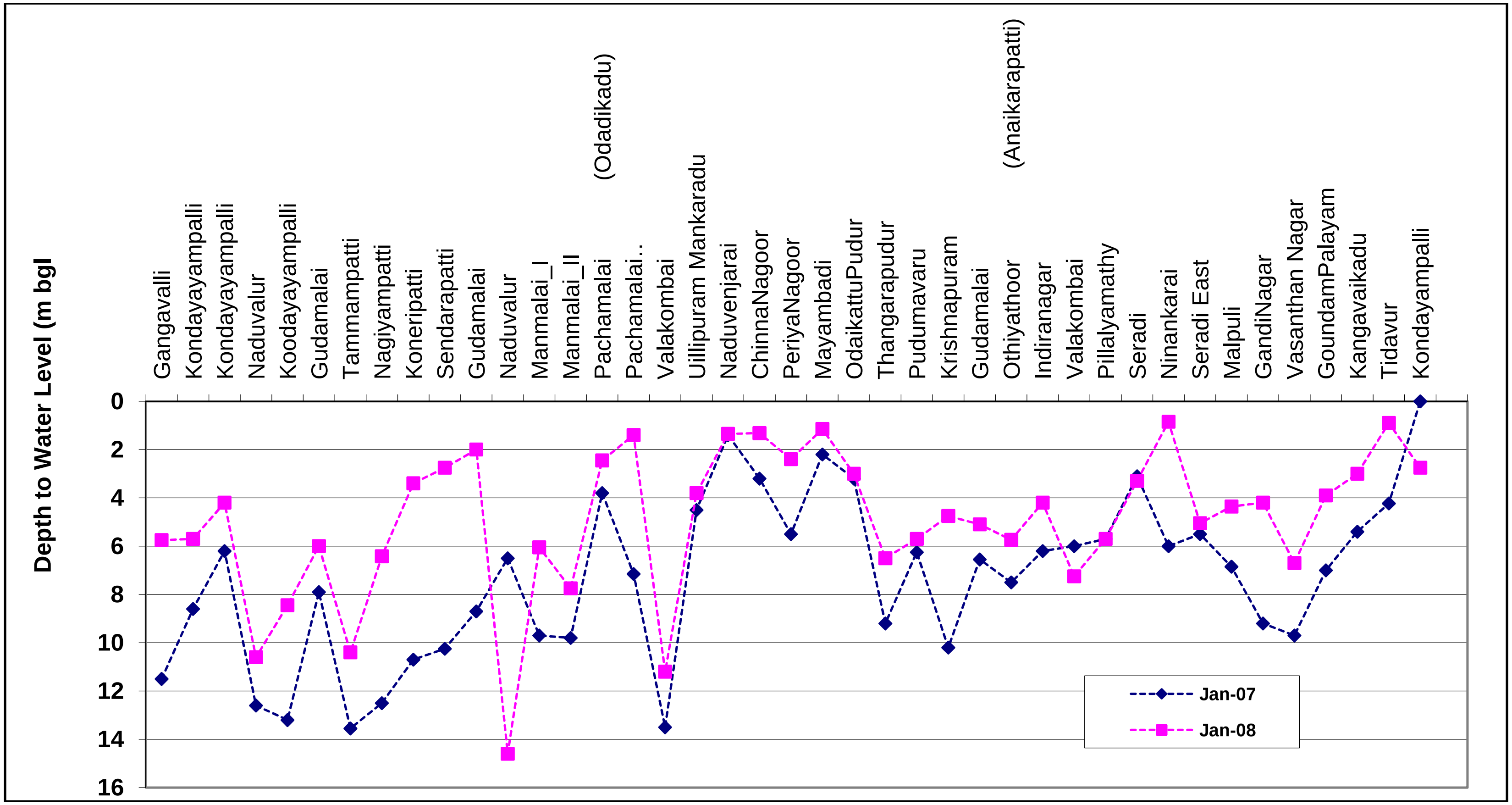


Figure 73. Impact on Water levels- Post monsoon period

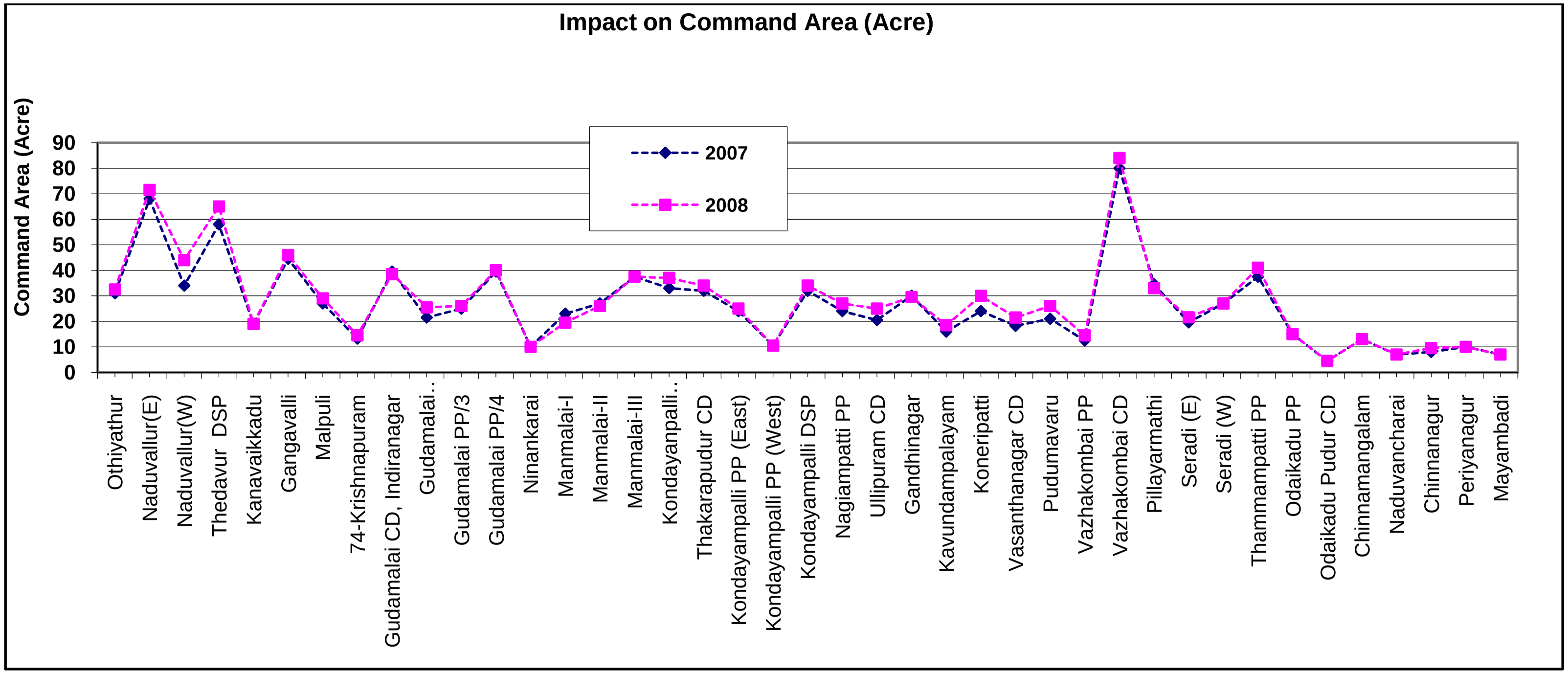


Figure 74. Impact of AR structures on command area

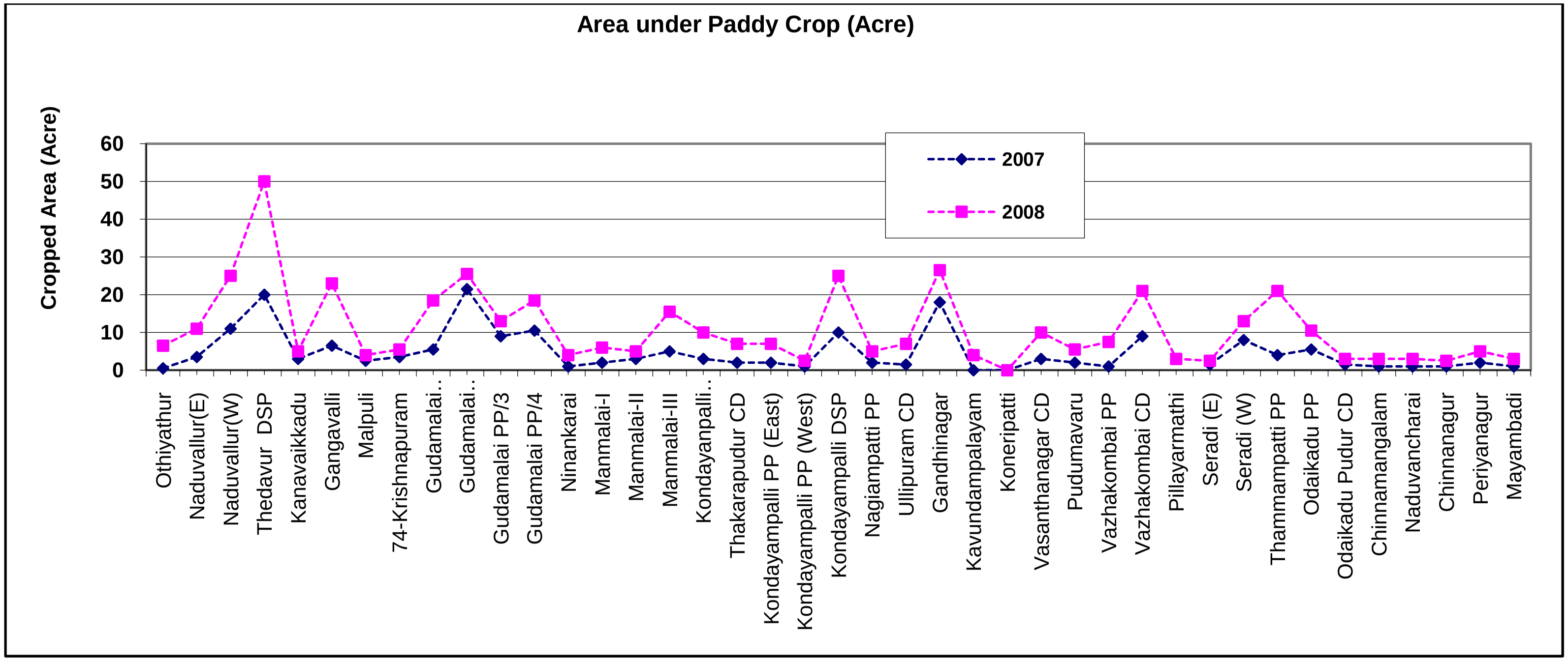


Figure 75: Impact of AR structures- increase in paddy cultivation area

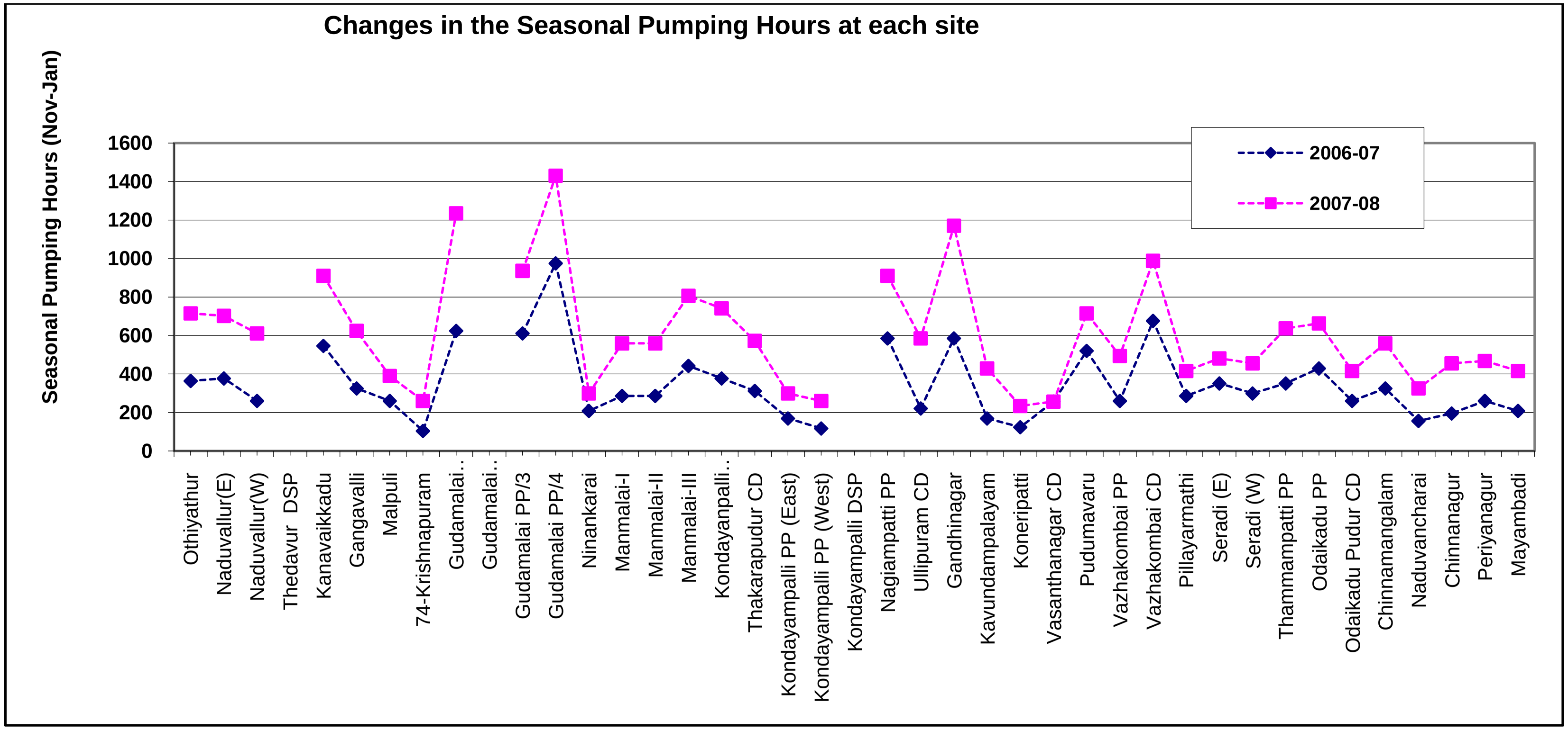


Figure 76. Impact of AR structures- increase & changes in pumping pattern

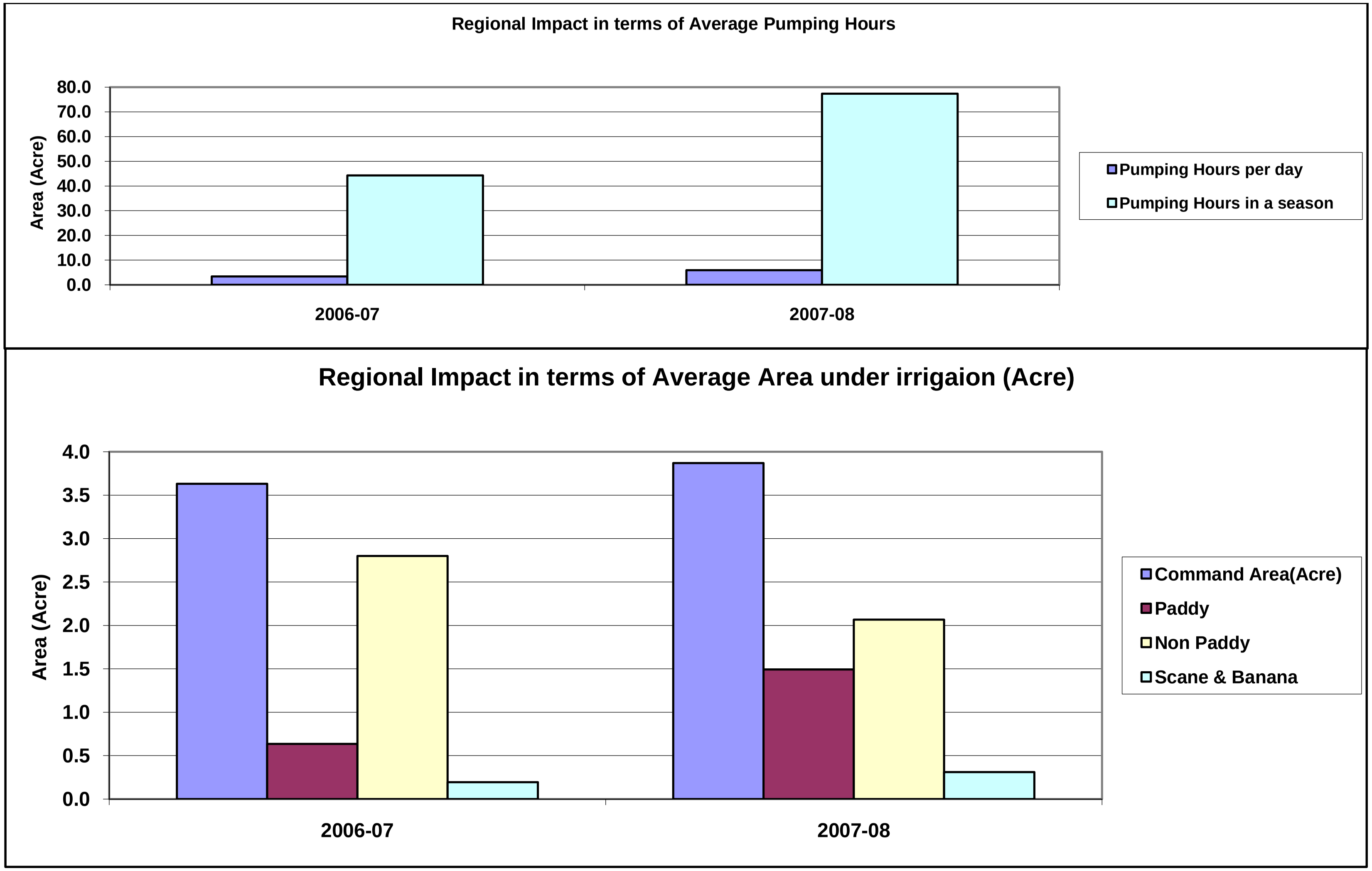


Figure.77. Regional impact in terms of area under irrigation & Pumping hour changes

K. WEST BENGAL AND SIKKIM

West Bengal state covers an area of 88,752 km^2. The state receives an average annual rainfall of 2074 mm. The state can be divided into two hydrogeological unit namely fissured hard rocks & porous alluvial formations. Fissured formation includes crystalline, meta-sedimentary and volcanic rocks. The yield of wells tapping fractured zones varies from 10-20 m^3/hr. Two third of the State is underlain by alluvial sediments mainly deposited by Ganga & Brahmaputra rivers. Based on the yield of wells tapping these alluvial sediments, aquifers of the alluvial area can be divided into three zones. 1. Yielding about 150m^3/hr, occurs from Jalpaiguri to Kochbihar in north to Medinipur & 24 Parganas in South. 2. Yielding about 50-150 m^3/hr, occurs in parts of Malda, Dinanjpur and western part of Murshidabad districts. 3. Yielding less than 50 m^3/hr, occurs as Marginal alluvial tract in parts of Birbhum, Burdawan, Bankura and Murshidabad districts.

Sikkim is a small mountainous state characterized by rugged topography with series of ridges and valleys. The various rock types prevalent in the state are Pelitic and carbonate rocks. Gondwanas and occasional alluvial terrains occur along streams and river courses. Groundwater occurs largely in disconnected localized pockets and in deeper fracture zones. Springs are the main source of water.
The annual replenishable groundwater resource of the state is 30.36 bcm with a net annual groundwater availability of 27.46 bcm. Ground water draft (as on 31st march 2004) is 11.65 bcm with a stage of ground water development of 42%. Out of the 269 assessment units in the state, 01 have been categorised as critical and 37 blocks as semi-critical and remaining 231 blocks as safe category from ground water development point of view.

Artificial recharge Techniques suitable for the state

Major portion of the state is occupied by alluvial formation deposited by Ganges and Brahmaputra rivers. Recharge pits/recharge shafts with tubewell and induced well recharge in certain regions may be ideally suited for these unconsolidated formations. For the semiconsolidated and consolidated formations percolation pond are suitable. For urban areas roof top rainwater harvesting and artificial recharge structures like the recharge pit and shaft with/without tubewell may be adopted.

Rain water harvesting and artificial recharge have been implemented by the Centre for Ground Water Studies, Tagore Society for Rural Development, Institute For Motivating Self-

Employment, Institute of Environmental Studies and Wetland Management and others institutes / organization and played proactive role in the state.

Construction of Rain Wate Harvestig Structures inTwenty Schools of West Bengal

Designed by : Centre for Ground Water Studies
Districts : Bankura and Birbhum, Puruliya and Darjeeling districts and Loreto Girls' School, Entally, Kolkata.

Bankura District

Name of the School	Roof Area in sq.m	Recharge Efficiency	Quantity of Recharge in litres
1.Bishnupur High School	213.00	0.68	1,73,808
2.Rajgram Vivekananda Hindu Vidyalaya	302.00	0.68	2,46,432
3.Dubrajpur Uttarayan Vidyatan	635.00	0.68	5,18,160
4.Bankura Municipal High School	650.00	0.68	5,30,400
5. Mejia High School	364.00	0.68	2,97,024

Birbhum District

1.Kirnahar Shiv Chandra High School	120.00	0.68	97,920
2.Kirnahar Tarapada Smriti Girls' High School	281.00	0.68	2,29,292
3.Satyanarayan Siksha Niketan Girls High School, Labpur	240.00	0.68	1,95,840
4.Ahmadpur,Joydurga High School	215.00	0.68	1,75,440

Darjeeling & Jalpaiguri Districts

1. Bagha Jatin Vidyapith, Siliguri	225.00	0.68	3,06,000
2. Siliguri Deshbandhu Hindu High School	220.00	0.68	3,00,000
3. Phansidewa High School	178.00	0.68	2,42,000
4. St. Mary's Girls' High School, Kamala Bagan	260.00	0.68	3,54,000
5. NJP Railway Girls High School, Jalpaiguri	250.00	0.68	3,46,000

Purulia District

1. Manbazar Girls' High School	195.00	0.68	1,46,250
2. Hutmura High School	350.00	0.68	2,62,500
3. Raghunathpur Girls' High School	350.00	0.68	2,62,500
4. Gar Jaipur R.B.B. High School	520.00	0.68	3,90,000
5. Chittaranjan High School, Puruliya	360.00	0.68	2,70,000

Two Storage Tanks of 5000 litres capacity each, earmarked for Two Schools, have been diverted and fitted with Loreto Girls' School, Entally as approved by the Coca-Cola Authority. A provision for recharging about 3,50,000 litres of water through a 80 m deep recharge well has been made. These twenty schools where ground water recharging through roof-top rain water harvesting were effected in the year 2005-2006, were further inspected in 2008. A general impression gathered from the School Authorities reveals that these structures successfully recharge the shallow aquifers and Water logging could be prevented in some school buildings as the water incident on the roofs could be recharged underground. Besides, a lot of awareness could be generated amongst the students and teachers regarding the necessity of rain water harvesting.

Designing of Rain Water Harvesting Structures in the Coca-Cola Campus of Raninagar (Jalpaiguri District), West Bengal

Centre for Ground Water Studies designed Rain Water Harvesting Structures for Ground Water Recharging in for the Roof-tops of the Factory at Raninagar, Jalpaiguri District, West Bengal of M/S Coca-Cola India Ltd. In Raninagar Campus, ground water recharging to the tune of 15 lakh litres through suitably designed recharge wells down to the depth of 40 m are working satisfactorily.

Rain Water Harvesting and Artificial Recharge by Tagore Society for Rural Development (TSRD)

Designed by	: Tagore Society for Rural Development (TSRD)
Sponsored by	: Council for the Advancement of Peoples' Action and Rural Technology (CAPART)
Scheme	: Development of Agricultural infrastructure for irrigation & Greening Program

Pond Excavation Program:

Before our intervention all the Project areas suffered from severe deficit of water for drinking, washing and irrigation.

Sunderbans: Thanks to an ambitious project promoted by the Sundarban Development Board, Govt. of West Bengal, the excavation of Tanks/Ponds for harvesting rain water in this area has received a major fillip. TSRD is the single biggest implementer of this program, specially in Sagar, Basanti and Gosaba blocks. These new tanks/ponds are on private lands. Thus, individual households now have access to water for year long irrigation, domestic purposes and the promotion of livelihood options through cash cropping, kitchen gardening, horticulture, pisciculture and duck rearing.

Drought prone areas: Regular drought and lack of irrigation infrastructure made it difficult to cultivate land for agriculture in our remaining project areas. Thus, most of the villagers were poor and frequently faced unemployment and starvation. Large numbers of people migrated to other states for off season employment. TSRD's interventions to promote water conservation through excavation of Tanks, Ponds, Canals, Kharis, construction of waste weirs on canals and Kharis proved beneficial to the local people. Integrated Water Shed Management improved the socio-economic scenario as cash crops, water for human use and livestock rearing were automatically promoted. Conservation of rain water through these improved water bodies helped recharge ground water in these areas. Green fields can be seen in these areas both in summer and winter.

Watershed management in Pakur and Patamda in East Singhbhum, Jharkhand means regeneration of soil water by recharging under ground aquifers, improved livelihoods through farming and agriculture.

Over the years, the Society excavated and re-excavated more than 1000 ponds, tanks, canals, Kharis, nullahs, etc. spread over all the project areas for enhanced water storage capacity. During the last 2 years, the Society has re-excavated more than 700 derelict tanks in Sagar, Gosaba and Basanti blocks of South 24-Parganas District, West Bengal.

- Constructed rain water reservoirs in some places of Jharkhand projects.
- Constructed check weirs on kharis, canals and nullahs to store run off rain water, both for irrigation and recharging ground water.
- Introduced in situ moisture conservation process by a network of run off management structures and devices in large stretches of upland and mid land for recharging ground water.
- Under TSRD's Greening Program, about 10 lakh saplings are planted annually to check run off, prevent soil erosion and promote percolation of water.

Awareness Generated

- Formation of Implementing teams (Excavation/Planting etc.) was around the creation of village based assets and community dynamics
- Maintenance and Usage by local communities
- As these are seen as Community assets
- The access and use of Dalits and Tribal to these assets
- Empowerment of Women and formation of SHGs to maintain these assets.

Type of innovative methodology/technology adopted:

Upland technology – Besides the excavation and re-excavation, the Society adopted small plots-cum-moisture storage pit technology for uplands and midlands where large stretches of uplands are divided into small plots. The Moisture collection pits are dug at the lower most corner of each plot. The pits are spread all over the area to store run off and improved sub-soil moisture. This is done over a large area. In contiguous plots which retains enough moisture and increases the ground water level in low lands. Organization of farmers of contiguous plots and their involvement is an integral part of process.

Plain land technology - 20% of total allotted land is used for water harvesting and storage for irrigating the remaining 80% which is used for farming.

Scope of replication: The fact that the Sunderbans Development Board has proposed to excavate 50,000 ponds and tanks by 2010.

Sustainability: As Village Users Committees/SHGs have taken over the use and maintenance of these community assets, sustainability is automatically ensured.
Many other NGOs/CBOs now working in these areas are already replicating these efforts as are local SHGs.
Cost - Benefit Ratio –
Total benefit accrued –

Tangible

- Water for most part of the year
- Increased irrigation and farm productivity
- Pisciculture
- Employment opportunity for byproduct activities

Non-Tangible

- Better health and hygiene
- Easier access to water for women
- Help reduce migration

Intensive agriculture and its required irrigation ensure the top soil is kept moist throughout the year.

Out put – In West Bengal for last 2 years

(Numbers): 771 ponds excavated/re-excavated
1800 Hectares of lands brought under Greening Program
205 Hectares of lands brought under irrigation

Out comes:

- Increased income
- Recharge of Ground Water
- Greater moisture retention
- Reduced run off
- Reduction of island erosion
- Increase in Wild Life habitat

Investment/Benefit: Rs. 1.9 crores and benefit accrued Rs.38.5 lakhs per annum (approximately) from cultivation – Agriculture & Pisciculture. Man days created 40,000 per annum. In addition to recharge of rain water and moisture conservation, these ponds provide additional income from Pond Management and Duckery.

Rain-Water Harvesting Project in Schools (Implemented in the districts of Murshidabad, Birbhum & Nadia)

IMSE was given responsibility for construction of rainwater harvesting structures in selected government schools through GRHC, Tilonia, Rajasthan.

Year	Birbhum	Murshidabad	Nadia
2005-06	-	05	05
2006-07	10	10	-

IMSE successfully implemented the projects. The one of the success stories of the projects of Birbhum district has been furnished below:

Gurisha Senior Madrasa's story is a story of success in rainwater harvesting in schools. Gurisha Madrasa is situated in the village of Gurisha, P.S. Ilambazar in the subdivision of Bolpur in the district of Birbhum.

Headmaster of Madrasa begins

The school is surrounded by villages where during the dry season due to high extraction of groundwater, the water level of the area becomes lower. The surrounding areas face acute crisis of drinking water.

Department of Water Resource Development Research Centre, Government of India sponsored the Barefoot College of Rajasthan for the RWH programme. In collaboration with the Barefoot College IMSE also embarked on the project.

IMSE team visited the affected areas and also found in some areas water was contaminated with Arsenic content where RWH would be a suitable way to solve the problem. After studying several areas IMSE team approached Gurisha Madrasa authority for the water harvesting programme, where other area suffered from acute water crisis. The school authority immediately agreed with IMSE team.

During the implementation a beneficiary committee was formed comprising Headmaster of the School, teachers' representative of the school, local NGO, local government official.

During the implementation, a purchase committee was formed, awareness campaign was held regarding use of rainwater, and a move to collect local funds was taken up. At the final stage after the completion of the project a social audit was organized where to maintain transparency, villagers were invited to query on expenditure of the project. After the successful implementation of the project the 300 hundred students realized that the rainwater is the only alternative source of drinking water. The people also use the water for worship and call it 'Allahar Pani' or water of God. People think that the RWH programme should be taken up in other areas at community level where the ordinary people would be further benefited.

During the implementation of the project the Central Ground Water Board provided necessary guidance and advice. We

Rain water harvesting schemes implemented by Institute of Environmental Studies and Wetland Management (IESWM) in Districts of West Bengal.

The Institute has installed Rooftop Rainwater Harvesting System in schools. Because in West Bengal state, the rain starts in June and lingers up to month of September, the system has been installed in such a way that water can be used continuously i.e. storage and use of water goes simultaneously. From the end of August the water is stored for use in the dry period i.e during summer.

S.N.O	District	Present Status
1.	Bankura	90% of well maintained and functioning smoothly
2.	Birbhum	80% of well maintained and functioning smoothly
3.	Purulia	75% of well maintained and functioning smoothly
4.	North 24 Paragnas	100% of well maintained and functioning smoothly

I. ANDMAN & NICOBAR ISLANDS

Andaman & Nicobar Islands receive a copious rainfall and availability of surface water as also ground water is inadequate to cater to the drinking water needs as also for development of irrigated agriculture because of hydrogeological, climatic and environmental reasons. However, detailed studies carried out by CGWB had paved the way for conservation of copious rainfall along the stream valleys through series of Check dams. Under the technical guidance of CGWB in 2003-04 Session 101 check dams were constructed in A&N islands of which 69 were constructed in South Andaman District while 32 were constructed in North-Middle Andaman District. Table-38 shows the salient details of select check dams in south Andaman after impact assessment. Through these check dams , for the first time irrigation potential of 724.50 Hectares was created in A&N islands. Ponds were under utilization for harvesting good quantity of rainfall depending upon the impervious nature of the bulk of the pervasive sedimentary geological formations. A sum total of 908 no of ponds were constructed which had facilitated to create an irrigation potential of 544.8 Hectares of land in entire A&N Islands. However, after the tsunami for rehabilitation of the people and their livelihood great deal of rainwater harvesting activities were in progress and a sum total of 498 pond and 33 check dams were constructed under Rajiv Gandhi Rehabilitation Project for Agriculture by Department of Agriculture A&N Administration which had further created an irrigation potential of 298.8 Hectares for Ponds and 165 Hectares for Check dams.

It is also narrated in the discussion that after the erath quake huge water crisis was created in the uplands due due to evacuation of ground water from the aquifers as new fractures were generated which were opened at lower topographic areas. For these new springs were developed. To tap these unabated flows under the recommendation of CGWB Check dams for drinking water supply augmentation were constructed by APWD,A&N Administration at Beadnabad and by the PRI on the streams at Superi Bagicha, in South Andaman.

Rooftop rain water harvesting (Figure.72) was done by APWD, A&N Administarion during 1998-2000 all over the islands an a sum total of over 100 nos of 10 KL capacity ferro cement tanks with filtration unit were constructed.

In Nicobar District there is a very primitive and tiny islands named Chowra exists. The total geographical area of the island is only 8.2 Sq.Km having a total population of 1502. Because of typical geomorphological set up and porous nature of the geological formation (coralline and Foraminiferal Limestone with Marls) groundwater reservoir could not be formed in the island. This is the only inhabited island in A&N Island where fresh water is unavialble. CGWB had carried out a detailed work in the island in 2004 and advocated artificial recharge in a closed aquifer condition from roof as also landscape catchments. The work was stated but it could not be completed by the Tsunami. However, there are three big rooftop rainwater harvesting unit available in the islands(Fig- 73) constructed by APWD,A&N Admn. and a Reverse osmosis plant was also installed in the pre tsunami. All these cannot fulfil the need of drinking water for the populace. In times of urgent crisis the islanders also collect water from contiguous Teressa island with canoes. One can see very primitive nature of rainwater harvesting in the island through coconut shells (Fig-79)

Fig-78 Rainwater harvesting tank in Portblair Jail

Fig-79 RWH tank in Chowra island,Nicobar District

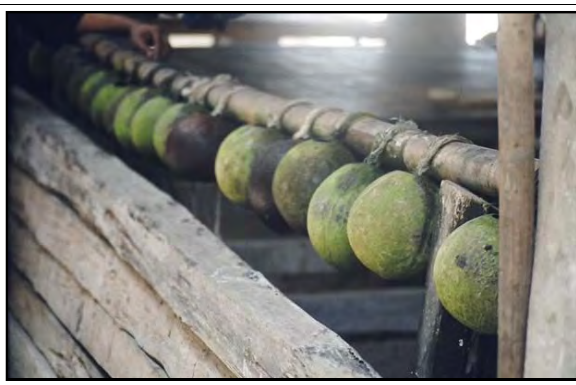


Fig-80 Primitive type of RWH practice through Coconut shells in Chowra Island

Fig. 81 RWH in Ponds by Britishers in Ross Island

Fig. 82 RWH in Ponds by Britishers in PortBlair

Fig-78 -82 Various types of Rainwater harvesting and traditional wisdom of primitive islanders & English rulers in the pre-Independence in A&N Islands

Besides, one can see the wisdom of Britishers in eighteen century while they constructed ponds on verification of the poor groundwater potential of the underlying geological formations in their Head quarters at Ross Island (Fig-75) and around Port Blair (Fig-76) . At Ross Island they even used to prepare mineral water from the pond shown in the picture. The water supply from the Dilthaman tank near Rajniwas was existent till 1974 which was stopped after the construction of Dhainikhari Dam. People at Port Blair faces extreme crisis of drinking water as the Dhanikhari supply often dwindles with delay in monsoon.

Table- 38 Rainwater harvesting through checkdams in South Andaman

Sl.no	Location	Width (m)	Depth of Water (in m)	Volume of water impounded(M^3)	Irrigation potential created (Hectare)	Cropping pattern
1	Beadnabad-I	4.46	0.9	137.68	6.0	Betel vine,Ladies finger,pumpkin,ridge gourd,cowpea,Radish
2	Kodiyaghat	4.50	0.55	24.85	5.0	Cowpea,Betel gourd, Ladiesfinger,Radish, Bean,French bean, Bottle gourd,pumpkin
3	Maccapahar-I	3.8	0.88	26.51	3.0	Drumstick,Betel vine, Areca nut
4	Maccapahar-II	4.0	0.7	34.66	4.0	Coconut,Areca nut, Cowpea, Ladies finger,ginger
5	Maccapahar-III	6.02	1.2	40.47	4.0	Coconut,Areca nut, Cowpea, Ladies finger
6	New Bimblitan-2	2.10	1.0	11.52	2.5	Coconut,Areca nut, Cowpea, Ladies finger
7	Calicut-II	8.5	1.0	119.98	10.0	Coconut,Areca nut

X. PROMOTION OF ARTIFICIAL RECHARGE – EFFORTS OF CENTRAL GROUND WATER AUTHORITY

A model bill for regulation & management of the ground water by the States was circulated by Ministry of Water Resources first in 1972, thereafter with changing scenario of ground water development model bill was revised and circulated in 1992, 1996 & latest in 2005 in which artificial recharge component was added and it became mandatory for the State Government to include Artificial Recharge while formulating the ground water regulation Act.

The development of ground water in different areas of the country has not been uniform. Highly intensive development of ground water in certain areas for irrigation, drinking, domestic and industrial uses in the country has resulted in over-exploitation leading to long term decline in ground water levels. For providing sustainability to ground water resources in such areas and keeping in view the increasing thrust on development of ground water resources for fulfilling the ever growing demand of water in various sectors, there was an urgent need to regulate over-exploitation of ground water resources and also to augment the depleting ground water resources.

Central Ground Water Authority (CGWA) has been constituted by Ministry of Environment and Forests vide S.O. No.38 (E) dated 14th January, 1997, under sub-section (3) of section 3 of the Environment (Protection) Act, 1986 (No. 29 of 1986), as per the directions of Hon'ble Supreme Court of India. The mandate given to Authority is "*to regulate and control, management and development of ground water in the country and to issue necessary regulatory directions for this purpose".* For the purpose of compliance of this given mandate the Central Government has conferred on the Authority certain powers under Environment Protection) Act, 1986.

Subsequently, Central Ground Water Authority (CGWA) under Section 5 of the Environmental (Protection) Act, 1986 issued directions to the Chief Secretaries of the States to adopt Rain Water Harvesting in all the Over Exploited /Critical blocks/taluks of the State. This was followed by issuance of more directions for implementation of Rain Water Harvesting in Urban and other areas, such as

- Directions to Civic bodies in NCR for drinking water supply network and Rainwater harvesting/recharge
- Direction to adopt Artificial Recharge/Rain Water Harvesting in 1065 areas/blocks
- Directions to all residential group housing societies/ institutions/ Schools/ Hotels/Industrial Establishments falling in OE/Critical Areas of country
- Direction for implementation of scheme of rainfall runoff across all national and state highways, Airports, Stadia etc., in the country for rain water harvesting and adopting Artificial recharge of ground water.

In compliance to CGWA directions, steps were taken by States/UTs to promote and to make rainwater harvesting mandatory as given below in table-39.

Table 39: Action taken by State/ UT Governments to promote rain water harvesting

S.No.	State/ UT	Action taken
1.	Andhra Pradesh	Under Chapter 3, Section 17 (1) of the 'Andhra Pradesh Water, Land and Tree Act, 2002' stipulates mandatory provision to construct rainwater harvesting structures at new and existing constructions for all residential, commercial and other premises and open space having area of not less than 200 sq.m. in the stipulated period, failing which the authority may get such rain water harvesting structures constructed and recover the co incurred along with the penalty as may be prescribed. Municipal Administration and Urban Development have notified that all Group Housing schemes shall be provided with required facilities and infrastructure for conservation and harvesting of rain water. Municipal Administration and Urban Development Department vide G.O. No. 185 dated May 5, 2001 have been assigned responsibilities and made special efforts to conserve rain water through rain water harvesting structures in urban environs. Municipal Corporation of Hyderabad, surrounding Municipalities and Panchayats have been made responsible for construction of rain water harvesting pits.
2.	Bihar	Enacted "The Bihar Ground Water(Regulation and Control of Development and Management) Act, 2006. Chapter-III (Clause 18) of the Act stipulates provision of roof top rain water harvesting structures in the building plan in an area of 1000 sq. mt. or more while according approval for construction by the Municipal Corporation/other local bodies.
3.	Chandigarh	UT Administration has made installation of rain water harvesting system mandatory for all buildings (existing and new) located on plot of one kanal and above to recharge ground water.
4.	Chhatisgarh	Rain Water Harvesting project "Gajra Sub Watershed Management Project" implemented in semi critical block Patan of Durg District by Public Health Engineering Department. There are proposals to take up works such as construction of stop dams, percolation tanks, boulder check dams across the nallas/smaller rivers to check depletion of ground water table.
5.	Delhi	Roof top rain water harvesting made mandatory for building having area of 100 sq.m. and above by amending building bye laws. Financial assistance of 50% of the cost upto Rs. 1 lakh is provided under Bhagidari programme to Group Housing Societies, Resident Welfare Associations, private/recognized schools, institutional buildings, hospitals, charitable institutions for construction of rain water harvesting structures. Registrar, Cooperative Societies advised all Group Housing Societies to adopt rain water harvesting in their premises. MOU signed with Confederation of Indian Industries (CII) for promotion of water conservation, water audit of Govt. buildings and industries. Requested all Govt. departments to adopt rain water harvesting and waste water recycling system.

		Education Department is implementing rain water harvesting in all schools under their control. NDMC, MCD, DDA, PWD sanctioning plan by including rain water harvesting and also implementing rain water harvesting in their buildings.
6.	Gujarat	Metropolitan areas have notified rules under which no new building plan is approved without corresponding rainwater harvesting structure. Construction of Check Dams, khet talavdi and tanks, spreading channels and Deeping of Percolation tanks under Sardar Patel Sahbhagi Jal Sanchay Yojana & Sujlam Suflam Yojna. Construction of Recharge Tube Wells.
7.	Haryana	Rain water harvesting made mandatory by Chief Administration, Haryana Urban Development Authority & Secretary to Govt. of Haryana vide notifications dated 31st October, 2001 and 13th December, 2002 respectively.
8.	Himachal Pradesh	Construction of rain water harvesting system has been made mandatory for all Schools, Govt. buildings and Rest Houses, upcoming industries, bus stands etc. Provision of rain water harvesting structures compulsory as per provisions in section-107 of H.P. Municipal Act, 1994 in all new buildings to be constructed within the jurisdiction of Municipal Councils/Nagar Panchayats in the State to stop the misuse of expensive treated water.
9.	Jharkhand	Ranchi Regional Development Authority amended building bye laws in November, 2006 and made adoption of rain water harvesting and recharge well mandatory for multi dwelling and commercial units.
10.	Karnataka	Amended Rules of Bangalore Water Supply and Sewerage Board which provide for mandatory provision of rain water harvesting structure by every owner with site dimension of 2400 sq ft and above, or every owner who proposes to construct new buildings with site area more than 1200 sq ft. Different line departments are implementing programmes of rainwater harvesting and artificial recharge in the state. Department of Mines & Geology is conducting the ground water public awareness programmes in over-exploited, critical and semi-critical districts of the state emphasizing importance of ground water conservation and rain water harvesting. Revival of conventional methods of rain water harvesting in ponds, lakes, wells, step wells used earlier are being implemented by the Jal Samvardhan Yojana Sangh, Rural Development & Panchayati Raj and other departments.
11.	Kerala	Vide G.O. (Ms) No. 19/2004/LSGD dated 12.1.2004, an amendment was made in Kerala Municipality Building Rules, 1999 in Chapter XVI-A to incorporate rainwater harvesting arrangements.
12.	Madhya Pradesh	Incorporated mandatory provision for rain water harvesting in the

		M.P. Bhumi Vikas Niyam (1984). Rule 78(4) makes it mandatory to provide for rain water harvesting in all houses of more than 140 sq.m.
13.	Maharashtra	Launched rain water recharge scheme named "Shivkalin Pani Sathawan Yojana" (Shivkalin Water Recharge Scheme) in the State from 2002. Under this scheme, drinking water sources are strengthened by recharging rainwater through different water harvesting structures. This scheme is implemented in rural areas. In urban areas, keeping in view the constraint of the available space, provision has been made in the Development Control Rules to make provision of rain water harvesting scheme in Greater Mumbai Municipal Corporation Area and other municipal areas of the State.
14.	Orissa	Dte. of Ground Water Survey & Investigation has undertaken construction of recharge structures like recharge tanks, recharge dugwell, recharge pits, renovation of existing ponds, recharge tubewell, recharge borewells, check dams, roof top rain water harvesting structures in different watersheds. Orissa Watershed Development Mission, Dte. of Soil Conservation and Minor Irrigation Department are also taking necessary steps for renovation, restoration and repair of water bodies like tanks, ponds, wells etc.
15.	Puducherry	Made provision of rain water harvesting mandatory in residential, offices and public buildings, commercial buildings, educational and health institutions and industrial buildings vide Govt. order No. 6/2010-Hg dated 19.3.2010.
16.	Punjab	Department of Local Government have amended and notified the building Bye-Laws and have made mandatory Rain Water Harvesting System in all buildings above 200 sq. yards. The same has been adopted by all Urban Local Bodies of the state. Punjab Urban Development Authority has also made provision of rain water harvesting mandatory in all institutional buildings while approving building plans as well as licensed colonies developed by private promoters.
17.	Tamil Nadu	Vide Ordinance No. 4 of 2003 dated July, 2003 laws relating to Municipal Corporations and Municipalities in the State have been amended making it mandatory for all the existing and new buildings to provide rain water harvesting facilities. The State has launched implementation of RWH scheme on massive scale in Government buildings, private houses/Institutions and commercial buildings in urban & rural areas. The State Government has achieved cent percent coverage in roof top rain water harvesting. It has also been made mandatory to include roof top rain water harvesting structure in the plan of the building itself for accordance of approval by the relevant

		competent authority. TWAD Board has constructed various recharge structures like check dams, percolation ponds, recharge pits, trenches, improvement to traditional ooranis, defucty borewells etc.
18.	Rajasthan	Provision of rain water harvesting made mandatory in respect of plots having more than 300 sq. m. area in Nagar Nigam/ Nagar Parishad/ Nagar Palika areas and notification in respect issued vie letter No. F 55/PA/AS/DLB/06-4280-4362 dated 16.1.2006 by the Local Self Department. The State Ground Water Department has prepared master Plan for artificial recharge of ground water in the state by utilizing rain water, which has been handed over to State Water Resources Department for its implementation by construction of artificial recharge structures on the sites proposed by GWD. About 300 artificial recharge structures (check dams, percolation tanks, dug out ponds, subsurface barriers etc.) have been constructed on pilot basis in Mandore – Osian, Distt. Jodhpur, Piprali, Distt. Sikar and Khamnor, Distt. Rajsamand under “Rajasthan Water Sector Restructuring Project”. Suitable artificial recharge structures are being constructed under National Rural Employment Guarantee Scheme. Structures like contour bunding, check dams. Contour furrows/ staggered trenches and various water harvesting structures like renovation of existing structures (nadi/ pond), farm ponds, anicuts are being constructed under Desert Development Programme, Drought Prone Area Programme and Integrated Wasteland Development Project, National Watershed Development Programme for Rainfed Areas and Integrated Watershed Management Programme by Watershed Development & Soil Conservation Department.
19.	Uttar Pradesh	Rain Water Harvesting made mandatory for all new housing schemes/plots/buildings/ group housing schemes with separate network of pipes for combined Rain Water Harvesting/Recharging system. In all developmental schemes (Govt./ private) roof top rain water harvesting is compulsory for plots of 100 sq.m. and above but below 200 sq.m., network of combined recharge system is essential and for plots of 300 sq.m. and above, if combined system is of recharge is not possible, landlord has to install the system. In Govt. Buildings (both new as well as old), installation of rain water harvesting structures has been made mandatory. For housing schemes of 20 acres and above it is mandatory to develop ponds/ water bodies in 5% of the total proposed area. For regular monitoring of different schemes of rain water

		harvesting by different departments, an 'Executive Committee' under the chairmanship of the Chief Secretary has been constituted.
20.	Uttarakhand	The Govt. (Awas evam Shahari Vikas) made rules for compulsory installation of rain water harvesting system and directed to adopt rules in building Bye-laws vide order dated 15.11.2003. Accordingly, all the Development Authorities have made partial amendments in the prevalent House Building and Development Bye-laws/Regulations. 109 traditional ponds and 104 percolation tanks have been constructed to conserve water. Besides these schemes basin/sub basin catchment programme has been taken up by the Project Management Unit (PMU) under "Swajal Project" under the Catchment Area Conservation and Management Plan (CACMP).
21.	West Bengal	Vide Gazette notification No. 67/MA/O/C-4/3R-8/2002 dated 14.2.2007, Govt. has promulgated "The West Bengal Municipal (Building) Rules, 2007 and vide its rule No. 168(13), Part – XII has made rain water harvesting mandatory for all buildings. The State Water Investigation Directorate undertakes the pilot schemes of demonstrative nature. The Water Resources Development Directorate is engaged to replicate it accordingly. SWID has also implemented artificial recharge schemes in drough prone districts of Purulia, Bankura and Paschim Medinipur as well as in some semi critical/ critical blocks. Already different types of artificial recharge schemes have been implemented under different programmes of state and central assistance. A good numbers of tanks in Uttar Dinajpur and South 24 Parganas have been rejuvenated under Repair, renovation and restoration of water bodies directly linked to agriculture under central assistance programme. The State Govt. has given importance towards formulating schemes based on impounding Reservoir, Rain Water Storage Pond, Rooftop Rain Water Harvesting etc. The Public Health Engineering Department, Govt. of West Bengal has undertaken 20 nos. of schemes in based on rain water storage ponds, 14 nos. of schemes based on impounding water of various dams and 22 nos. schemes based on rooftop rain water harvesting.

Water requirement for industries in India is comparatively small as compared to the quantity of water needed for agriculture. However, when industrial demand is concentrated in specific locations, heavy withdrawals are done from available water resources. Mostly the industrial uses are non-consumptive, thus making reuse through recycling and other conservation measures possible. The amount of water consumed for any product, varies widely depending upon the processes used, plant efficiency, technology employed, the degree to which water is re-circulated and other factors. Industrial waste may contain different kinds of toxic pollutants, which if untreated may result in contamination of water resources. Treatment of industrial waste water and recycling are essential to conserve water resources.

The prime objective of the recharge by the industries and infrastructure projects, is to focus on a specific part of ground water management viz. ensuring sustainability of ground water both in terms of quantity & quality and also focus on land based management of ground water resources.

As per the ground water resource estimates of 2004, out of the 5723 assessed units (Blocks, Mandals, Talukas, districts), 839 over-exploited units, 226 critical units and 550 semi-critical units have been identified across the country by Central Ground Water Board.

Criteria for the Development & Management of ground water vary widely. The prospects for the management of ground water in various regions are also varying and required to be addressed on area specific basis. The criteria to be considered for various purpose of ground water development like Drinking and Domestic, Industries, Infrastructure, Mining, Recreation etc., are different in different areas. They vary as per availability of aquifers (like shallow, deeper aquifer in both alluvium and hard-rock areas), water conservation and recharge to ground water/water harvesting potentials.

Various methods/techniques of recharge for groundwater to overcome the impact of withdrawal are mandated for implementation depending on the local hydro-geological set up for which following criteria are considered

A The quantum of harvested rain water and recharge to ground water for neutralizing /improving the effects of ground water abstraction. Whether rainwater harvesting structures exist, Proposed rain water harvesting structure(s), Creation of water bodies in the premises, Adoption of water bodies in the micro-watershed with Panchayati Raj Institution/ Local Govt. bodies.

B. Adoption of water conservation measures like, technologies used for ensuring water conservation, Water audits for ensuring minimal use of water in various sectors, In terms of quantity, Quality, Recycle/Reuse and the purpose.

C. Recycling and reuse of effluents, Quantity of effluent generated, quality of effluent generated, treatment technologies existing or proposed to be adopted, Whether the effluents quality conforms to the standard norms of CPCB/SPCB/PCC(s), Whether utilization of treated water is as per the norms of PCB/SPCB/PCC(s)/MOEF.

In the areas where saline ground water aquifers exists saturated thickness of fresh water zones above saline water zones/ saturated thickness of fresh water zones below saline water zones, saturated thickness of fresh water zones between saline water zones. Abstraction of fresh ground water is to be regulated to prevent.

- Up-coning of saline water into fresh water zone
- Lateral ingress of saline water
- Depletion/ shrinkage of fresh ground water zones

Based on above, the project proposals for various purposes are evaluated for consideration of ground water abstractions under different hydro-geological conditions including water conservation measures in Safe, Semi-critical, Critical and Over-exploited areas as per criteria given in table 40.

Table 40: Criteria for Granting NOC for Ground Water withdrawal to Industries

Category	Stage of Development (%)	Recycle/Reuse	Other Water Conservation Practices	Withdrawal permitted (%age of proposed recharge)
Safe	< 70	Mandatory recycling and reuse of water	Water audit measures to be adopted	To be brought under the purview if quantity of abstraction exceeds 1000 m3/day in hard rock areas and 2000 m3/day in alluvial areas. RWH to be adopted.
Semi-critical	70 - 100	Efficient utilization of recycled water and reuse of water should be mandatory.	Water audit measures to be adopted	Withdrawal may be permitted subject to undertaking of recharge measures. Since the area is less stressed, at least 50% recharge be made mandatory.
Critical	90 – 100	Efficient utilization of recycled water and reuse of water should be mandatory.	Water audit measures to be adopted	Withdrawal may be permitted subject to undertaking of recharge measures. The quantum of recharge should be equal to or more than the proposed withdrawal.
Over-exploited	>100	Efficient utilization of recycled water and reuse of water should be mandatory.	Water audit measures to be adopted	Withdrawal may be permitted upto 60 % of proposed recharge. Also withdrawal should not exceed a maximum limit of 1500 m3/day for each unit.

In compliance with water conservation measures, recharge to ground water to neutralize the impact of withdrawal of water and its monitoring. During the year, 2009-10 and 2010-11, the CGWA issued NOC for withdrawal of ground water in Over Exploited/Critical/Semi-Critical areas. State wise details of NOC issued and artificial recharge/rainwater harvesting measures made compulsory by the industries are presented in the table 41.

Table 41: Table showing NOC granted by CGWA and Rain water Harvesting Adopted by Industries

S.No.	State/Year	2009-2010		2010-2011	
		Number of Industries to whom permission accorded	Quantum of water to be recharged in Cubic meter/year	Number of Industries to whom permission accorded	Quantum of water to be recharged in Cubic meter/year
1	Andhra pradesh	11	563168	2	69360
2	Chhatisgarh	3	457262	12	3455321
3	Gujarat	40	1679948	6	1151945
4	Haryana	17	1920156	8	1625188
5	Karnataka	6	1393330	-	-
6	Madhya Pradesh	12	1723664	6	734417
7	Orissa	2	81198	11	869161
8	Punjab	21	1204309	10	1580035
9	Rajasthan	58	6324567	18	3376187
10	Tamil Nadu	40	1653705	30	3214750
11	Uttar Pradesh	13	537446	7	194308
12	Uttarakhand	4	181741	-	-
	Total (MCM)	227	17.72	110	16.27

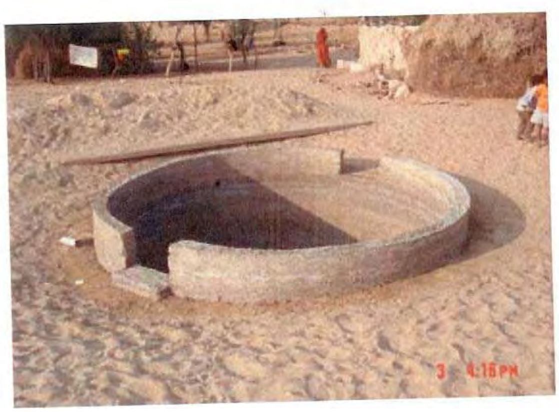
ARTIFICIAL RECHARGE TO GROUND WATER BY M/s CAIRN ENERGY INDIA PVT LTD AT MANGALA AND AISHWARIYA FIELDS, BARMER

CAIRN ENERGY INDIA PTY. LIMITED

Annexure-I

Ground water recharge measures in the industrial area for augmenting the groundwater resources in the area

- *More than 1300 structures constructed / repaired*
- *Created more than 21, 000 m³ rainwater harvesting capacity*



The total amount of recharge by the above structures - 21,000 cum/annum

CAIRN ENERGY INDIA PTY. LIMITED

ARTIFICIAL RECHARGE TO GROUND WATER BY M/s SANGAM SPINNERS FOR THEIR SPINNING MILL AT DHUWALIYA VILLAGE, HURDA BLOCK, BHILWARA DISTRICT

LOCATION/ CATCHMENT AREA OF RAIN WATER HARVESTING STRUCTURES

The total amount of recharge by Five recharge ponds is - 235329 cum/annum.

ARTIFICIAL RECHARGE TO GROUND WATER AT M/S VARUN BEVERAGES LIMITED AT CHOPANKI, TIJARA BLOCK, DISTRICT ALWAR

ARTIFICIAL RECHARGE TO GROUND WATER AT M/S VARUN BEVERAGES LIMITED AT CHOPANKI, TIJARA BLOCK, DISTRICT ALWAR

The total amount of recharge by the above structures - 45,465 cum/annum

ARTIFICIAL RECHARGE TO GROUND WATER BY M/S JUBLIANT ORGANOSYS FOR THEIR FERTILISER PLANT AT SINGHPUR VILLAGE, KAPASAN BLOCK, CHITTAURGARH DISTRICT

RECHARGE TRENCHES WITH INJECTION WELLS

ARTIFICIAL RECHARGE TO GROUND WATER BY M/S JUBLIANT ORGANOSYS FOR THEIR FERTILISER PLANT AT SINGHPUR VILLAGE, KAPASAN BLOCK, CHITTAURGARH DISTRICT

ANICUT

The total amount of recharge by all the above structures - 227691 cum/annum

ARTIFICIAL RECHARGE TO GROUND WATER BY M/S JUBLIANT ORGANOSYS FOR THEIR FERTILISER PLANT AT SINGHPUR VILLAGE, KAPASAN BLOCK, CHITTAURGARH DISTRICT

RAINWATER HARVESING STRUCTURES

The total amount of recharge by all the above structures - 227691 cum/annum

Photo plate No.1: Check dam south of Amli Mines near Malap area

Photo plate No.2: Check dam in the southern part of Thandiberi Mines

Photo plate No.3: Check dam in the western part of Amli Mines

Photo plate No.4: Earthen Check dam in the western part of Amli Mines

Photo plate No.5: Check dam in the western part of Amli Mines

Photo plate No.6: Large Mine pit serving as a recharge reservoir in Thandiberi mines

Anicut and diversion channels under construction in the central part of Amli mines:

The total amount of recharge by all the above structures - 14,14,238 cum/annum

ARTIFICIAL RECHARGE TO GROUND WATER BY M/S BADRI ENTERPRISES FOR THEIR AERATED UNIT AT VILLAGE VALAYAPETTAI, TALUK KUMBAKONAM, DISTRICT THANJAVUR

ANNEXURE – I

Details of schemes undertaken by Central Ground Water Board during VIII, IX,X and XI Plan

VIII Plan		
Sl No	State	Name of the Scheme
1	Chandigarh	Roof top rain water harvesting at CSIO, Chandigarh
2	Karnataka	Rain water harvesting in Mulbagul and Gauribidnaur Talukas, Kolar district.
3	Madhya Pradesh	Construction of Sub-surface Dykes at Dhobighat and Chhintaharan in Utawali Watershed, Block Burhanpur, District Khandwa
4	Madhya Pradesh	Artificial recharge studies in Khargone district
5	Madhya Pradesh	Artificial recharge studies in Londhri Watershed, village Narayana, Dewas district
6	Madhya Pradesh	Artificial recharge studies in Barwa Kalan, Rajgarh district
7	Madhya Pradesh	Construction of sub-surface Dyke at Walmi Farm
8	Maharashtra	Artificial recharge in Besaltic terrain, Warud taluka, Amravati district
9	Maharashtra	Mountain Front recharge of alluvial aquifers, Yaval Taluka, Jalgaon district
10	Delhi	Artificial Recharge in JNU & IIT
11	Delhi	Roof top rain water harvesting in IIT
12	Punjab	Artificial recharge to ground water utilizing canal and surplus pond water at village Channian, Nakodar block, District Jalandhar
13	Rajasthan	Artificial Recharge in Mainpura Jhunjhunu district.
14	West Bengal	Artificial Recharge Project-Saltora Block, Bankura district
IX Plan		
Sl No	State	Name of the Scheme
1	Andaman & Nicobar	Development of lal Pahar Nallah, Andhaman & Nicobar Islands.
2	Andaman & Nicobar	Development of water sources at Majori. Andaman & Nicobar Islands.
3	Andaman & Nicobar	Development of water sources at Prothrapur, Bird line, Andhaman & Nicobar Islands.
4	Andhra Pradesh	Artificial recharge of ground water in Abhangapatnam village, Koilkonda Mandal, Mahaboobnagar district, AP.
5	Andhra Pradesh	Artificial recharge of ground water in Malkapur village, Koilkonda mandal, Mahaboobnagar district, Andhra Pradesh.
6	Andhra Pradesh	Artificial recharge of ground water in Ananthpur village, Koilkonda Mandal, Mahaboobnagar district, Andhra Pradesh.
7	Andhra Pradesh	Artificial recharge of ground water in Kesahvapur village, koilkonda mandal, Mahaboobnagar district, Andhra Pradesh.
8	Andhra Pradesh	Artificial recharge of ground water in Mallapur village, Koilkonda Mandal, Mahaboobnagar district, Andhra Pradesh.
9	Andhra Pradesh	Water conservation at Khammam district, Andhra Praesh.

10	Andhra Pradesh	Artificial recharge of ground water in Bora Banda Wadika, Thimmannapally H/O Revelly Village, Midjil Mandal, Mahboobnagar District, Andhra Pradesh.
11	Andhra Pradesh	Artificial recharge of ground water in Tekula Kunta Wadika Thimmannapally H/o Revelly Village, Midjil Mandal, Mahboobnagar District, Andhra Pradesh.
12	Andhra Pradesh	Artificial recharge of ground water in Mondoni Kunta Wadika Thimmannapally H/o Revelly Village, Midjil Mandal, Mahboobnagar District, Andhra Pradesh.
13	Andhra Pradesh	Artificial recharge of ground water in Revelly Village, Midjil Mandal, Mahboobnagar District, Andhra Pradesh. SY no.62, check dam across yatakirosi Chelka alike of 2nd order of stream.
14	Arunachal Pradesh	Roof top rain water harvesting in Ruksin sub-division in East Siang district, Arunachal Pradesh.
15	Assam	Rain water harvesting in Selected areas of Sonapur Block & Guwahati Area of Kamrup district, Assam.
16	Bihar	Project proposal for artificial recharge ground water in Patna University Campus, Patna, Bihar,
17	Chandigarh	Artificial recharge to ground water under central sector scheme in Punjab university, Chandigarh.
18	Chandigarh	Artificial recharge to ground water in Shantikunj area sector –16 (Leisure Valley) Chandigarh.
19	Chandigarh	Roof top Rain Water Harvesting at Bhujal Bhawan Chandigarh
20	Chandigarh	Artificial recharge to ground water at office of Chandigarh housing board in Sector 9, Chandigarh.
21	Chandigarh	Rain water harvesting at DAV School in Sector 8, Chandigarh.
22	Chandigarh	Artificial recharge to ground water at Technical Teachers Training institute (TTTI), Sector 26, Chandigarh.
23	Chandigarh	Utilizing surplus water monsoon runoff for sector 26,27,19,30,20, Chandigarh.
24	Delhi	Scheme for Artificial Recharge to Ground water at Tuglak Lane and surrounding area's , New Delhi.
25	Delhi	Scheme for Artificial Recharge to Ground water at Meera Bai Polytechnic Campus, Mahrani Bag, New Delhi
26	Delhi	Artificial recharge scheme in park of D-Block, Vasant Vihar, New Delhi.
27	Delhi	Scheme for artificial recharge to ground water at 5, Janpath Raod, New Delhi.
28	Delhi	Scheme for artificial recharge to ground water at group housing for abhiyan CGHS ltd. Plot - 15 , sector- 12, Dwarka, New Delhi.
29	Delhi	Artificial recharge to ground water at sultangarhi tomb, New Delhi.
30	Delhi	Artificial Recharge Scheme for President Estate, New Delhi
31	Delhi	Artificial recharge to ground water in Kushak Nala, New Delhi
32	Delhi	Artificial recharge to ground water in Lodi Garden, New Delhi

33	Delhi	Rain water harvesting in Shram Shakti Bhawan, New Delhi
34	Delhi	Artificial recharge to ground water at Prime Minister's office, South Block, New Delhi.
35	Delhi	Artificial recharge to ground water at Vayusenabad, Air force station, Tughlakabad, New Delhi.
36	Delhi	Artificial recharge to ground water at Deen Dayal Upadhyay Hospital, New Delhi.
37	Delhi	Artificial recharge scheme to ground water at Safdargunj Hospital, New Delhi.
38	Delhi	Scheme for Artificial recharge to ground water at DTC Central Workshop-II, Okhla, New Delhi.
39	Delhi	Scheme for Artificial Recharge to Ground Water at Sena Bhawan, South Block, New Delhi
40	Gujarat	Roof top Harvesting of Rain water at Gujarat High Court Building, Sola, Ahmedabad, Gujarat.
41	Gujarat	Rain water harvesting scheme – IFFCO Residential colony Kasturinagar – Sertha, District Gandhinagar, Gujarat.
42	Gujarat	Rain water Harvesting at Physical Research Laboratory, Ahmedabad, Gujarat.
43	Haryana	Artificial recharge to ground water from Brahm sarovar, Kurukshetra town, Haryana.
44	Haryana	Artificial Recharge through Shafts in depressions of village Kirmich and Samaspur, district Kurukshetra, Haryana.
45	Haryana	Artificial Recharge through Roof Top Rain Water Harvesting in DC office, Faridabad . (Haryana)
46	Haryana	Artificial recharge to ground water through link channel of Hasanpur distributary at Hamidpur bund, Mahandergarh district, Haryana.
47	Haryana	Artificial recharge to ground water through escape water of JLN canal at Deroli-Ahir Mahenderagarh district, Haryana.
48	Haryana	Artificial recharge to ground water through water in depression in district Panipat, Haryana.
49	Haryana	Artificial recharge to ground water from Markanda river in Shahabad block, district Kurukshetra, Haryana.
50	Haryana	Artificial recharge to ground water at Aravalli view Rail Vihar, Sector-56, Gurgaon, Haryana.
51	Himachal Pradesh	Pilot scheme for Roof top rain water harvesting to recharge ground water in the premises of Executive engineer, IPH division, Indora , Kangra district.
52	Himachal Pradesh	Scheme for irrigation and artificial recharge through check dam on nallah at village Chalokhar, Hamirpur district, H.P.
53	Himachal Pradesh	Pilot scheme for artificial recharge through check dam on Bhatti nala in Kathog (Kunli) village, Kangra district, H.P.
54	Himachal Pradesh	Pilot scheme for roof top rainfall harvesting to recharge ground water in Palanpur town district Kangra, Himachal Pradesh.

55	Himachal Pradesh	Pilot scheme for artificial recharge through check dam cum ground water dam in Naker Khad village Renta Dhawala tehsil Dehra, district Kangra, H.P.
56	Himachal Pradesh	Check dam on Suhal Nallah in village Adhwani in Dehra tehsil, Kangra district, H.P.
57	Jammu & kashmir	Artificial recharge to ground water at Sunghwal in Kandi belt, Jammu district.
58	Jammu & kashmir	Scheme for Roof Top Rain Water Harvesting at Nirman Bhawan, panama Chowk, Jammu
59	Jammu & kashmir	Scheme for Roof Top Rain Water Harvesting at Airport Building, Satwari, Jammu.
60	Jammu & kashmir	Scheme for artificial recharge to ground water at Dewal in Bilawar Tehsil, Kathua district.
61	Jammu & kashmir	Roof top rain water harvesting at Govt. higher secondary school Barwal, Kathua district.
62	Jammu & kashmir	Artificial recharge project - Jammu action plan for project design and implementation of roof top rain water harvesting at PHC, Bhalwal, Jammu district
63	Jammu & kashmir	Artificial recharge project - Jammu action plan for project design and implementation of roof top rain water harvesting at Government women college, Gandhi Nagar, Jammu
64	Jammu & kashmir	Rooftop rainwater harvesting for Mata Vaishno Devi Shrine, Katra Udhampur district.
65	Jharkhand	Roof top rain water harvesting in the office building of Central Horticulture (Indian Institute of Horticulture Research, Ranchi, Jharkhand.
66	Jharkhand	Roof top rain water harvesting for engineers line cantonment area, Ranchi, Jharkand.
67	Jharkhand	Roof top rainwater harvesting and artificial recharge to ground water in Dipatoli Cantonment area, Ranchi, Jharkhand.
68	Karnataka	Artificial Recharge in Bangalore University Campus".Karnataka.
69	Karnataka	Artificial recharge in Jnanabharathi campus, Bangalore university Sector, I and Sector II, and Phase-II.
70	Kerala	Construction of subsurface dyke at Ayilam in Trivandrum district, Kerala.
71	Kerala	Recharge well at Printhanam, Uzhavoor block, Kerala (Artificial recharge structure in part of Kottayam district, Kerala)
72	Kerala	Percolation tank at Chirakulam, Uzhavoor block, Kerala (Artificial recharge structure in part of Kottayam district, Kerala)
73	Kerala	Check dam with tidal regulator at Ayandikadayu, Chirayinkil Trivandrum district, Kerala
74	Kerala	Artificial recharge structure at Bangalamkulam in Kasargad district, Kerala.
75	Kerala	Artificial recharge to ground water at Chunnambukalthodu, in Palghat district, Kerala.
76	Kerala	Artificial recharge structure at Kadapallam in Kasargad district, Kerala State

77	Kerala	Roof water harvesting in Mayyil Colony, Taliparamba taluk, Kannur, Kerala.
78	Kerala	Recharge to ground water at naval Academy, Ezhimala, Kannur district, Kerala.
79	Kerala	Construction of subsurface dam at Thalayil-Mottakavu in Manikkal Panchayat, Thiruvananthapuram district, Kerala.
80	Kerala	Investigation for subsurface dam at Komuttychella-Kadubampallam-Pudussery Panchayath, Palakkad, Kerala.
81	Kerala	Construction of Checkdam at Aninja across Kunduni Thodu in Chemnad Grama Pachayath in Kasaragod district, Kerala.
82	Kerala	Artificial recharge scheme proposal at Civil station building, kasaragod, Kerala
83	Lakshadweep	Scheme proposal for rain water harvesting/artificial recharge in the U.T. of Lakshadweep Islands/Tribal Area Kavaratti Island at the Fisheries complex, Lakshadweep Islands.
84	Lakshadweep	Scheme proposal for rain water harvesting/artificial recharge in the U.T. of Lakshadweep Islands/Tribal Area Indira Gandhi Hospital, Lakshadweep islands.
85	Madhya Pradesh	Scheme for construction of percolation tank in sikheri village, District Mandsaur, M.P.
86	Madhya Pradesh	Pilot project for ground water recharge through Roof Top Rain water harvesting in Narmada Water Supply,PHED Colony, Musakhedi, Indore
87	Madhya Pradesh	Conservation & artificial recharge of ground water in Tumar watershed , Mandsaur block, Mandsaur district, Madhya Pradesh.
88	Madhya Pradesh	Scheme for roof top rain water harvesting for Dewas City, Dewas district,
89	Madhya Pradesh	Artificial recharge to ground water in Dewasdistrict, Madhya Pradesh.
90	Maharashtra	Artificial recharge to ground water in Watershed TE-11 of Jalgaon district, Maharashtra.
91	Maharashtra	Roof top rain water harvesting at Panchanyat Samiti Office premises, Warud District Amravati, Maharshtra.
92	Maharashtra	Roof top rain water harvesting in KITS campus, Ramtek, Maharashtra
93	Meghalaya	Scheme for roof top rain water harvesting in Shillong city, Meghalaya
94	Mizoram	Scheme for roof top rain water harvesting in Mizoram.
95	Nagaland	Project for rooftop rain water conservation for multipurpose use in Kohima and Mokokchung townships, Nagaland.
96	Nagaland	Roof top rain water harvesting and storage in Rengma Area in Nagaland.
97	Nagaland	Roof top rain water harvesting in Mokokchung Town, Nagaland.
98	Orissa	Arresting salinity Ingress through ground water recharge in Bhadrak, Kendrapara and parts of puri district, Orissa.

99	Orissa	Scheme of rain water harvesting/roof top rain water harvesting in Raj Bhawan Premises, Bhubhaneshwar, Orissa.
100	Orissa	Arresting salinity ingress and ground water recharge in Chandbali and Basudevpur blocks of Bhadrak district of Orissa.
101	Orissa	Artificial recharge scheme for Kalajore Watershed Khalikote Block, Ganjam District, Orissa.
102	Orissa	Artificial recharge scheme for Tamkajodi watershed Sharapada block Keonjhar district, Orissa.
103	Orissa	Pilot project scheme for roof top rain water harvesting for application for artificial recharge in the Premises of Hydrology project building delta square, Bhubaneshwar,
104	Orissa	Artificial recharge scheme for Barkatia watershed Athagarh block, Cuttack district, Orissa.
105	Punjab	Scheme for Recharge of sarovar water in Golden Temple area, Amritsar,.
106	Punjab	Pilot Scheme for Roof Top Rain water harvesting to recharge ground water in Kheti Bhavan, Amritsar town,
107	Punjab	Scheme for Artificial Recharge to Ground Water from Dhuri Link Drain in Dhuri Block, District Sangrur. (Punjab).
108	Punjab	Pilot project for Artificial Recharge to Ground Water from Village Pond in Village Issru, Khanna Block, District Ludhiana, Punjab.
109	Punjab	Artificial recharge to ground water from Bist Doab canal system in Nurmahal area, district Jallandhar, Punjab
110	Punjab	Artificial Recharge scheme to ground water from Dhuri drain in Sangrur district, Punjab
111	Punjab	Pilot project for artificial recharge from Choe no 1 Bhakhara Main Line Canal near village Dhanetha Samana Block, Patiala, Punjab.
112	Punjab	Pilot study for artificial recharge to ground water from Bassain drain in Moga district, Punjab.
113	Punjab	Pilot study for artificial recharge to ground water from Sirhind Choe in Patiala district, Punjab.
114	Punjab	Scheme for artificial recharge to ground water from existing and new rain water harvesting structures, Village Parol Naggal, Block Majri, Tehsil Kharar, District Ropar, Punjab
115	Punjab	Scheme for artificial recharge to ground water by utilising water of existing water harvesting structures (low dams), Village Chhoti Bari Naggal, Majri Block, Tehsil Kharar, District Ropar, Punjab.
116	Punjab	Scheme for artificial recharge to ground water harvesting rain water in Low dam village Majra, Block Majri, Tehsil Kharar, District Ropar, Punjab.
117	Punjab	Scheme for Artificial recharge to ground water by harvesting rainwater in low Dam Village Siswan, Block Majri, Teshil Kharar, District Ropar, Punjab.
118	Punjab	Scheme for Artificial recharge to ground water by Harvesting Rainwater in Low Dam Village Bardar, District Ropar, Punjab.
119	Punjab	Pilot study for artificial recharge to ground water from Patiala Nadi, District Patiala, Punjab.

120	Punjab	Pilot study for artificial recharge to ground water from Miranpur Choe, district Patiala, Punjab.
121	Punjab	Scheme for artificial recharge to ground water from Khanna Distributary in Bhattian canal colony, block Khanna, District Ludhiana, Punjab.
122	Rajasthan	Scheme for construction of subsurface barriers (SSB) at Makhar and Bhagoli village on Kantli river, District Jhunjhunu, Rajasthan.
123	Rajasthan	Scheme for construction of roof top/pavement rain water harvesting structures for artificial recharge in the office building of CGWB,Western Region ,Jaipur.
124	Rajasthan	Roof top /pavement rain water run off harvesting at Sinchai Bhawan, Jaipur
125	Rajasthan	Roof top rain water harvesting at Chief Minister's residence, Jaipur.
126	Rajasthan	Rooftop rain water harvesting at Governor house, Raj Bhavan,Jaipur.
127	Rajasthan	Roof top/ pavement rain water runoff harvesting structures at Rajsthan High Court Jaipur.
128	Rajasthan	Roof top/ pavement rain water runoff harvesting structures at State Secretariat (part-I & part-II),Jaipur.
129	Rajasthan	Roof top runoff harvesting artificial recharge structures part of Institutional building of MREC, Jaipur.
130	Rajasthan	Roof top/ pavement rain water runoff harvseting at Vitta Bhavan, Jaipur, Rajasthan.
131	Rajasthan	Roof top/ pavement rain water runoff harvesting at Reserve Bank of India,ram Bagh Circle, Jaipur, Rajasthan.
132	Rajasthan	Roof top rain water harvsesting structure at ground water department building premises,Jaipur, Rajasthan.
133	Rajasthan	Concept plan for proejct design and implementation of Roof Top/Pavement Rain water Run-off harvesting structures at officers training school (OTS, Nehru Bhawan), Jaipur, Rajasthan.
134	Rajasthan	Artificial recharge at College of Technology and Engineering, (CTAE), Udiapur, Rajasthan.
135	Rajasthan	Concept Plan for project design and implementation of Roof top/pavement rain water run-off harvesting structure premises of PHED, Head office (New building), Jaipur, Rajasthan.
136	Rajasthan	Artificial recharge scheme site Palasara, district Sikar, Rajasthan.
137	Rajasthan	Artificial recharge scheme of Prithvipura, District Sikar, Rajasthan.
138	Rajasthan	Artificial recharge scheme of Ajabpura, District Sikar, Rajasthan.
139	Rajasthan	Concept plan for project Design and Implementation of roof top/pavement Rain water run-off harvesting structure at collectorate (I), Jaipur, Rajasthan.
140	Tamil Nadu	Construction of subsurface dyke for Artificial recharge/Ground water conservation Nallan Pillai petral of Gingee block, Gingee village, Villupuram district, Tamil Nadu.
141	Tamil Nadu	Construction of percolation pond at Narasipuram,Alandurai watershed, Coimbatore, Tamil Nadu.

142	Tamil Nadu	Construction of percolation pond at Vadipalayam village, Tiruppur Taluk, Coimbatore district, Tamil Nadu.
143	Tamil Nadu	Augmentation of ground water through artificial recharge in Vanur Watershed, Villupuram district, Tamil Nadu.
144	Tamil Nadu	Construction of a water harvesting structure at 240 Thondamuthur, Coimbatore, Tamil Nadu.
145	Tamil Nadu	Formation of a pond in Kosavampalayam village near Arasur in Udumalpet Taluk, Coimbatore, Tamil Nadu.
146	Tamil Nadu	Reconsideration of modified scheme on Revitalisation of a percolation pond at Vadapatti village, Virudhunagar district, TamilNadu".
147	Tamil Nadu	Artificial recharge to ground water in Central Leather Research Institute, Chennai, Tamil Nadu.
148	Tamil Nadu	Recharge to ground water construction of subsurface dyke in Thiruchirapalli district, Tamil Nadu.
149	Tamil Nadu	Implementation of rain water harvesting in Collectorate complex, Ramanathapuram, T.N.
150	Uttalranchal	Artificial Recharge in Thano Micro-watershed at Ramnagar Danda, Thano Reserved Forest, Doiwala Block, District Dehradun (U.P.)
151	Uttar Pradesh	Scheme for Artificial Recharge to Ground Water in Chogawan Area, District Baghpat (U.P.)
152	Uttar Pradesh	Project proposal for artificial recharge by roof top rain water harvesting at Bhujal Bhavan, Lucknow.
153	Uttar Pradesh	Artificial recharge by roof top rain water harvesting at New Lucknow University Campus, Jankipuram, Lucknow , U.P
154	Uttar Pradesh	Artificial recharge by roof top rain water harvesting at Jal Nigam Colony, Indira Nagar, Lucknow, UP
155	Uttar Pradesh	Artificial recharge to ground water water through storm water run off in Aligarh city, U.P.
156	Uttar Pradesh	Rain water harvesting and artificial recharge to groundwater at Niryat Bhawan, Office Complex of BIDA in Bhadohi, Sant Ravi Das Nagar (Bhadohi), U.P.
157	Uttar Pradesh	Roof top rain water harvesting at Vikas Bhawan, Allahabad, U.P.
158	Uttar Pradesh	Roof top rain water harvesting at Ambedkar Vihar, Chauphataka in lieu of Sangam Place, Civil Lines, Allahabad, U.P.
159	Uttar Pradesh	Rainwater harvesting and artificial recharge in selected government buildings in Seven sites at Lucknow, Uttar Pradesh
160	West Bengal	Scheme for Artificial Recharge by Recasting of Channel from Chetua to Jamuna, Pandua Block, District Hoogly, West Bengal
161	West Bengal	Artificial Recharge at Khatura Bangar (Kankana Bangar) Over-Developed and Arsenic affected area, parts of Swarup Nagar and Gaighat Blocks, District North 24-Parganas, West Bengal.
162	West Bengal	Integrated Approach of Artificial Recharge of Ground Water for Improvement in the Watershed management in the water scarce area of Purulia District, West Bengal.
163	West Bengal	Study of artificial recharge in different ground water conditions for improvement of watershed management in Midnapur district in the State of West Bengal.

164	West Bengal	A pilot study of evaluate the effect of Roof top rain water harvesting on Ground water resources (unconfined shallow aquifer) of Visva Bharati Area, Bolpur, West Bengal
165	West Bengal	Roof top rain water harvesting at Baishnabghatapatuli office campus, Calcutta.
X Plan		
1	Andhra Pradesh	Artificial Recharge to Groundwater in Lingala, Kadapa district.
2	Andhra Pradesh	Artificial Recharge to Groundwater in Pulivendula, Kadapa district.
3	Andhra Pradesh	Artificial Recharge to Groundwater in Vemula, Kadapa district.
4	Andhra Pradesh	Artificial Recharge to Groundwater in Vempalli, Kadapa district.
5	Karnataka	Artificial Recharge to Groundwater in Malur, Kolar district.
6	Madhya Pradesh	Artificial Recharge to Groundwater in Bel Watershed of Amla and Muitai blocks, Betul district.
7	Madhya Pradesh	Artificial Recharge to Groundwater in Sonkatch Watershed of Amla and Muitai blocks, Betul district.
8	Tamil Nadu	Artificial Recharge to Groundwater in Gangavalli, Salem district.
XI Plan		
1	Kerala	Artificial Recharge to Groundwater using Roof Top Rainwater in the premises of government upper primary school, Kolathur II, Bedadka Grama Panchayat of Kasargod
2	Kerala	Artificial Recharge at Govind Pai Memorial College Manjeshwar Kasargod Dist.
3	Kerala	Desiltation of Pond at Pallipara in Kayyur Cheemeni Gram Panchayat, Kasargod dist. Kerala
4	Kerala	Project Propsoal for AR system at Jawahar Navodaya Vidyalaya , Kasargod
5	Kerala	Artificial Recharge System at Kendriya Vidyala, Vidyalaya No. 2, Vidyanagar, Kasagod
6	Kerala	Rainwater harvesting to recharge groundwater at Govt college, Chittoor, Palakhad Dist.
7	Punjab	Pilot project on Artificial Recharge to augment declining groundwater resources of Moga Dist.
8	Punjab	Artificial Recharge by using Canal water to augment declining Groundwater Resources at Majjupur and Kohali canal rest house of district Amritsar of Punjab state.
9	Punjab	Artificial Recharge by using Canal water to augment declining Groundwater Resources at Bucher and Khalra canal rest house of district Tarantaran of Punjab state.
10	Arunachal Pradesh	Roof top rain water harvesting in Arunachal Pradesh

11	West Bengal	Study of artificial recharge in the blocks of Nalhati I and Murarai-I of Birbhum dist.
12	Tamil Nadu	Artificial Recharge to Groundwater in Thalaivasal block of Salem District, Tamil Nadu
13	Tamil Nadu	Rain Water Harvesting Arrangements in the premise of the National Institute of Technical Teachers Training and Research, Taramani, Chennai. Tamil Nadu.
14	Tamil Nadu	Artificial recharge to Groundwater in Karuvatur watershed, Nammakal district, Tamil Nadu
15	Tamil Nadu	Artificial groundwater recharge through road side and open space rainwater harvesting structures in Coimbatore city, Tamil Nadu.
16	Andhra Pradesh	Rainwater harvesting in premises of Kakatiya University, Warangal dist. Andhra Pradesh
17	Andhra Pradesh	Construction of Artificial recharge structures in Chittoor District, Andhra Pradesh
18	Andhra Pradesh	Rain Water Harvesting structures in Jawaharlal Nehru Technology University, Hyderabad.
19	Andhra Pradesh	Artificial Recharge Project in Medak district, Andhra Pradesh
20	Karnataka	Artificial recharge to Groundwater in Bangalore Rural District, Karnataka
21	Karnataka	Demonstrative artificial recharge project in Malur taluk., Kolar District, Karnataka
22	Karnataka	Rain water Harvesting & Artificial Recharge To Ground Water' in the campus of University of Agricultural Sciences, Dharwad
23	Karnataka	Demonstrative Artificial Recharge Project in Panmanglore Sub Watershed, Bantwal Taluk, Dakshin Kannada district, Karnataka
24	Uttar Pradesh	Artificial recharge to Groundwater in Sataon Block of Rae Bareli District, Uttar Pradesh.
25	Uttar Pradesh	Artificial recharge structures in Indira Nagar & Gomti Nagar regions of Lucknow city
26	Madhya Pradesh	Artificial recharge to Groundwater in Ratlam District, Madhya Pradesh.
27	Madhya Pradesh	Artificial recharge to Groundwater in Shajapur District, Madhya Pradesh.
28	Chandigarh	Artificial recharge structures in the premises of Panjab University, Chandigarh. Punjab
29	Gujarat	Artificial recharge structures in Watrak (Mohar) watershed (Sabarmati Basin) area of Kheda & Sabarkanth district, Gujarat
30	Gujarat	Artificial recharge structures in Saraswati River Bed at Madhu Pavdi check dam, Siddhpur, district Patan, Gujarat
31	Maharashtra	Artificial recharge structures in Raj Bhawan, Nagpur
32	Jharkhand	Construction of Artificial recharge structures in Ranchi Urban Area, jharkhand
33	Himachal Pradesh	Construction of Check Dam on Mandir Nala at Jwalamukhi, District Kangra
34	Himachal Pradesh	Construction of Check Dam on Kona Nala in Village Duhuk, District Kangra
35	Himachal Pradesh	Construction of Check Dam on Jajhar Nala in Village Duhuk, District Kangra
36	Himachal Pradesh	Construction of Check Dam on Thehra Nala in Village Toru, District Kangra

37	Himachal Pradesh	Construction of Ground Water Recharge through Borewells in Dhamandri in Tehsil & District Una
38	Himachal Pradesh	Construction of Artificial Recharge through Check Dam at Piyungal nala near Village Sakoh, Tehsil Dharamshala
39	Himachal Pradesh	Construction of Artificial Recharge to Ground Water by sub-surface dyke cum Check Dam across pung Khad for LWSS Bhaleth
40	Himachal Pradesh	Construction of Artificial recharge through check dam in Kohi Nallah up stream of Jansoh scheme Tehsil Nadaun, district Hamirpur
41	Himachal Pradesh	Construction of Artificial Recharge through Check Dam at Haretta Khad near LWSS Ghalian" Tehsil Nadaun District Hamirpur
42	Rajasthan	Construction of Roof Top Run off Harvesting Structure at Govt. Mahila Polytechnical College, Bikaner City
43	Rajasthan	Construction of Roof Top Run off Harvesting Structure at Govt. Polytechnical College (boys) Bikaner City
44	Rajasthan	Construction of Roof Top Run off Harvesting Structure at CE, IGNP officer Building Bikaner City.
45	Jammu & Kashmir	Pilot scheme for Artificial recharge of groundwater at Phangeri, Tehsil Hiranagar Dist- Kathua.
46	Jammu & Kashmir	Pilot scheme for Artificial recharge of groundwater at Dabbie, Tehsil Hiranagar Dist- Kathua.
47	Jammu & Kashmir	Pilot scheme for Artificial recharge of groundwater at Marchola, Tehsil Sunderbani Dist- Rajauri
48	Delhi	Artificial recharge to ground water in the office , mess and the adjacent area in and around chief engineer office WAC, Palam, New Delhi
49	Orissa	Artificial Recharge Scheme for Ganda Watershed (Part), Korei Block, Jajpur dist.
50	Orissa	Artificial Recharge Scheme for Himtira Watershed (Part), Kishornagar Block,, Angul dist
51	Orissa	Artificial Recharge Scheme for Ligarakat Watershed (Part), Block Banerpal, Angul dist.
52	Orissa	Artificial Recharge Scheme for Uppalairai Desibatia Watershed (Part), Block Gosani, Gajapati dist.
53	Orissa	Artificial Recharge Scheme for Burudi Watershed (Part), Block Ganjam dist.Ganjam
54	Orissa	Artificial Recharge Scheme for Kasia Nalla Watershed, Block – Joda , Keonjhar dist.
55	Orissa	Artificial Recharge Scheme for Bologarh Nalla Watershed, Block -Bolagarh, Khurda dist.
56	Orissa	Artificial Recharge Scheme for Karmeli Mini Watershed, Block -Saintala, Bolangir dist.
57	Orissa	Artificial Recharge in the DRDA Office Building inside Collectorate Campus, KHURDA
58	Orissa	Artificial Recharge in the Govt. Women's Polytechnic Hostel Building, Berhampur, Rangeilunda Block, district Ganjam.

59	Orissa	Roof Top rain Water Harvesting Scheme for Application of Artificial at WQL & CC (Level- II) Bilding, Takatpur, Baripada, district Mayurbhanj
60	Orissa	Roof Top rain Water Harvesting Scheme for Application of Artificial at in the Premises of the Office Building of The Hydrologist, GWS&I Division at Danipali, Dhankauda block, Sambalpur dist
61	Orissa	Artificial Recharge Scheme for Pandripatha nala micro watershed, Jharsuguda block, Jharsuguda dist.
62	Orissa	Artificial Recharge Scheme for Katikela Nala micro watershed, Jharsuguda block, Jharsuguda dist.Jharsuguda dist.
63	Bihar	Scheme for Demonstrative AR of GW by Sub surface dam on different nalla and rivers , Jamui district of Bihar
64	Bihar	Scheme for Demonstrative AR of GW by SSD on different nalas and river of Munger district of Bihar

ANNEXURE - II

CGWA/IND/Proj/2010-

No.21-4(/CGWA/2011- **Dated :-**

To

Sub:- NOC for ground water withdrawal by M/s , in respect of their proposed at , Block and Tehsil , District – reg.

Sir,

Kindly refer to your letter dated on the above cited subject. Based on recommendations of Regional Director, Central Ground Water Board, vide their office letter no. dated and further deliberations on the subject, the NOC of Central Ground Water Authority is hereby accorded to M/s , in respect of their at , Block and Tehsil , District . The NOC is, however subject to the following conditions:-

1. The firm may abstract upto **m^3/day** (including the existing ground water abstraction of m^3/day) of ground water, through existing tube wells only. No additional ground water abstraction structures to be constructed for this purpose without prior approval of the CGWA.
2. The wells to be fitted with water meter by the firm at its own cost and monitoring of ground water abstraction to be undertaken accordingly on regular basis, at least once in a month. The ground water quality to be monitored twice in a year during pre monsoon and post monsoon periods.
3. M/s , shall, in consultation with the Regional Director, Central Ground Water Board, implement ground water recharge measures for augmenting the ground water resources of the area.
4. The photographs of additional recharge structures, if any, are to be furnished immediately to the Regional Director, Central Ground Water Board,

after completion of the same for verification and under intimation to this office.

5. The firm at its own cost shall install piezometers at suitable locations and execute ground water regime monitoring programme in and around the project area on regular basis in consultation with the Central Ground Water Board,
6. The ground water monitoring data in respect of S. No. 2 & 5 to be submitted to Central Ground Water Board, on regular basis at least once in a year.
7. The firm shall ensure proper recycling and reuse of waste water after adequate treatment.
8. Action taken report in respect of S. No. 1 to 7 may be submitted to CGWA within one year period.
9. The permission is liable to be cancelled in case of non-compliance of any of the conditions as mentioned in S. No. 1 to 8.

Yours faithfully

Regional Director

Copy for information to:

1. The Member Secretary, State Pollution Control Board,
2. The Director, Ministry of Environment and Forests, Paryavaran Bhawan, Lodhi Road, CGO Complex, New Delhi 110003.
3. The Regional Director, Central Ground Water Board, This has reference to your letter no. dated
4. TS to Chairman, Central Ground Water Board, Bhujal Bhawan, Faridabad.

Regional Director