MASTER PLAN FOR ARTIFICIAL RECHARGE TO GROUNDWATER IN INDIA – 2020

CENTRAL GROUND WATER BOARD
DEPARTMENT OF WATER RESOURCES, RD & GR
MINISTRY OF JAL SHAKTI
GOVERNMNET OF INDIA

APRIL 2021

जी. सी. पति
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G. C. PATI
Chairman

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जल शक्ति मंत्रालय
जल संसाधन, नदी विकास
और गंगा संरक्षण विभाग
केन्द्रीय भूमि जल बोर्ड
Government of India
Ministry of Jal Shakti
Department of Water Resources,
River Development & Ganga Rejuvenation
Central Ground Water Board

FOREWORD

Groundwater is a replenishable resource and hence the availability of groundwater has been taken for granted. The limitation of available surface water resources has put an onus on groundwater to meet the requirement. The groundwater development has gone up manifolds to cater to the demand from agriculture, industry and domestic activities. The availability of groundwater is always expressed either in relation to its availability or to the annual replenishment, for management purposes. Thus the term safe yield or sustainable yield is generally used by many developed countries for sustainable development of groundwater. In India, the replenishable groundwater resources are assessed periodically and areas are categorized on the basis of Stage of groundwater extraction (safe yield).

The groundwater scenario is becoming precarious due to over extraction and both State and Central agencies have taken proactive steps of dovetailing the existing schemes towards water conservation. Any executable plan requires macro planning at the initial stage and regional master plan is essential to get the ball park figure for making any implementable plan. Accordingly, Department of Water Resources, RD & GR of Ministry of Jal Shakti had constituted an interministrial committee to revise the Master Plan, under the Chairmanship of Member, CGWB with members drawn from other allied departments within the Ministry and outside the Ministry, including State groundwater agencies.

The enormous data collated for the reports indicates lots of dedication and focus and I appreciate the efforts of committee members and especially the officers from Regional Offices & Water Conservation division of Central Head Quarters of CGWB, for their untiring efforts in bringing out this revised volume. I am sure this revision will help in the effective implementation of MGNREGS, Watershed Development and other water conservation works undertaken by State and center through many schemes.

I wish Joint Water Conservation Efforts a grand success.

G.C.Pati
Chairman

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PREFACE

The water stress is being felt at different parts of the country owing to the increasing demand resulting from the population explosion and food security. In order to meet the demand, the share of groundwater has increased exponentially, and it has far exceeded the natural recharge in many parts of the country, necessitating the both Central and State government to take up water conservation and recharge measures.

The revised Master Plan for artificial recharge to groundwater is a frame work document prepared for the entire country, taking district/Block as unit of Ground Water Management. This document is a macro plan formulated to demarcate the areas feasible for artificial recharge and water conservation and recommendation for various structures for the different terrain conditions of the country. The plan also brings out the broader outlines and expected investments for implementation.

The area for artificial recharge has been identified based on post monsoon water level (2018) and long term post monsoon water trend in most of the States & UTs. In order to assess the scope of artificial recharge, available sub surface space for recharge in aquifers, ability of aquifers to accept the recharge, surplus water available and terrain conditions has been considered.

The master plan envisages a large investment in the ground water sector to improve the water security of the country. The budget allocation in the ongoing water conservation and recharge schemes need to be invested in the water stressed districts of the country for which Government of India has also made announcement. The existing schemes such as MGNREGA, Watershed Development etc can dovetail their activities for convergence towards water conservation and can take cue from the master plan for preparation of detailed scheme in the priority areas following the overall guidelines of the schemes.

The revised Master Plan will provide general guidance for construction of terrain specific recharge structures, their typical design and indicate a rough ball park figure for culminating such efforts.

सुनील कुमार

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Member, CGWB
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EXECUTIVE SUMMARY

Groundwater is a replenishable resources and hence the availability of groundwater has been taken for granted. The limitation of available surface water resources has put an onus on groundwater to meet the requirement. The groundwater development has gone up manifolds to cater to the demand from agriculture, industry and domestic activities. The availability of groundwater is always expressed either in relation to its availability or to the annual replenishment, for management purposes. Thus, the term safe yield or sustainable yield is generally used by many developed countries for sustainable development of groundwater. In India, the replenishable groundwater resources are assessed periodically (every three years) and areas are categorized on the basis of Stage of groundwater extraction (safe yield).

The water stress is being felt at different parts of the country owing to the increasing demand resulting from the population explosion. In order to meet the demand, the share of groundwater has increased exponentially, it has far exceeded the natural recharge in many parts of the country, necessitating the both central and State government to take up water conservation through many schemes. The revised master plan will provide general guidance for terrain specific structures considering the availability of surplus source water and indicate a rough ball park figure for culminating such efforts.

Master Plan for artificial Recharge to Groundwater in India was prepared by CGWB in the year 2013, which was the revision of the conceptual plan made in 2002. In view of the active participation of central and State agencies in water conservation, a need was felt to revise the master plan prepared in 2013. Accordingly, an inter departmental committee was constituted by the Ministry to revise the master plan and the document is the resultant of the efforts of the committee through the Regional offices of CGWB.

The revised master plan for artificial recharge to groundwater has been made for the whole country at the level of district/Block. The plan is macro plan formulated to work out the feasibility of various structures for the different terrain conditions of the country and respective estimated cost. Hence, the revision of the master plan is like any other master plan prepared for a State or city, which brings out the broad outline of the project and expected investments and for implementation, DPR has to be prepared at an implementable level like any other water supply project or city development project.

The area for artificial recharge has been identified based on post monsoon water level (2018) and long-term post monsoon water trend in most of the States & UTs. However, due to paucity of data and local groundwater issues, additional/different criteria were used in different States/UTs. In the case of NE States, UT of Jammu & Kashmir & UT of Ladakh, the criteria of water scarcity have been used and structures have been suggested to harness the run off generated from the rain. In case of UT of Lakshadweep & UT of Daman & Diu, due to shallow groundwater level, only RTRWH has been suggested. An area of 11.23 Lakh sq.km has been identified for artificial recharge.

The scope of artificial recharge depends on the available sub surface space for recharge, water required for recharge and surplus water available for recharge. The volume of space available up to 3m bgl or 5m bgl depending on the criteria adopted in different States multiplied by the specific yield of the aquifers will provide the space available for recharge. Considering an efficiency of 60% or 75% as deemed fit in different States, the water required for artificial recharge has been worked out for each State. The surplus available for recharge after deducting the committed supply has been estimated for each State. The available sub-surface space for artificial recharge 537.349 BCM, while the water required to saturate the aquifer up to 3 to 5m bgl is 716.917 BCM. The surplus source water available for recharge is of the order of 185.092 BCM. The availability of source water for recharge is not uniform and in many districts in the States of Rajasthan, Punjab, Haryana, Gujarat etc., the source water available is less than the requirement and artificial recharge structures are restricted to the source water availability.

The types of structures are decided by the terrain conditions and the number of structures are decided by the source water availability. The different type of structures suitable for different terrain conditions and the use of different terminology for the similar structures in various States have resulted in more than 25 types of structures. In order to group different structures and bring in standardization, the structures were studied and grouped in to 10 groups and in the group “Others” all the uncommon structures are classified. About 75% of structures are towards RTRWH, while 17% is for “Others”, with 3% for RS, 2% of structures are in the category of CD & Gabion structures and 1% under PT category. The unit cost of structure also is found varying within the States for different districts for some States, while in some States/UTs they have assumed a uniform rate. RTRWH accounts for 28% of cost, while “others” category is for 23% of cost and CD & PT account for 19% & RS for 07% of cost. The total cost for implementation of this revised master plan is Rs 133529.69 Cr, with Rs 96735.45 Cr (72%) for rural areas and Rs 36794.23 Cr (28%) for Urban areas.

The implementation approach of artificial recharge projects shall depend on various factors and hence cannot be uniform for the entire country. The major factors in this regard are hydro-geomorphological settings of different areas which vary in different terrain conditions. The watershed approach can be considered to best fit for hard rock terrains, while the basin/sub basin approach is practically suitable for alluvial/sedimentary terrain having large & thick aquifers. Similarly, in hilly terrains, springshed approach can be more scientific & useful in implementation while taking up spring rejuvenation projects. Depending upon the type of existing terrain conditions, the plan for artificial recharge need to be conceptualised by States/UTs while collecting various information/data.

There are many existing schemes and a new scheme is under preparation in respect of comprehensive measures for water conservation in select water stressed districts in the country, resulted out of Budget announcement of the Government, which can cater to the implementation of the revised master plan. No separate funding is required for executing the revised master plan. The different scheme can take the cue from the master plan and construct these structures as per the norms of the schemes. The execution of these structure may take a period of 10 years, if the existing schemes dovetail their activities for convergence towards water conservation.

Owing to the over dependence on groundwater, both State & Central Government Agencies are dovetailing their activities towards water conservation. Consequently, construction of the artificial recharge structures has increased over the years. Further, the construction of structures also depends on the surplus water availability and hence it becomes imperative that geotagging of these structures is made and their functional status monitored. Hence, one Nodal agency is to be identified for each State/UT by the respective States /UTs, which will function as a focal point for the water conservation database and documentations.

The master plan for artificial recharge to groundwater has been revised considering the existing data availability. Considering the technological advancement and parallel scientific studies of NAQUIM being taken up in the country, it is proposed to carry out next revision on a larger scale of 1: 10,000. With the large scale thematic maps, it would be feasible to have micro-level information on area-specific feasible recharge structures & their location, which can be refined during preparation of Detailed Project Reports (DPRs) by the implementing agency in the state. The watershed approach is best fit for hard rock terrains, while the basin/sub basin approach is practically feasible for alluvial/sedimentary terrain & in hilly terrains, springshed approach can be more appropriate for spring rejuvenation projects. In the chapter “Way forward”, formulation of Master plan, institutional mechanism, documentation, critical factors in formulation and execution of artificial recharge projects and impact assessment have been discussed in detail. In the formulation of master plan, use of DRASTIC model, NAQUIM outputs and DPR preparation has been proposed using the GIS technique. The importance of treatment work in upper reaches, prior to implementation of the artificial recharge projects have also been emphasized. Institutional mechanism of District & State level committees for preparation of master plan and DPR, its approval and execution have been outlined to have seamless execution of the activity. Identification of State Level Nodal Agency (SLNA) is very important for the success of this activity. Central Ground Water Board can take up the impact assessment, however, the updation of database on artificial recharge by State agencies is mandatory for talking up impact assessment studies.

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CHAPTER 1.0

1.0 INTRODUCTION

1.1 Background

Groundwater is a replenishable resources and hence the availability of groundwater has been taken for granted. The limitation of available surface water resources has put an onus on groundwater to meet the requirement. The groundwater development has gone up manifolds to cater to the demand from agriculture, industry and domestic requirements. The availability of groundwater is always expressed either in relation to its availability or to the annual replenishment. Thus the term safe yield or sustainable yield is generally used by many developed countries for sustainable development of groundwater. In India, the replenishable groundwater resources are assessed periodically (every three years) and areas are categorized on the basis of Stage of groundwater extraction (safe yield).
Groundwater Resources Assessment are jointly carried out by CGWB & respective State Agencies using Groundwater Estimation Committee methodology, as a standard method to assess the groundwater resources. The latest assessment of dynamic groundwater resources is GWRA-2017, using GEC-2015 methodology. In the assessment, the total annual ground water recharge has been estimated as 432bcm. Keeping an allocation for natural discharge, the annual extractable ground water resource is 393bcm. The total current annual ground water extraction (as in March, 2017) is 249bcm. The average stage of ground water extraction for the country as a whole works out to be about 63 %. The extraction of ground water for various uses in different parts of the country is not uniform. Out of the total 6881 assessment units (Blocks/ Mandals/ Talukas/Firkas) in the country,1186 units in various States (17%)have been categorized as 'Over-Exploited' indicating ground water extraction exceeding the annually replenishable ground water recharge. In these areas the percentage of groundwater extraction is morethan100percent. In addition, 313units (5%) are 'Critical', where the stage of ground water extraction is between 90-100 %. There are 972 semi-critical units (14%), where the stage of ground water extraction is between 70% and 90% and 4310 assessment units (63%) have been categorized as 'Safe', where the stage of Ground water extraction is less than 70 %. Apart from this, there are 100 assessment units (1%), which have been categorized, as 'Saline' as major part of the ground water in phreatic aquifers is brackish or saline. In respect of West Bengal, the results of GWRA-2017 indicated a huge variation with respect of previous assessment of resources and the reasons for the changes in West Bengal was not found reasonable and adequate and further, SLC has also not approved the GWRA-2017 assessment. Hence, CLEG recommended that the results of 2013 assessment in respect of West Bengal may be used in place of GWRA-2017 assessment for national compilation of GWRA-2017 with a rider that after approval of GWRA- 2017 by SLC of West Bengal, a corrigendum may be issued separately, incorporating the results of GWRA-2017. Accordingly, the results of 2013 assessment have been considered for West Bengal. The categorization map of India (GWRA-2017) is given as Fig 1.1.

In order to tackle the twin hazards of de-saturation of aquifer zones and consequent deterioration of ground water quality, there is an urgent need to augment the ground water resources through suitable management interventions. Artificial recharge has now been accepted world-wide as a cost-effective method to augment ground water resources in areas where continued overexploitation without due regard to their recharging options has resulted in various undesirable environmental consequences.

Any executable plan requires the planning to be made in macro level at the first instance and thereafter taken to micro level at the time of execution. Master Plan for artificial Recharge to Groundwater in India was prepared by CGWB in the year 2013, which was the revision of the conceptual plan made in 2002. In view of the fact active participation of central and State agencies in water conservation efforts, a need was felt to revise the master plan prepared in 2013.

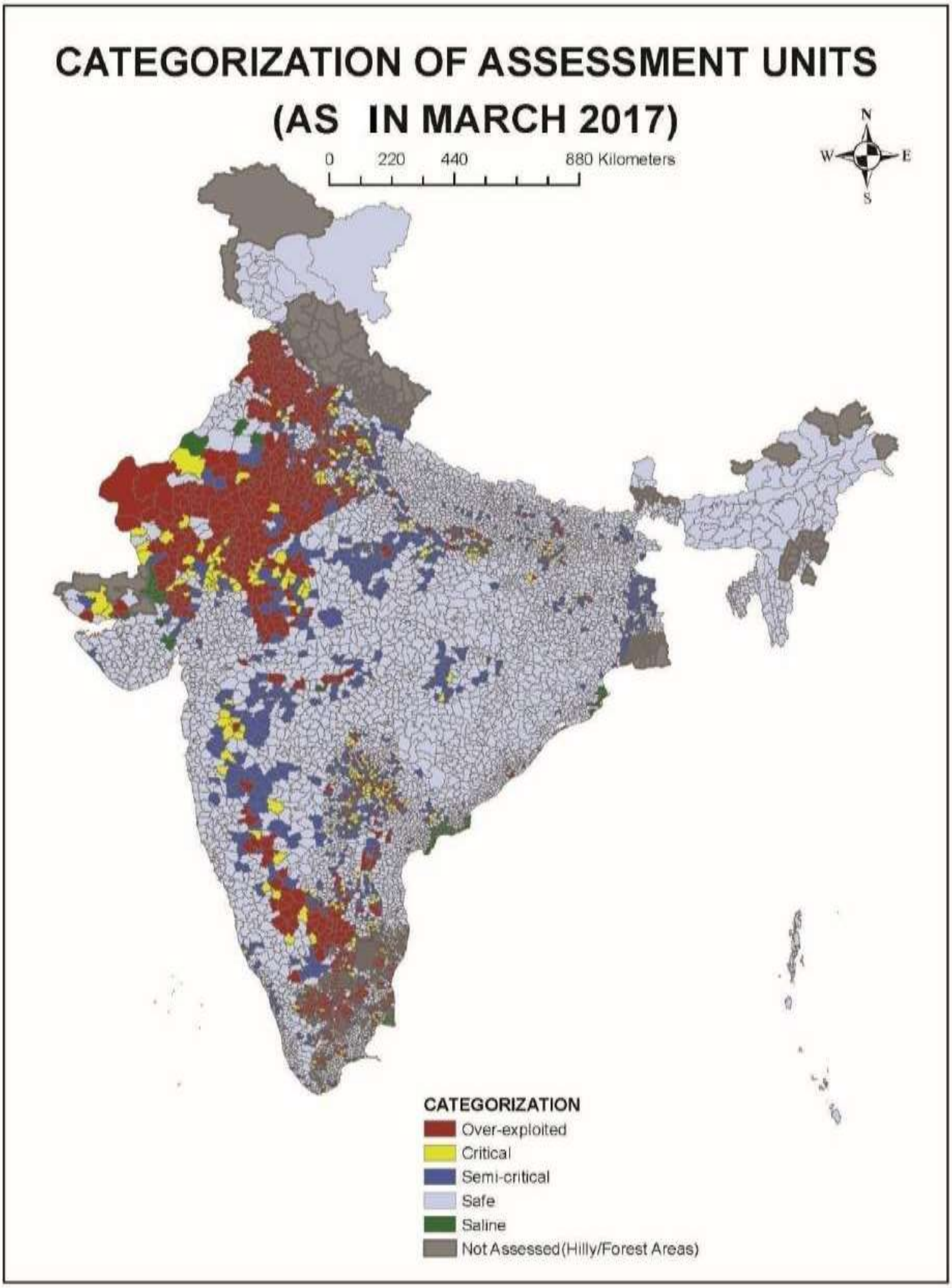

Fig 1.1 Categorization Map of India (GWRA-2017)

1.2 Salient Features of Master Plan (2013)

The preparation of master plan for artificial recharge to ground water in different states, prepared by Central Ground Water Board in 2013, aims at providing terrain specific artificial recharge techniques to augment the ground water reservoir based on the twin important requirements of source water availability and capability of ground water reservoir to accommodate it. The specific problems in different areas in the states like excessive ground water development resulting in ground water decline, water scarcity due to inadequate recharge in arid areas, low ground water retention in hilly areas despite substantial rainfall, urban areas with limited ground water recharge avenues and related problems of urban pollution, etc., have been considered while preparing the master plan. To fully utilize the available surplus monsoon runoff in rural areas, emphasis has been given for adoption of artificial recharge techniques based on surface spreading like percolation tanks, nala bunds, etc., and sub-surface techniques of recharge shaft, well recharge, etc. In urban areas, hilly areas and coastal regions priority has to be given to rain water conservation measures through roof top harvesting techniques etc.

The Master Plan while bringing out the areas suitable for artificial recharge to ground water reservoir, prioritizes the areas wherein schemes need to be implemented as a first priority to ameliorate the water scarcity problems. The proposals and schemes recommended are not the ultimate ones but are the first stage of implementation. These need to be further extended in other areas depending on the availability of infrastructure, finances and future problems. The master plan envisaged the number of artificial recharge and water conservation structures in the country as 110lakh at an estimated cost of Rs.79178 crores.

1.3 Efforts of Water Conservation by the Government

(http://mowr.gov.in/sites/default/files/Steps_to_control_water_depletion_Jun2019.pdf)

Hon'ble Prime Minister has written a letter to all sarpanchs on 08.06.2019 regarding the importance of water conservation and harvesting and exhorted them to adopt all appropriate measures to make water conservation a mass movement.

Creation of a new Ministry of Jal Shakti for dealing with all matters relating to water at one place in an integrated manner.

The National Water Policy (2012) has been formulated by Department of Water Resources, RD & GR, inter-alia, advocates rain water harvesting and conservation of water and highlights the need for augmenting the availability of water through direct use of rainfall. It also, inter-alia, advocates conservation of river, river bodies and infrastructure should be undertaken in a scientifically planned manner through community participation. Further, encroachment and diversion of water bodies and drainage channels must not be allowed and wherever, it has taken place, it should be restored to the extent feasible and maintained properly.

In compliance to the decision taken by the Committee of Secretaries, an 'Inter-Ministerial Committee' under the Chairmanship of Secretary(WR, RD & GR) has been constituted to take forward the subject of 'Push on Water Conservation Related Activities for Optimum Utilization of Monsoon Rainfall'.

DoWR, RD &GR has circulated a Model Bill to all the States/UTs to enable them to enact suitable ground water legislation for its regulation and development, which includes provision of rain water harvesting. So far, 15 States/UTs have adopted and implemented the ground water legislation on the lines of Model bill.

Central Ground Water Authority (CGWA) has issued directions under Section 5 of "The Environment Protection Act, 1986" for mandatory Rain Water Harvesting / Roof Top Rain Water Harvesting for all target areas in the Country including UTs. While granting 'No Objection Certificate (NOC)' for drawing ground water, CGWA insists for mandatory rain water harvesting as per the guidelines issued.

Central Ground Water Board (CGWB) under DoWR, RD & GR has also prepared a conceptual document entitled "Master Plan for Artificial Recharge to Ground Water in India" during the year 2013, which envisages construction of 1.11 crore rain water harvesting and artificial recharge structures in the Country at an estimated cost of Rs.

79,178 crores to harness 85 BCM (Billion Cubic Metre) of water, in an area of 9,41,541 sq.km by harnessing surplus monsoon runoff to augment ground water resources.

Besides, CGWB has taken up Aquifer Mapping and Management programme during XII Plan, under the scheme of Ground Water Management and Regulation. The Aquifer Mapping is aimed to delineate aquifer disposition and their characterization for preparation of aquifer/area specific ground water management plans with community participation. The management plans are shared with the respective State Governments for taking appropriate measures.

Department of Water Resource, RD&GR has instituted National Water Awards to incentivise good practices in water conservation and ground water recharge.

Mass awareness programmes (Trainings, Seminars, Workshops, Exhibitions, Trade Fares and Painting Competitions etc.) are conducted from time to time each year under the Information, Education & Communication (IEC) Scheme of DoWR, RD & GR in various parts of the Country to promote rain water harvesting and artificial recharge to ground water.

The Ministry of Rural Development in consultation and agreement with the Department of Water Resources, RD & GR and the Ministry of Agriculture & Farmers' Welfare has developed an actionable framework for Natural Resources Management (NRM), titled "Mission Water Conservation" to ensure gainful utilization of funds. The Framework strives to ensure synergies in Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Pradhan Mantri Krishi Sinchayee Yojana (PMKSY), erstwhile Integrated Watershed Management Programme (IWMP) now PMKSY-Watershed Development Component and Command Area Development & Water Management (CAD&WM), given their common objectives. Types of common works undertaken under these programmes/schemes are water conservation and management, water harvesting, soil and moisture conservation, groundwater recharge, flood protection, land development, Command Area Development & Watershed Management

Department of Land Resources is currently implementing 8214 watershed development projects in 28 States covering an area of about 39.07 million ha. under the Watershed Development Component (WDC) of the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) principally for development of rainfed portions of net cultivated area and culturable wastelands. The major activities taken up under the WDC-PMKSY, inter-alia, include ridge area treatment, drainage line afforestation, soil and moisture conservation, rain water harvesting, horticulture, and pasture development etc.

Ministry of Housing & Urban Affairs has released Model Building Bye-laws, 2016 which recommends Rainwater Harvesting for all types of Building with plot size 100 sq.m or more. Barring the States/UT of Sikkim, Mizoram and Lakshadweep, all the States have incorporated the provisions in their respective building bye laws. The plans submitted to the local bodies shall indicate the system of storm water drainage along with points of collection of rain water in surface reservoirs or in recharge wells. Further, all building having a minimum discharge of 10,000 litre and above per day shall incorporate waste water recycling system. The recycled water should be used for horticultural purposes.

Government of India has approved Atal Bhujal Yojana (Atal Jal), a Rs. 6000 Crore Central Sector Scheme, for sustainable management of ground water resources with community participation in water stressed blocks of Gujarat, Haryana, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Uttar Pradesh.

1.4 Past Initiatives of CGWB

Experiments on artificial recharge to aquifers started in India from1970 onwards by Central and State Government Departments and individually by some NGOs in different parts of the country where early signs of overexploitation of ground water were noticed. The Central Ground Water Board under took artificial recharge experiments through injection well around Kamliwala in Central Mehsana, Gujarat where sufficient water was available from Saraswati River during monsoon period. A detailed injection recharge experiment was carried out at the Kamliwala site by injecting water from the source well in Saraswati River bed 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 building of 5 meters piezometric head in the injection well and 0.6 to 1.0m in wells in areas of 150 m away. These experiments indicated feasibility of ground water recharge through injection wells in the area. Subsequently several such studies were taken up in different states of the country. The details of demonstrative artificial recharge studies taken up by CGWB during different five year plans are furnished in Table 1.1.

Table 1.1 Artificial Recharge Studies taken by CGWB during different Five Year Plans

Plan	Status	Cost (crores)
VIII (1992-97)	Maharashtra, Karnataka, Andhra Pradesh, Delhi, Kerala, Madhya Pradesh, Tamil Nadu, West Bengal & Chandigarh (Total States/UT – 9)	3.23
IX (1997-2002)	Andhra Pradesh, Arunachal Pradesh, Assam, Andaman & Nicobar, Bihar, Chandigarh, Gujarat, Haryana, Himachal Pradesh, Jammu & Kashmir, Jharkand, Karnataka, Kerala, Lakshdweep, Madhya Pradesh, Maharashtra, Meghalaya, Mizoram, Nagaland, Delhi, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, Uttrakhand and West Bengal (Total States/UT – 27)	33.10
X (2002-2007)	Andhra Pradesh, Karnataka, Madhya Pradesh & Tamil Nadu (Total States – 4)	5.60
XI (2007-2012)	Andhra Pradesh, Arunachal Pradesh, Bihar, Chhattisgarh, Chandigarh, Delhi, Gujarat, Himachal Pradesh, Jammu & Kashmir, Jharkhand, Kerala, Karnataka, Maharashtra, Madhya Pradesh, Nagaland, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh and West Bengal (Total States/UT – 21)	99.87

Over exploited, critical, coastal and urban aquifers as well as ground water quality issues were given focus in the above schemes and some suggestions were also received for revision of the Master Plan. A separate scheme on Dug well recharge was prepared for Tamil Nadu, Gujarat, Madhya Pradesh, Karnataka, Maharashtra, Rajasthan and Andhra Pradesh states at the estimated cost of Rs 1871 crores covering 4.455 Million irrigation dug wells covering 1155 blocks in seven participating states. The Scheme was implemented through NABARD, CGWB and identified nodal agencies in the state. Under this scheme, farmers were given fund directly for the construction of recharge pits near the dug well at a average cost of Rs 4000/- which varies from Rs.3600/- (Maharashtra) to Rs.5700/- (Andhra Pradesh).
In the course of water conservation work, CGWB also brought out following documentations in an attempt to disseminate the experiences gained during various ground water 6+augmentation projects implemented by the Board in the country and also hosted in CGWB website. (http://cgwb.gov.in/Manuals-Guidelines.html)

- Manual on Artificial Recharge of Ground Water
- Artificial Recharge Guide
- Rain Water Harvesting Guide
- Booklet on "Simple Ways to Save Water"
- Elixir of Life Water (In Urdu language)
- Standard Designs for Adoption Of Roof Top Rainwater Harvesting In Delhi
- Rainwater Harvesting techniques to Augment Ground Water
- Interim Report on Project wise Impact Assessment of Completed Demonstative Artificial Recharge Projects of XI Plan (http://cgwb.gov.in/Ar-reports.html)

The manual on Artificial recharge, provides detailed guidelines on investigative techniques for selection of sites, planning and design of artificial recharge structures, monitoring and economic evaluation of artificial recharge schemes. It also included elaborate case studies and field examples of artificial recharge schemes from different parts of the world. The manual has been used extensively for planning and implementation of schemes for augmentation of ground water resources by various agencies.

Apart from these, Central Ground Water Board has also published technical brochures on various aspects of artificial recharge through its Regional Directorates, in its local vernacular languages, which served as guidelines to various governmental and non-governmental agencies and the general public. Some of the State Departments have also brought out manuals and guidelines on artificial recharge to ground water, which dealt with specific areas in most cases. There were also many projects implemented at state and national level with people's participatory approach in executing recharge projects.

1.5 Revision of Master Plan

A need was felt to revise the master plan, considering the implementation of various schemes for water conservation and augmentation across the country by both Central & State agencies. Accordingly, an inter departmental committee was constituted by the Ministry (Annexure 1) to revise the master plan as given below.

1.	Shri Sunil Kumar, Member, CGWB	Chairman
2.	Dr S.Suresh, Superintending Hydrogeologist	Member Secretary
3.	Director Level officer of CWC	Member
4.	Shri M.K.Garg, Scientist-D	Member
5.	Representative of NIH	Member
6.	Representative from MoH&UA	Member
7.	Representative from MoRD	Member
8.	Representative of WR Department /concerned Department of Concerned State	Member
9.	Concerned Regional Director of CGWB	Member

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The terms of reference of the committee were as given below.

To prepare a detailed report for creation of possible artificial recharge structures and its expected benefits based on similar works carried out by CGWB

Finalization of tentative list of artificial recharge structures with types of structures (through MGNERGS funds otherwise) on Pan-India basis

To work out the tentative cost of structures keeping the current market price in view.

To finalize consolidated cost of structures on Pan-India basis with tentative outlays.

A meeting of the committee was held on 28.05.2020 and the minutes of the meeting is given as Annexure 2. The following decisions were taken after lots of deliberations.

1. The committee approves the report for submission to DoWR, RD & GR, after incorporating the corrections suggested by respective States.
2. Each State may nominate a Nodal Agency, for maintaining the data base and documentation of water conservation efforts being undertaken by the respective States and Nodal Agency will remain a focal point for contact in respect of water conservation in the States.

CHAPTER 2.0

2.0 NATIONAL SCENARIO OF GROUNDWATER

2.1 Hydrogeological Set Up

India is a vast country with varied hydrogeological situations resulting from diversified geological, climatological and topographic set up. The rock formations, ranging in age from Archaean to Recent, control occurrence and movement of ground water. Physiography varies widely from rugged mountainous terrains of Himalayas, Eastern Ghats, Western Ghats and Deccan Plateau to the flat alluvial plains of the river valleys and coastal tracts, and the Aeolian deserts in western part. Similarly rainfall pattern also shows region wise variations.
Various rock types occurring in the country have been categorized as follows to describe the ground water characteristics.

1. Porous rock formation

(a) Unconsolidated formations.
(b) Semi-consolidated formations

2. Hard rock/ consolidated formations

The proper understanding of the characteristics of rock types help in site selection and designing artificial recharge structures. The area recording high yield is obviously having more storage potential and hence there is scope for more recharge to ground water.

2.1.1 Porous Rock Formations

2.1.1.1Unconsolidated Formations

The sediments comprising newer alluvium, older alluvium and coastal alluvium are by and large the important repositories of ground water. These are essentially composed of clay, sand, gravel and boulders, ferruginous nodules, kankar (calcareous concretions), etc. The beds of sand and gravel and their admixtures form potential aquifers. The aquifer materials vary in particle size, roundness and sorting. Consequently, their water yielding capabilities also vary considerably. The coastal aquifers show wide variations in the water quality both laterally and vertically.
The piedmont zone of the Himalayas extending from Jammu and Kashmir in the west to Tripura in the east, offers suitable locations for artificial recharge. The hydrogeological conditions and ground water regime in Indo-Ganga-Brahmaputra basin indicate existence of large quantities of fresh ground water down to 600 m or more below land surface. Bestowed with high rainfall and good recharge conditions, the ground water gets replenished every year in these zones. The alluvial aquifers to the explored depth of 600 m have transmissivity values from 250 to 4000 m^2/day and hydraulic conductivity from 10 to 800 m/day.

2.1.1.2 Semi-consolidated Formations

The semi-consolidated formations mainly comprise shales, sandstones and limestones. The sedimentary deposits belonging to Gondwana and Tertiary formations are included under this category. The sandstones form highly potential aquifers locally, particularly in Peninsular India. Elsewhere they have only moderate potential and at places they yield meagre supplies. These sediments normally occur at narrow valleys or structurally faulted basins. Though these formations have been identified to possess moderate potential, the physiography of the terrain normally restricts development. Under favorable situations, these sediments give rise to artesian conditions as in parts of GodavariValley, Cambay basin and parts of West Coast, Puducherry and Neyveli in Tamil Nadu. Potential aquifers particularly those belonging to Gondwanas and Tertiaries have Transmissivity values from 100 to 2300 m^2/day and the hydraulic conductivity from 0.5 to 70 m/day. Generally, the well yields in productive areas range from 10 to 50 lps. Lathi and Nagaur sandstone in Rajasthan and Tipam sandstone in Tripura state also form productive aquifers.

2.1.2 Hard Rock Formation

2.1.2.1 Consolidated Formations

The consolidated formations occupy almost two thirds of the country. From the hydrogeological point of view, the consolidated rocks are broadly classified into the following three types:

a) Igneous and metamorphic rocks excluding volcanic and carbonate rocks
b) Volcanic rocks
c) Carbonate rocks

These formations control the ground water availability and scope for augmentation and artificial recharge. The nature, occurrence and movement of ground water in these formations are described as follows:

2.1.2.2 Igneous and Metamorphic Rocks

The most common rock types are granites, gneisses, charnockites, khondalites, quartzites, schist and associated phyllite, slate, etc. These rocks do not possess primary porosity but are rendered porous and permeable due to secondary porosity created by fracturing and weathering.

Ground water yield and capability to accept recharge also depend on rock types. Granite and gneiss are better repositories than Charnockites. The ground water studies carried out in the crystalline hard rocks reveal the existence of lineaments along deeply weathered and fractured zones, locally forming potential aquifers. These lineament zones are found to be highly productive for construction of bore wells. These in turn offer good scope for recharge through suitable techniques.

In areas underlain by hard crystalline and meta-sedimentaries viz; granite, gneiss, schist, phyllite, quartzite, charnockites, etc., occurrence of ground water in the fracture system has been identified even up to 300 m and beyond locally. In most of the granite/ gneiss area, the weathered residuum serves as an effective ground water repository. It has been observed that the fracture systems are generally hydraulically connected with the overlying weathered saturated residuum. The yield potential of the crystalline and meta-sedimentary aquifers show wide variations. Bore wells tapping the fracture systems generally yield from less than 1.0 lps to 10 lps. The Transmissivity values vary from 10 to 500 m^2/day and the hydraulic conductivity values vary from 0.1 to 10 m/day.

2.1.2.3 Volcanic Rocks

The basaltic lava flows are mostly horizontal to gently dipping. Ground water occurrence in these hard rocks is controlled by the contrasting water bearing properties of different lava flows. The topography, nature and extent of weathering, jointing and fracture pattern, thickness and depth of occurrence of vesicular basalts are the important factors which play a major role in the occurrence and movement of ground water in these rocks. Basalts or Deccan Traps usually have medium to low permeability depending on the presence of primary and secondary porosity. Pumping tests have shown that under favourable conditions, bore wells yield about 3 to 6 lps at moderate drawdown. Transmissivity and the hydraulic conductivity values of these aquifers are generally in the range of 25 to 100 m^2/day and 0.05 to 15 m/day respectively.

2.1.2.4 Carbonate Rocks

Carbonate rocks include limestone, marble and dolomite. Among the carbonate rocks, limestones occur extensively. In carbonate rocks, solution cavities lead to widely contrasting permeability within short distances. Potential limestone aquifers are found to occur in Rajasthan and Peninsular India in which the yields range from 5 to 25 lps. Large springs exist in the Himalayan Region in the limestone formations. The distribution and potential of the major hydrogeological units are presented in Table-2.1 and Fig. 2.1.

Table 2.1: Distribution of Hydrogeological Units in India and their Ground Water Potential

Geologic Age		Rock Formations	Hydrogeological Characters
UN-CONSOLIDATED FORMATIONS			
Pieistocene to Recent	a)Fluvio-glacial deposits b)Glacio lacustrine deposits	a) Mixed Boulders, Cobbles, Sands and Silts b) Conglomerates, Sands Gravels, Carbonaceous shales and blue Clays.	The morainic deposits occupy valleys and gorges in interior Himalayas. Karewas (Kashmir Valley) are lacustrine deposits displaying cyclic layers of clayey, silty and coarser deposits with intervening boulder beds. Locally significant hydrogeological potential.
	c)Pediment, Himalayan and foot hill regions	c) Boulders, Cobbles, Pebble beds, Gravels, Sands, Silt and Clays	The Bhabar piedmont belt contains many productive boulder-cobble-gravel-sand aquifers. The water table is deep. Forms recharge zone for deeper aquifers of alluvial plains in south. Tarai belt is down-slope continuation of Bhabhar aquifers display flowing artesian conditions. Shallow water table yields upto 28 lps.
	d) Alluvial Plains (Older & Newer Alluvium)	d) Clays &Silts, Gravels and Sands of different mix. Lenses of Peat & Organic matter. Carbonate and Siliceous Concretions (Kankar)	Occur widespread in the Indo-Ganga-Brahmaputra alluvial plains. Form the most potential ground water reservoirs with a thick sequence of sandy aquifers down to great depths. The unconfined sand aquifers sometimes extend down to moderate depth (125 m). Deeper aquifers are leaky-confined/confined. The older alluvium is relatively compact. The unconfined aquifers generally show high storativity (5 to 25% and high). Transmissivity (500 to 3,000 sq.m/day). The deeper confined aquifers generally occurring below 200 to 300 m depth have low Storativity (0.005 to 0.0005) and Transmissivity (300 to 1000/sq.m/day). Highly productive aquifers yield up to 67 lps and above. The potentials of peninsular river, alluvium are rather moderate with yield up to 14 lps. But the alluvial valley fill deposits of Narmada, Tapi, Purna basins, 100m thick, sustain yield up to 28 lps. The quality of ground water at deeper levels is inferior. Storativity ($4x10^{-6}$ to $1.6x\ 10^{-2}$) and Transmissivity 100 to 1,000 sq.m./day. The alluvial sequences in deltas of major rivers on the eastern coast and in Gujarat estuarine tracts have their hydrogeological potential limited by salinity.
	e) Aeolian deposits	e) Fine to very fine sand and slit	The Aeolian deposits occurring in West Rajasthan, Gujarat, Haryana, Delhi, Punjab have moderate to high yield potentials; are well sorted and permeable; lie in arid region; natural recharge is poor and water table is deep.
SEMI-CONSOLIDATED FORMATIONS			
Tertiary		Nummulitic Shales and Limestones Carbonaceous Shales Sandstones Shales Conglomerates Ferruginous Sandstones Calcareous Sandstones Pebble Beds and Boulder-Conglomerate Sands Clay	The Hydrogeological potential of these formations is relevant only in the valley areas. Lower Siwaliks and their equivalents in Himachal Pradesh, Jammu & Kashmir, Assam, Punjab, Haryana, Uttar Pradesh, Sikkim generally do not form potential aquifers. The Upper Siwaliks have moderate ground water potential in suitable topographic locations. Tertiary sandstones of Rajasthan, Gujarat, Kutch, Kerala, Odisha, Tamil Nadu, Andhra Pradesh, West Bengal and North Eastern States have moderate to good yield potential up to 28 lps. Possess moderate primary porosity and hydraulic conductivity.
Upper Carboniferous to Jurassic	Gondwana Jurassic of Kutch and Rajasthan	Boulder-Pebble Beds Sandstones Shales Coal Seams Sandstones Calcareous sandstone Shales	Occur in Bihar, Maharashtra, Andhra Pradesh, Odisha, Madhya Pradesh, Gujarat, Rajasthan and Tamil Nadu. These formations do not have wide regional distribution, possess moderate primary porosity and hydraulic conductivity. Karstified limestones are good water yielders. Friable sandstones in Barkaras and Kamthis (Lower Gondwana) and their equivalent

Geologic Age		Rock Formations	Hydrogeological Characters
	Baghbeds Lametas and Equivalents	Quartzites Limestones	formations possess moderately good potential yield up to 14 lps.
CONSOLIDATED FORMATIONS			
Jurassic/ Upper Cretaceous to Eocene	Rajmahal Traps, Deccan Traps	Basalts, Dolerties Diorites and other acidic derivatives of Basaltic magma	Occur in West Bengal, Bihar, Madhya Pradesh, Gujarat, Maharashtra, Andhra Pradesh, Karnataka. Hydrogeological characteristics almost same as above. Fractured and Vesicular basaltic layers and inter-trappeansedimentaries are productive. Yield up to 5 lps, Storativity: 1 to 4%. Hydraulic conductivity 5 to 15 m/day. Unconfined shallow aquifers and leaky confined/confined deeper aquifers.
Pre-Cambrian	Cuddapahs Delhi & Equivalent Systems	Consolidated Sandstones Shales, Conglomerates, Limestones, Dolomites Quartzites, Marbles Intrusive Granites &MalaniVolcanics.	Occur in all States. These formations are devoid of primary porosity. Weathering & denudation, structural weak planes and fractures impart porosity and permeability in the rock mass. Solution cavities (caverns) in carbonate rocks at places, give rise to large ground water storage/ Circulation. The ground water circulation is generally limited within 200m depth. Storativity value of unconfined aquifer is generally low (0.2% to 3%). Hydraulic conductivity areas widely depending on fracture incidence (2 to 10m/day). Leaky confined/confined aquifers may be present in layered formations. Granites and granite-gneisses are the most productive aquifers. Yield range 2 to 10 lps and more.

2.2 Groundwater Quality

The ground water in most of the areas in the country is fresh. Brackish ground water occurs in the arid zones of Rajasthan, close to coastal tracts in Saurashtra and Kutch, and in some zones in the east coast and certain parts of Punjab, Haryana, Western Uttar Pradesh, etc., which are under extensive surface water irrigation. The fluoride levels in the ground water are considerably higher than the permissible limit in vast areas of Andhra Pradesh, Haryana and Rajasthan and in some parts of Punjab, Uttar Pradesh, M.P., Karnataka and Tamil Nadu. In the north-eastern regions, ground water with iron content above the desirable limit occurs widely. Pollution due to human and animal wastes and fertilizer application has resulted in high levels of nitrate and potassium in ground water in some parts of the country. Ground water contamination in pockets of industrial zones is observed in localized areas. The over-exploitation of the coastal aquifers in the Saurashtra and Kutch regions of Gujarat has resulted in salinisation of coastal aquifers due to sea water ingress. The excessive ground water withdrawal near the city of Chennai has led to seawater intrusion into coastal aquifers. The artificial recharge techniques can be utilized in improving the quality of ground water through dilution and to maintain the delicate fresh water-salt water interface in coastal zone.

2.3 Groundwater Resource Potential

The rock formations and their properties have a significant influence in ground water recharge. Porous formations like alluvial formations in the Indo-Ganga-Brahmaputra basin having high specificyieldvaluesarethemostimportantrepositoryofgroundwaterresources.Groundwater occurrencesinthefissuredformations,ontheother hand, arelimitedtoweathered,jointedand fractured portions of the rocks, which occupy almost two-third part of the country including peninsularIndia.Annual Groundwater recharge is significantly high in the Indus-Ganga-Brahmaputra alluvial belt in the North, East and North East India covering the states of Punjab, Haryana, Uttar Pradesh, Bihar, West Bengal and valley areas of North Eastern States, where rainfall is plenty and thick piles of unconsolidated alluvial formations are conducive for recharge. The prolific aquifers are also potential for accepting greater recharge, provided sufficient space is available. The Hydrogeology map with the spatial variation of yield potential is given as Fig 2.1. The annual precipitation including snowfall in India is of the order of 3880 BCM and the total water availability is computed as 1999 BCM. The utilizable surface water and replenishable ground water resources are of the order of 690 BCM and 432 BCM respectively. Thus, the total water resources available for various uses, on an annual basis, are of the order of 1122 BCM. Although the per capita availability of water in India is about 1341 cubic meters/year as in 2025 against the benchmark value of 1000 Cu m/year signifying 'water-scarce' condition (Fig.2.2), 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/year per capita in Brahmaputra/ BarakBasin and as low as 307 cu m/year/person in Sabarmati basin. Many other basins like Mahi, Tapi and Pennar are already water stressed.

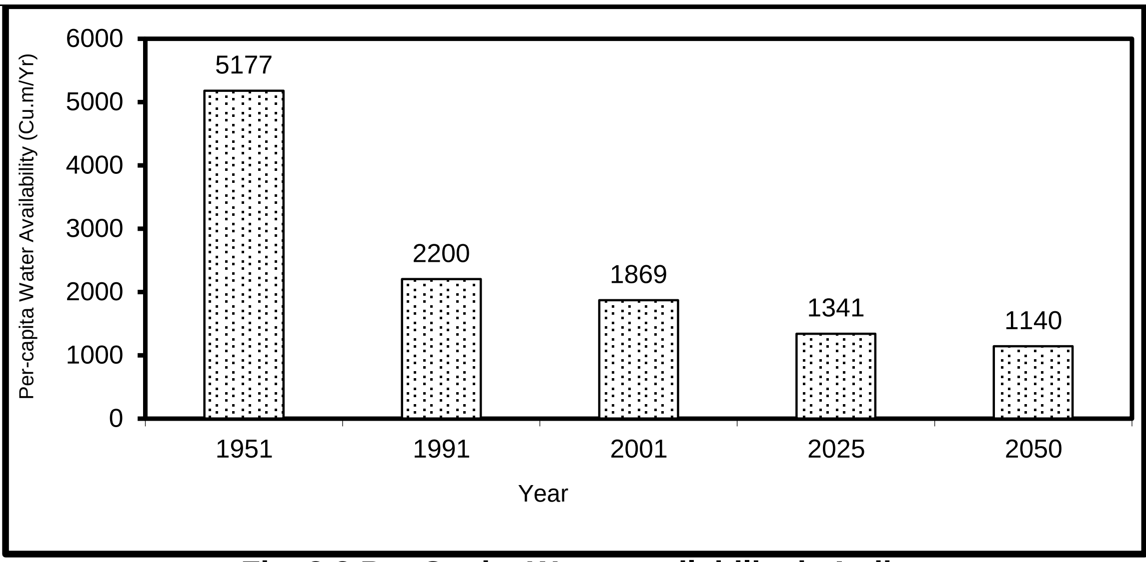


Fig. 2.2 Per Capita Water availability in India

2.4 Groundwater Development Scenario

During the past four decades, there has been a phenomenal increase in the growth of ground water abstraction structures due to implementation of technically viable schemes for development of the resource, backed by liberal funding from institutional finance agencies, improvement in availability of electric power and diesel, good quality seeds, fertilizers, government subsidies, etc. During the period 1951-2014, the number of dug wells increased from 3.86 million to 8.78 million that of shallow tube wells from 3000 to 5.94 million and deep tube wells from negligible to 5.8 million. There has been a steady increase in the area irrigated from ground water from 6.5 Mha in 1951 to 63.38Mha in 2014. The groundwater extraction for all uses as per GWRA-2017 is 248.69 B.Cu.m.

Such a magnitude of ground water development with sub optimal planning has resulted in creating deleterious effects in terms of ground water depletion and quality deterioration. These multiple challenges emerging in different parts of country need a suitable ground water management approach. Augmentation and artificial recharge to ground water reservoir offers a positive approach to curb the problems of ground water depletion and affected quality. The revision of Master Plan for Artificial Recharge is an effort in this direction.

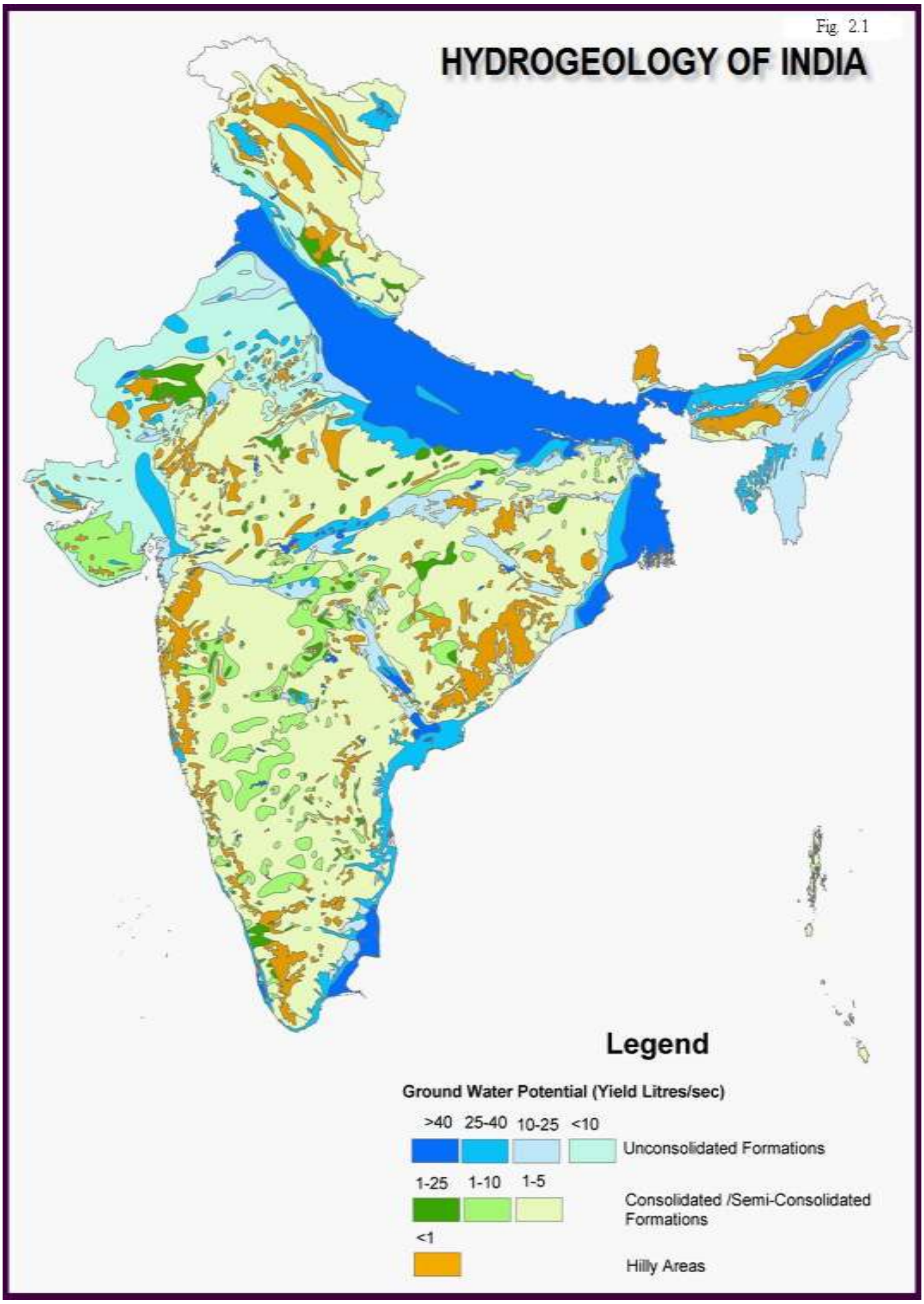


Fig. 2.1 Hydrogeology of India

CHAPTER 3.0

3.0 CONCEPT OF ARTIFICIAL RECHARGE TO GROUNDWATER

The artificial recharge to ground water aims at augmentation of ground water reservoir by modifying the natural movement of surface water utilizing suitable civil construction techniques. Artificial recharge techniques normally address to the following issues:

- To enhance the sustainability in areas where over-development has depleted the aquifer.
- Conservation and storage of excess surface water for future requirements, since these requirements often change within a season or a period
- To improve the quality of existing ground water through dilution.

3.1 Groundwater Reservoirs

The rivers and rivulets of the Indian sub continent are mainly monsoon fed with 80 to 90 percent runoff generated during the monsoon. The principle source for ground water recharge is also monsoon precipitation. The country receives more than 75% monsoon rainfall from June to September except in the eastern coast. Annually the rainy days vary from 12 to 100, and actual rainfall time varies from a few hours to over 300 hours. Incidences of up to 60 percent annual rainfall within a few days duration in a year are common in many parts of the country, causing excessive runoff, taking a heavy toll of life, agriculture and property. Harnessing of excess monsoon runoff in ground water storage/reservoir will not only increase the availability of water to meet the growing water demands, but also help in controlling damages from floods.

The sub surface reservoirs are technically feasible alternatives for storing surplus monsoon runoff and store substantial quantity of water. The sub surface geological formations may be considered as “warehouse” for storing water that come from sources located on the land surface. Besides suitable lithological condition, other considerations for creating sub surface storages are favorable geological structures and physiographic units, whose dimensions and shape will allow retention of substantial volume of water in porous and permeable formations. The sub surface reservoirs located in suitable hydrogeological situations will be environment friendly and economically viable for artificial recharge. The sub surface storages have advantages of being free from the adverse effects like inundation of large surface area, loss of cultivable land, displacement of local population, substantial evaporation losses and sensitivity to earthquakes. No gigantic structures are needed to store sub-surface water. The underground storage of water also has beneficial influence on the existing ground water regime and abstraction structures. The deeper water levels in many parts of the country either of natural occurrence or due to excessive ground water development, may be substantially raised, resulting in reduction on lifting costs and energy saving. The quality of natural ground water would substantially improve in brackish and saline areas. The conduit function of aquifers can further help in natural sub surface transfer of water to various needy centres, thereby reducing the cost intensive surface water conveyance system. The effluence resulting from such sub surface storage of various surface intersection points in the form of spring line, or stream emergence, would enhance the river flows and improve the degraded eco-system of riverine tracts, particularly in the outfall areas. The structures required for arresting surface runoff and recharging to ground water reservoirs are of small dimensions and cost effective such as check dams, percolation tanks, surface spreading basins, pits, sub-surface dykes, etc. and these can be constructed with local knowhow.

3.2 Basic Requirements

The basic requirements for recharging the ground water reservoir are:

- Need for the artificial recharge, indicated by deeper water levels and declining water level trends

Scope for artificial recharge, indicated by the availability of non-committed surplus monsoon run off in space and time and the ability of system to accept the recharge

Benefit cost ratio

Based on the above criteria, suitable sites would be selected for taking up artificial recharge.

3.2.1 Source water Availability

The availability of source water, one of the prime requisites for ground water recharge, is basically assessed in terms of non-committed surplus monsoon run off, which as per present water resource development scenario is going unutilized. This component can be assessed by analyzing the monsoon rainfall pattern, its frequency, number of rainy days, and maximum rainfall in a day and its variation in space and time. The committed water supply required for the existing water bodies and downstream rights would define the uncommitted surplus, considering the variations in rainfall pattern in space and time.

3.2.2 Hydrogeological Aspects

Detailed knowledge of geological and hydrological features of the area is necessary for selecting the site and the type of recharge structure. In particular, the features, parameters and data to be considered are geological boundaries, hydraulic boundaries, inflow and outflow of waters, storage capacity, porosity, hydraulic conductivity, transmissivity, natural discharge of springs, water resources available for recharge, natural recharge, water balance, lithology, depth of the aquifer, and tectonic boundaries.

The evaluation of the storage potential of sub-surface reservoir is invariably based on the knowledge of dimensional data of reservoir rock, which includes their thickness and lateral extent. The availability of sub-surface storage space and its replenishment capacity further govern the extent of recharge. The hydrogeological situation in each area needs to be appraised with a view to assess the recharge capabilities of the underlying hydrogeological formations. The unsaturated thickness of rock formations, occurring beyond three meters below ground level should be considered to assess the requirement of water to build up the sub-surface storage by saturating the entire thickness of the vadose zone to 3 meter below ground level. The upper 3 m of the unsaturated zone is not considered for recharging, since it may cause adverse environmental impact in terms of water logging, soil salinity, etc. The historical water level behaviour gives an idea of the maximum saturation existed in a given area and the present endeavour should also aim for restoration of the maximum saturation for a given hydrogeological set up. There are few states like Rajasthan where the water level is very deep in the historical past also. Similarly, the states with undulating terrain will have steep hydraulic gradient and the saturation up to 3 m below ground level is not logical. The post-monsoon depth to water level represents a situation of minimum thickness of vadose zone available for recharge which can be considered vis-à-vis surplus monsoon run off in the area. In view of the above, depth below 3 m from ground level is taken for estimation of thickness of available unsaturated zone in post monsoon period for most of the states. However, some of the States also have taken different criteria based on the prevailing hydrogeological situations and have been discussed in the respective State section. Further, shallow level is considered in coastal and island aquifers, where the head above mean sea level should be raised to a maximum possible extent to keep the fresh water-salt water interface at safe level. Depth to water level map for post monsoon period of 2018 is presented in**Fig. 3.1.**The artificial recharge techniques inter relate and integrate the source water to ground water reservoir. This results in rise in water level and increment in the total volume of the ground water reservoir.

3.3 Traditional water harvesting Systems

The water harvesting in India has been very old features and some of the structures can also function as indirect recharge structures, facilitating the movement water to groundwater system. The traditional methods are prevalent from Kashmir to Kanyakumari and the local wisdom to tap the terrain characteristics to store water has been phenomenal. Select traditional methods/structures along with the locales have been summarized in Table 3.1

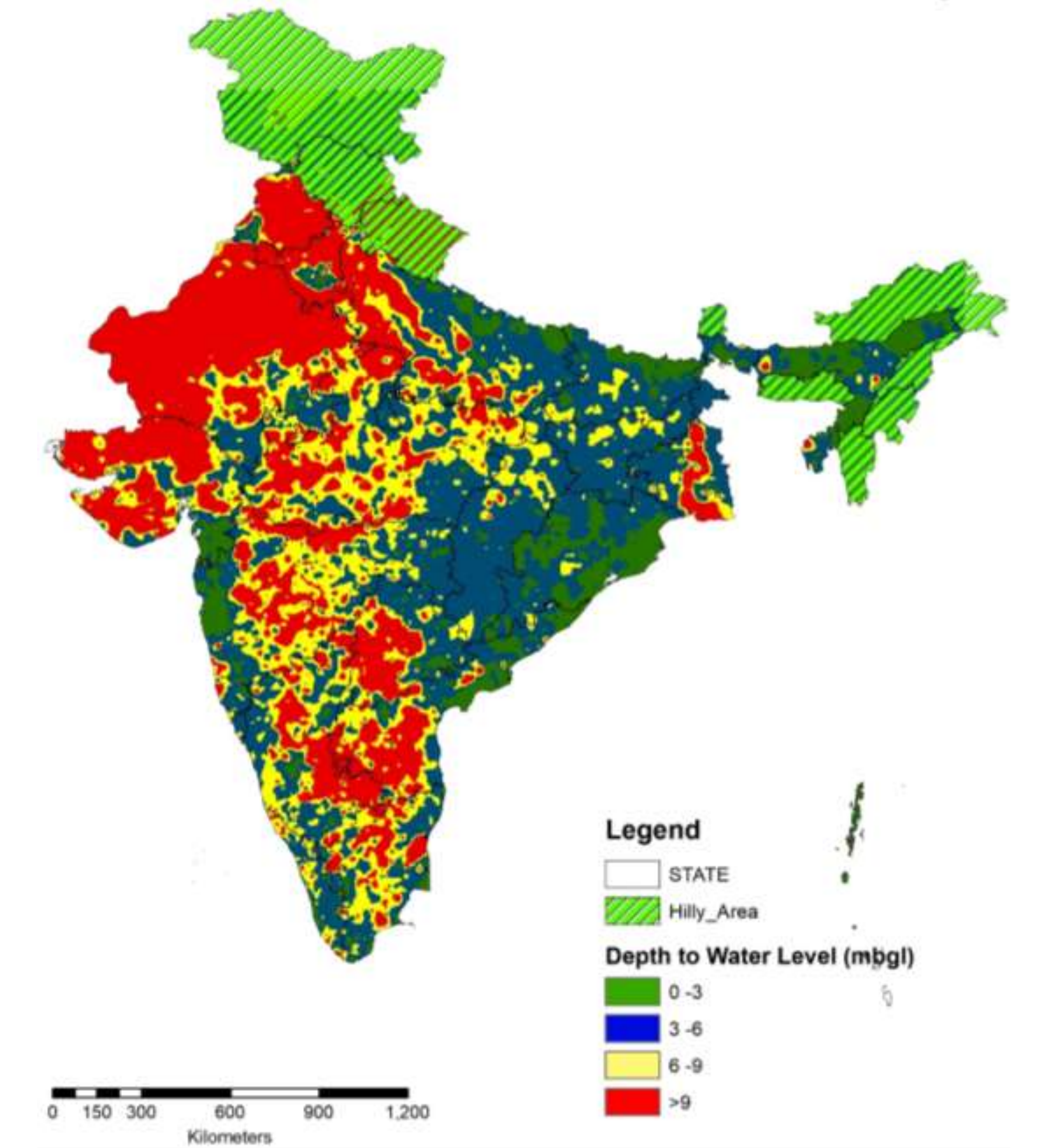


Fig.3.1 Depth to Water Level Map (Post Monsoon -2018)

Table - 3.1. Traditional Artificial Recharge Practices in India

Sl. No.	Region	Structure	Description	Areas
1	Trans Himalayan Region, Jammu & Kashmir	Zings	Small tank like structures used to collect melted glacier water with a network of guiding channels	Ladakh &Kargil area

Sl. No.	Region	Structure	Description	Areas
2	Western Himalayan Region Kashmir Valley to Uttarakhand region	Kul, Naula, Khatri Kuhl	Water channels lined with rocks, to collect melted glaciers water Small ponds /wells to collect water from the streams by making stone wall 10 x12 x 12 size carved structure in hard rock mountain. Surface channels diverting water from natural flowing streams	Spiti Valley and Jammu region Hilly areas of Uttarakhand Hamirpur, Kangra and Mandi (HP) Jammu &Kashmir Himachal Pradesh Uttarakhand
3	Eastern Himalayas Sikkim, Arunachal Pradesh & Darjeeling (WB)	Apatani	The slope of the valley is terraced in to plots separated by earth dams supported by bamboo frames.	Lower Subansiri (Arunachal Pradesh)
4	Northern Hill Regions Assam, Nagaland, Manipur, Mizoram, Meghalaya &Triputra	Zabo Bamboo drip irrigation	Pond like structures located on high ridges runoff water from hill top passes through terraces and collected in ponds Bamboo pipes are used to divert perennial spring water from hill top to irrigation field in the lower reaches	Nagaland Khasi &Jaintia hills
5	Brahmaputra Valley	Dungs	Small irrigation channels linking paddy fields	Assam
6	Indo- Gangetic Plains	Dighi Baolis	Square/circular reservoir with steps Step wells	
7	Thar Deserts Western Rajasthan, Kutch region of Gujarat, Parts of Punjab and Haryana	Kundi Kuis/ Beris/ Baoris/Bers Jhalaras Nadis Tobas Tanks Khadin Vav/Vavdi/ Bavoli/ Bavadi Virdas Paar	Looks like an upturned cup nestling in a saucer 10-12 m deep pits dug near tanks to collect the seepage water Community wells used for drinking needs Rectangular Tanks having steps used for Religious rites Ponds storing water during rainy season Natural catchment with ground depression Lined circular holes made in the ground Built across the lower hill slopes Traditional step wells with a sluice constructed at the rim Shallow wells in low depressions A common water harvesting place, rain water flows from the catchment and percolates into the sandy soil	Western Rajasthan and some parts of Gujarat Rajasthan Rajasthan Jodhpur city Jodhpur city Bikaner Jaisalmer Rajasthan and Gujarat Rann of Kutch, Gujarat Western Rajasthan
8	Central high lands, Rajasthan, Gujarat, Madhya Pradesh	Talabs/ Bandhis Saza Kuva Johads Naada Pat Rapat Chandela tanks	Human made/natural lakes Open well with multiple owners Earthern check dams A small stone check dam across a stream or gully Structures to store the water by diverting swift flowing hill streams Percolation tank with a bund to impound rain water flowing through a watershed Constructed by stopping run off in Rivulet flowing between hills by erecting massive earthen embankment	Bundelkhand region Rajasthan and Madhya Pradesh

Sl. No.	Region	Structure	Description	Areas
		Bundela tanks	Similar to Chandala tank constructed with steps	
9	Eastern high lands, Bihar, Madhya Pradesh, Odisha	Katas/ Mundas/ Bandhas	Strong earthen embankment curved at either end built across drainage line.	
10	Maharashtra, Karnataka and parts of AP	Cheruvu Kohlis Bandharas Phad Kere Ramtek model	Lake like structure Water tanks Small check dams/diversion weirs built across river Community managed irrigation system Check dam like structures built across streams for irrigation Network of ground water and surface water bodies connected through surface and underground canals	Chittoor, Kadapa districts of AP Maharashtra Maharashtra North West Maharashtra Karnataka Ramtek, Maharashtra

CHAPTER 4.0

4.0 METHODOLOGY FOR PREPARATION OF MASTER PLAN

The Master Plan for Artificial Recharge has been prepared considering the hydrogeological parameters and hydrological data base. The following aspects were considered for preparation of the plan:

- Identification and prioritization of need based areas for artificial recharge to ground water.
- Estimation of sub surface storage space based on the water table behaviour and quantity of water needed to saturate the unsaturated zone (up to a depth of 3 to 8 m bgl depending on the prevailing hydraulic conditions and zone of fluctuation in the state, to fully utilize the unsaturated zone without allowing water logging condition)
- Quantification of local surplus annual run off availability as source water for artificial recharge in each sub basin/watershed and possibility of transporting surplus run off from adjoining watersheds/sub-basins also to be considered.
- Areas of poor chemical quality of ground water and scope of improvement by suitable recharge measures.
- Working out design of suitable recharge structures, their numbers and type; storage capacity and efficiency considering the estimated storage space and available source water for recharge.
- Cost estimates of artificial recharge structures required to be constructed in identified areas.

The generalised methodology followed in the country is described below and due to data constraints, small tweaking of the methodology was made in some States and have been described in State wise discussion.

4.1 Identification of Feasible Areas

The areas feasible for artificial recharge have been demarcated into different categories as follows in most of the states:

- Areas showing post monsoon water levels deeper than 3 m bgl and declining trend of more than 10 cm/year in plains
- Post monsoon Water level above 4 to 8 m in undulating/ hilly terrain and poor rainfall with deep water table zones.
- Areas with deeper pressure head in known principal aquifers.
- Areas having less fresh water lenses in coastal/island aquifers

In addition, water scares areas, over exploited areas have also been included to bring about an overall improvement in groundwater levels. The water table map, long term trend map were super imposed to demarcate the area identified for artificial recharge. In some States, category map and water scarcity area map were also super imposed to include more areas for artificial recharge.

4.2 Estimation of Available Storage

The thickness of available unsaturated zone (below 3 bgl) described earlier is estimated by considering the different ranges of water level. The different ranges of DTW (depth to water level) are averaged to arrive at thickness of unsaturated zone. The total volume of unsaturated strata is calculated by considering the above categories and unsaturated thickness of different ranges. This volume was then multiplied by average specific yield on an area specific basis to arrive at volume of water required to saturate the aquifer to 3 m bgl.

4.3 Source water Requirement

After assessing the volume of water required for saturating the vadose zone, the actual requirement of source water is to be estimated. Based on the experience gained in the pilot/demonstrative recharge projects implemented in different hydrogeological situations, an average recharge efficiency of 75% of the individual structure is considered. The volume of source water required for artificial recharge was calculated by multiplying a factor of 1.33 (i.e. reciprocal of 0.75). In few cases different values are taken depending upon the regional scenario prevailing thereupon.

4.4 Source Water Availability

The surface water resources available in various basins and sub basins utilized for preparation of plan were based on information mostly provided by State Government. In few cases information from other Government Agencies were considered. The data availability for source water availability for each sub basin includes committed run off& provision for future planning. The surplus water available is then worked out by subtracting the committed supply form total availability. The basis/sub basin wise surplus availability is apportioned to District.

4.5 Capacity of Recharge Structures

The capacity of recharge structures was worked out based on the findings of various artificial recharge studies under taken in different States and the same was used for planning the recharge structures.Maximum storage capacity (single filling) and gross capacity due to multiple fillings during rainy season were taken into consideration for designing percolation tanks, cement plugs, check dams and other surface storage structures. The number of rainy days and the possible number of fillings to the proposed recharge structure (3 to 5 fillings for check dams, 2 to 3 fillings for ponds etc) is also taken into consideration.

4.6 Number of Recharge Structures

The numbers of recharge structures required to store and recharge the ground water reservoir have been worked out as follows: -

$$\text{No. of Structures} = \frac{\text{Total surplus Surface Water runoff Considered}}{\text{Average Gross Capacity of Water Spreading Recharge Structures (Considering Multiple Fillings)}}$$

The type and design of different types of structures like percolation tanks, check dams, recharge shafts etc. in a particular block/watershed would be guided by prevailing hydrogeological situation, existing density and number of structures, land availability etc. The planning of type and design of proposed structures should accordingly be decided. The allocation of source water for recharge through specific type of artificial recharge structures should be done considering these aspects. In case of deeper aquifers, injection wells are recommended on the basis of thickness of aquifer and status of ground water withdrawal and the feasibility of gravity injection at safe rate obtained from trial tests at Neyveli aquifer in Tamil Nadu. Few structures are based on conceptual projection, which can be fine-tuned by more site specific field studies during preparation of Detailed Project Reports (DPRs).

CHAPTER 5.0

5.0 DESIGN OF ARTIFICIAL RECHARGE STRUCTURES

A wide spectrum of techniques is in vogues which are being implemented to recharge the ground water reservoir. The artificial recharge technique will vary in consonance with the variations in hydrogeological framework. The artificial recharge structures, which are feasible in varied hydrogeological situation, are described as follows:

5.1 Percolation Tanks

Percolation tank is an artificially created surface water body, submerging in its reservoir highly permeable land areas, so that the surface run off is made to percolate and recharge the ground water storage. The percolation tank should have adequate catchment area. The hydrogeological condition of site for percolation tank is of utmost importance. The rocks coming under submergence area should have high permeability. The degree and extent of weathering of rocks should be uniform and not just localized. The purpose of percolation tank is to conserve the surface run off and diverts the maximum possible surface water to the ground water storage. Thus the water accumulated in the tank after monsoon should percolate at the earliest, without much evaporation losses.

The size of a percolation tank should be governed by the percolation capacity of the strata in the tank bed rather than yield of the catchment. For, in case the percolation rate is not adequate, the impounded water is locked up and wasted more through evaporation losses, thus depriving the downstream area of the valuable resource.These are the most prevalent structures in India as a measure to recharge the groundwater reservoir both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures is more in hard rock formation where the rocks are highly fractured and weathered. In the States of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Gujarat, the percolation tanks have been constructed in plenty in basaltic lava flows and crystalline rocks. The percolation tanks are, however, also feasible in mountain fronts occupied by talus scree deposits. The percolation tanks can also be constructed in the Bhabar zone. Percolation tanks with wells and shafts can also be constructed in areas where shallow or superficial formations are highly impermeable or clayey.

5.1.1 Site Characteristics and Design Guidelines

A detailed analysis of rainfall pattern, number of rainy days, dry spells and evaporation rate and detailed hydrogeological studies to demarcate suitable percolation tank sites, is necessary. In Peninsular India with semi-arid climate, the storage capacity of percolation tank is designed such that the water percolates to ground water reservoir by January/February. The submergence area should be in uncultivable land as far as possible. Percolation tank be located on highly fractured and weathered rock for speedy recharge. In case of alluvium, the bouldary formations are ideal for locating percolation tanks. The aquifer to be recharged should have sufficient thickness of permeable vadose zone to accommodate recharge. The benefited area should have sufficient number of wells and cultivable land to develop the recharged water. Detailed hydrological studies for run off assessment be done and designed capacity should not normally be more than 50 percent of total quantum of rain fall in catchment. Waste weir or spillway is suitably designed based on single day maximum rain fall to allow flow of surplus water after the tank is filled to its maximum capacity. Cut off trench be provided to minimize seepage losses both below and above nala bed. To avoid erosion of embankment due to ripple action stone pitching be provided upstream up to highest flood level (HFL).

5.2 Check Dam / Cement Plug / Nala Bund

Check Dams are constructed across small streams having gentle slope and are feasible both in hard rock as well as alluvial formation. The site selected for check dam should have sufficient thickness of permeable bed or weathered formation to facilitate recharge of stored water within short span of time. The water stored in these structures is mostly confined to stream course and the height is normally around 2 m. These are designed based on stream width and excess water is allowed to flow over the wall. In order to avoid scouring from excess run off, water cushions are provided at down streamside. To harness the maximum run off in the stream, series of such check dams can be constructed to have recharge on a regional scale. The peak flow should not create bank erosion and damage to structures.

A series of small bunds or weirs are made across selected nala sections such that the flow of surface water in the stream channel is impeded and water is retained on pervious soil/ rock surface for longer period Nala-Bunds are constructed across bigger nala or second order streams in areas having gentler slopes. A nala bund acts like a mini percolation tank with water storage confined to stream course.

5.2.1 Site Characteristics and Design Guidelines

For selecting a site for Check Dams/ Nala Bunds the following aspects may be observed

- The total catchment of the nala should normally be between 40 to 100 Hectares though the local situations can be guiding factor for this.
- The width of nala bed should be at least 5 meters and not exceed 15 meters and the depth of bed should not be less than 1 meter.
- The lands downstream of Check Dam/ Bund should have land under well irrigation.
- The rock strata exposed in the ponded area should be adequately permeable to cause ground water recharge through ponded water.
- The structures should not block the flow of water during the rainfall totally and hence the sufficient carrying capacity of nala/stream should be ensured.

5.3 Gabion Structure

This is a kind of check dam being commonly constructed across small stream to conserve stream flows with practically no submergence beyond stream course. The boulders locally available are stored in a steel wire. This is put up across the stream to make a small dam by anchoring it to the streamside. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure leaving some storage water to serve as source of recharge. The silt content of stream water is deposited in the interstices of the boulders in due course to make it more impermeable. These structures are common in the states of Maharashtra, Madhya Pradesh, Andhra Pradesh, etc.

5.4 Modification of Village Tanks As Recharge Structure

The existing village tanks which are normally silted and damaged can be modified to serve as recharge structure in case these are suitably located to serve as percolation tanks. In general, no “Cut Off Trench” (COT) and Waste Weir is provided for village tanks. Desilting, coupled with providing proper waste weir and COT on the upstream side, the village tanks can be converted into recharge structure. Several such tanks are available which can be modified for enhancing ground water recharge. Studies, however, are needed to ascertain whether the village tanks are suitably located to serve as recharge structures. Some of the tanks in Maharashtra and Karnataka have been converted into percolation tanks.

5.5 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 ground water. The storm water, tank water, canal water, etc. can be diverted into these structures to directly recharge the dried aquifer. By doing so the soil moisture losses during the normal process of recharge, are reduced. The recharge water is guided through a pipe to the bottom of well, below the water level to avoid scoring of bottom and entrapment of air bubbles in the aquifer. The quality of source water including the silt content should be such that the quality of ground water reservoir is not deteriorated. In rural areas the rain water runoff can be channelized and recharged to dug wells through a filter.

5.6 Recharge Shafts

In areas where phreatic aquifer is overlain by poorly permeable strata, the recharge to ground water storage by water spreading method becomes ineffective or has very low efficiency. This situation also occurs in ponds/depressions where due to siltation an impermeable layer or lens is formed which affects hydraulic connection of surface water and phreatic aquifers. Recharge shaft is an artificial recharge structure which penetrates the overlying impervious horizon and provides affective access of surface water for recharging the phreatic aquifer. These structures are ideally suited for areas with deep water levels. In areas where low permeable sandy horizon is within shallow depths, a trench can be excavated to 3 m depth and back filled with boulder and gravel. The trench can be provided with recharge shaft to effectively recharge the deeper aquifers.

5.6.1 Site Characteristic And Design Guidelines

The following are the site characteristics and design guidelines:

- To be dug manually if the strata is of non-caving nature.
- If the strata are caving, proper permeable lining should be provided.
- The diameter of shaft should normally be more than 2 m to accommodate more water and to avoid eddies in the well.

5.7 Injection Well

The aquifer to be replenished is generally one which is already over exploited by tube well pumpage and the declining trend of water levels in the aquifer has set in. Because of the confining layers of low permeability the aquifer cannot get natural replenishment from the surface and needs direct injection through recharge wells. Artificial Recharge of aquifers by injection well is also done in coastal regions to arrest the ingress of sea water and to combat the problems of land subsidence in areas where confined aquifers are heavily pumped.

In alluvial areas injection well recharging a single aquifer or multiple aquifers can be constructed in a fashion similar to normal gravel packed pumping well. The only difference is that cement sealing of the upper section of the well is done in order to prevent the injection pressures from forcing leakage of water through the annular space of borehole and well assembly. In hard rock areas casing and well screens may not be required. An injection pipe with opening against the aquifer to be recharged may be sufficient. However, in case of number of permeable horizons separated by impervious rocks, a properly designed injection well may be constructed with slotted pipe against the aquifer to be recharged. In practice the injection rates are limited by the physical characteristics of the aquifer. In the vicinity of well, the velocity of ground water flow may increase to the point that the aquifer is eroded, especially if it is made up of unconsolidated or semi-consolidated rocks. In confined aquifer, confining layers may fail if too great pressure is created under them. If this occurs, the aquifer will become clogged in the vicinity of the borehole and/or may collapse. Hence, care may be taken to design the injection discharge, which are generally equal to the yield of the well.

5.8 Ground Water Dams Or Sub Surface Dykes Or Underground Bandharas

These are basically ground water conservation structures and are effective to provide sustainability to ground water structures by delimiting sub surface flow. A ground water dam is a sub surface barrier across stream which retards the natural ground water flow of the system and stores water below ground surface to meet the demands 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. This helps in rising of water levels in upstream part of ground water dam rise, thus saturating the otherwise dry part of aquifer.

5.9 Roof Top Rain Water Harvesting

In Urban areas, the roof top rain water can be conserved and used for recharge of ground water. This approach requires connecting the outlet pipes from roof top to divert the water to either existing wells/ tube wells/ bore well or specially designed wells. The urban housing complexes or institutional buildings have large roof area and can be utilized for harvesting roof top rain water and recharging.

CHAPTER 6.0

6.0 MONITORING MECHANISM

The monitoring of water levels and water quality is of prime importance in any scheme of artificial recharge to ground water. The monitoring data speaks for the efficacy of structures constructed for artificial recharge and greatly helps in taking effective measures for ground water management on scientific lines. As such the plan for artificial recharge should have the monitoring mechanism inbuilt with the scheme.

6.1 Water Level Monitoring

The monitoring of surface water and ground water levels during feasibility studies greatly help in identifying the method of artificial recharge. Network of observation wells is used to study the ground water flow pattern and temporal changes in potentiometric head in the aquifer.

The observation well network during feasibility stage is generally of low density, spread over a large area with the primary aim of defining the boundary zonation of the aquifer to be recharged and to know the hydraulic characteristics of the natural ground water system. After identification of the feasible ground water structures, the observation well network is redefined in a smaller area with greater well density. The objective of monitoring system is to study the effect of artificial recharge on the natural ground water system. Depending on the method of artificial recharge and the hydrogeology of the area, the observation well network has to be designed.

The monitoring system of observation well network should be designed specially to monitor impact of individual structures which can further be extended and dovetailed to monitor the impact of group of such structures in the artificial recharge scheme area. The network of observation wells should be

- adjacent to the recharge facility
- at a sufficient distance from the recharge facility to observe composite effects and
- near the limit of hydrological boundaries.

If the recharged aquifer is overlain by confining/ semi-confining layer, piezometers should be installed to monitor the water levels of overlying and underlying aquifers which helps in the study of leakages etc. Where the surface water bodies are hydraulically connected with the aquifers which are being recharged, it is advisable to monitor the water level profiles of both surface water and ground water.

The periodic monitoring of water levels can demarcate the zone of benefit. In this method a network of observation wells is established in the area likely to be benefitted to study the following:

- In the zone benefitted, the water levels be observed as to whether the well hydrographs have a flat apex during the time when there is water in the recharge structure (tank, pit, etc.)
- Wells situated outside the zone of influence normally show an angular apex for the period when the recharge is taking place, while those situated within the zone of influence have a flatter area.
- The recession limbs of hydrograph wells close to a recharge structure normally have a gentle gradient as compared to those located far off. Crops in the zone of influence will be healthy compared to those outside such an area. Furthermore, in the zone of influence there is a tendency by the farmers to grow crops with high water requirements. Well yields in the zone of influence are generally being greater than those outside it. The wells in benefitted zones may have more sustainability in lean period than those outside.

The above criteria can be used to define the zone of influence and thereby, a real and temporal demarcation of the effectiveness of recharges structures.

6.2 Tracer Technique for Demarcating Zone Of Benefit

Tracers are useful in demarcating the area benefitted by artificial recharge, Tritium; Rodhomine B, fluorescent dye and environmental isotopes, etc. are quite useful in assessing the extent of recharge and efficiency of recharge structures.

6.3 Water Quality Monitoring

The monitoring of water quality during the implementation of artificial recharge schemes is essential to maintain the quality standards for specified uses of the augmented resource. In case of injection wells the composition of native water in the aquifer and the recharged water is important to know prevent clogging of well and aquifer due to excessive precipitation of salts. The data on the chemical quality of native water and the changes which may take place during the implementation of artificial recharge schemes should be collected by regular sampling from observation well network. Where treated wastewater is used for recharge a careful monitoring is required to detect any possibility of contamination through a network of monitoring wells. Thus, the type of water quality monitoring programme depends on the specific problem being studied i.e. changes in ground water quality; effect of soil salinization and prevention of any contamination etc. The samples to be collected will also depend on the purpose and are generally categorized into

- Indicative: The indicative samples are collected at 1 to 4 months intervals and used to ascertain the presence of injected effluent.
- Basic: Basic samples are taken at monthly intervals for wells already influenced by recharge to determine the effect of recharge effluent on ground water quality and the purification provided by flow through the soil and aquifer system.
- Comprehensive: Comprehensive samples are taken at intervals of 6 months to 1 year for observation wells to determine water quality with respect to specific standards for intended water use.

6.4 Impact Assessment

The groundwater system is characterised by many points of recharge and many points of discharge. Groundwater system is hence dynamic and ever changing due to natural flow pattern guided by head difference. Hence due to simultaneous addition and withdrawal from the groundwater system, the impact of artificial recharge measures may not result in water level rise. Hence the impacts can be reflected by indirect impacts other than rise in water levels, as enumerated below.

- Arresting of Declining water level (rate/absolute Vale)
- Ground water structures in the benefited zone of the structures gains sustainability
- Wells provide water in lean months.
- Longer duration of pumping or increase in number of pumping days.
- Reduced pumping hours but constant command area
- Cropping pattern in the benefited zone may undergo marked changes
- Increase in the area covered by water intensive crops
- More area with the same crop coverage
- In spite of having a monsoon failure, the cropped area remains the same.
- Green vegetation cover may increase in the zone of benefit and also along the periphery of the structures due to increase in soil moisture.
- Quality of ground water may improve due to dilution.

CHAPTER 7.0

7.0 NATIONAL SCENARIO OF THE PROPOSED MASTER PLAN

In consequence to the extraction of groundwater resources to meet the ever increasing demand, the depletion of groundwater level has been noticed over the period, necessitating the supply side and demand side measures to conserve the available water resources. The central and State government has taken up schemes for augmentation of groundwater over the years. A bird's eye view of the need and proposal for augmentation was prepared by CGWB in 2013 and a need was felt to revise the same. Accordingly, the master plan has been revised and country level estimation is discussed in this chapter and State level estimations is discussed in the subsequent chapter.

7.1 Identified Area

The area for artificial recharge has been identified based on post monsoon water level (2018) and long term post monsoon water trend in most of the States & UTs. However, due to paucity of data and local groundwater issues, additional/different criteria were used in different States/UTs and have been discussed under each State/UT separately in next chapter. In the case of NE States, UT of Jammu & Kashmir & UT of Ladakh, the criteria of water scarcity have been used and structures have been suggested to harness the run off generated from the rain. In case of UT of Lakshadweep & UT of Daman & Diu, due to shallow groundwater level, only RTRWH has been suggested. The identified area for artificial recharge in each State/UT has been provided as Table 7.1.

Table 7.1 Scope for Artificial Recharge

S.No	State	Area identified for Artificial Recharge (Sq.km)	Available Sub Surface storage for Artificial Recharge (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Andhra Pradesh	83914.18	15948.69	21211.74	1246.95
2	Bihar	25959.57	8750.77	13476.25	66352.03
3	Chhattisgarh	25667.94	1030.12	1370.05	8609.63
4	Delhi	824.50	982.48	1306.73	94.62
5	Goa	1267.84	627.01	833.93	393.16
6	Gujarat	53123.19	14825.31	19717.69	4459.26
7	Haryana	39381.20	77964.29	103692.51	679.26
8	Himachal Pradesh	5468.80	2671.71	3553.38	0.00
9	Jharkhand	28748.31	1323.78	2197.47	4898.06
10	Karnataka	143453.00	10233.74	13610.88	12874.17
11	Kerala	11957.00	810.37	1080.48	12455.00
12	Madhya Pradesh	146053.45	24957.34	33193.23	9188.29
13	Maharashtra	123884.45	13621.24	18081.12	3871.98
14	Odisha	4043.61	669.46	890.41	1786.49
15	Punjab	45592.00	86789.21	115429.65	1200.99
16	Rajasthan	113498.00	159115.00	211626.00	5305.00
17	Sikkim	1834.00	249.94	332.41	332.41
18	Tamilnadu	91224.09	8700.80	11572.06	959.33
19	Telangana	42155.89	3342.80	4445.97	1186.47
20	Uttar Pradesh	97338.00	66970.00	89069.00	2743.00
21	Uttarakhand	13372.00	4012.00	5335.00	33449.00
22	West Bengal	22888.67	33177.41	44125.96	8532.86
23	UT-Lakshadweep	0.00	0.00	0.00	0.00
24	UT-Puducherry	300.14	10.65	14.17	32.05
25	UT-DNH	281.50	11.26	15.01	6.50
26	UT-Chandigarh	114.00	54.60	72.61	0.00

Table 7.1 Scope for Artificial Recharge					
S.No	**State**	**Area identified for Artificial Recharge (Sq.km)**	**Available Sub Surface storage for Artificial Recharge (MCM)**	**Water Required for Recharge (MCM)**	**Surplus Available for Recharge (MCM)**
27	UT-Andaman & Nicobar Islands	792.90	499.18	663.90	4436.05
		1123138.24	537349.16	716917.60	185092.56
Note:					
The area has been identified for AR in NE States, UT of J&K, UT of Ladhak & UT of Daman & Diu, quantification of area could not be made.					
Himachal Pradesh - The source water availability could not be assessed, as the data is confidential					
Sikkim - Surplus Available for artificial recharge is taken as equal to water required, in view of the rugged Himalayan terrain, which is 0.1 % of surplus available. Hence source water availability is considered as Harnessable water for artificial recharge					

7.2 Scope of Artificial Recharge

The scope of artificial recharge depends on the available sub surface space for recharge, water required for recharge and surplus water available for recharge. The volume of space available up to 3m bgl or 5m bgl depending on the criteria adopted in different States multiplied by the specific yield of the aquifers will provide the space available for recharge. Considering an efficiency of 60% or 75% as deemed fit in different States, the water required for artificial recharge has been worked out for each State. The surplus available for recharge after deducting the committed supply has been estimated for each State. The scope of artificial recharge for each State has been provided in Table 7.1.

A perusal of the table shows that an area of 11.23 Lakh sq.km has been identified for artificial recharge, with available space for artificial recharge works out to be 537.349 BCM. Considering an efficiency of 60 to 70%, water required for recharge works out to be of the order of 716.917 BCM. However, the surplus available for recharge is of the order of 185.092 BCM.

In the committee meeting, the representative from CWC opined that surplus available for recharge needs to be checked up and not to be consider new structures in the catchment area of the big dam, which may result in reduction of flow to Dams. In case of first point, CWC suggested that only 240 BCM is available as unutilized from the utilizable water, which can only be considered as surplus. Subsequently, the information on availability of water was obtained from CWC as given below.

	Surface water	Groundwater	Total
Total precipitation (BCM)			3880
Total water availability after losses (BCM)			1999
Total Utilizable water (BCM)	690	432	1122
Total water Utilized (BCM)	450	249	699

The artificial recharge measures are intended to harvest the rain through small structures at the places, where it falls, which may include hitherto considered unavailable after deducting the losses (3880-1999 = 1881 BCM) and the balance unutilized water from utilizable water (240 BCM). Hence the surplus source water estimated in the revision may be considered as available at present and detailed surplus availability needs to be worked out and updated as a separate project.

7.3 Artificial Recharge & Cost Estimate

The types of structures are decided by the terrain conditions and the number of structures are decided by the source water availability. The different type of structures suitable for different terrain conditions and the use of different terminology for the similar structures in various States have resulted in more than 25 types of structures. In order to group different structures and bring in standardization, the structures were studied and grouped in to 10 groups and in the group "Others" all the uncommon structures are classified and the grouping of various Structures for each State is given in Table 7.2. It is also pertinent to point out that percolation tank in Dadra Nagar Haveli, is very large of about 100 Ha, while in rest of the States, it will be less than 1 ha. Hence the structure and its connotations are different in different States. Further, in respect of RTRWH, in the absence of data, a percentage of houses and roof tops have been assumed in the calculations. In some States, unit cost per household has been given while in some unit cost is per unit area. In the States of UP for RTRWH and in Rajasthan for Catchment Area Treatment, unit cost is given per unit area and hence in these State, the number of structures for this activity has been excluded in the calculation but has been included in the calculation of cost. A summary of number of structures under various categories in various States/UTs is tabulated in Table 7.3 and illustrated in Fig 7.1. A perusal of the table and figure shows that about 75% of structures are towards RTRWH, while 17% is for others, with 3% for RS, with 2% of structures are in the category of CD & Gabion structures and 1% under PT category. The unit cost of structure also is found varying within the States for different districts for some States, while in some States/UTs they have assumed a uniform rate. The cost of the structures for each State has been given in Table 7.4 & Fig 7.2. A perusal of the table indicates that RTRWH account for 28% & "others" category account for 23% of cost each, while for CD & PT for 19% & RS for 07% of cost. Considering RTRWH is for Urban Areas and rest of the structures for Rural Areas and in addition, RS considered in UT of Chandigarh is also being taken in Urban areas, the cost of estimates for urban and rural areas work out to be Rs 36794.23 Cr (28%) & Rs 96735.45 Cr (72%) respectively and total cost is Rs 133529.69 Cr.

Table 7.2 Grouping of AR Structures

S.No	State	CD	RS	RTRWH	PT	Gabion	DS	Injection wells	SSD	SS Dev / WS Dev	Others			
1	Andhra Pradesh	CD		RTRWH	PT									
2	Bihar	CD	RS	RTRWH	PT(H) +PT (M)		DS-tank + Revival of UWB+Mauns+ Ahar Payne	Inj. Wells			CB &T(H)	GP	NB	CB & T (M)
3	Chhattisgarh		RS	RTRWH	PT						GP/CB/GS	NB/CP/KT Bhandara		
4	Delhi	CD	RS & RT		RTRWH									
5	Goa										Vented Dam			
6	Gujarat	CD		RTRWH	PT						Recharge through defunct tube wells			
7	Haryana	CD	RS	RWH							FP			
8	Himachal Pradesh	CD/ NB/CP	RS	RTRWH		Gabion	Modification of Village Pond/Tank	Inj. Well	SSD		Check dam cum SSD			
9	Jharkhand	NB/ CD/GP	RS	RTRWH area 300 to 1000 sq. m.	PT						RTRWH area more than 1000 sq. meter			
10	Karnataka	CD	RS		PT						SSD & CD Cum SSD			
11	Kerala	CD		RTRWH	PP	GP/Gabion	0	injection wells	SSD		CB	NB	RTRWH in Commercial buildings	

Table 7.2 Grouping of AR Structures

S.No	State	CD	RS	RTRWH	PT	Gabion	DS	Injection wells	SSD	SS Dev / WS Dev	Others			
12	Madhya Pradesh	CD	RS	RTRWH in Major Urban Area	PT						VP	NB/CP		
13	Maharashtra	CD	RS	RTRWH	PT						Urban Runoff Harvesting			
14	NE States	CD		RTRWH		Gabion				No. of villages with springs	NB			
15	Odisha	CD	RS		PT				SSD		NB/CB	ST conversion to PT		
16	Punjab	CD	RS	RTRWH				Injection Wells			FP			
17	Rajasthan	CD	RS		PT						FP	CAT(ha)	Tanka	Anicut
18	Sikkim	CD/CD cum DW with conveyance drain/pipe		RTRWH		Gabion /Contour bund			SSD	Spring Shed Development	Rej of Lake/pond rejuvenation/excv of new pond	Rainwater harvesting in slope		
19	Tamilnadu	CD/NB	RS/ BW		PP						FP/RP	RT	RTW	
20	Telangana	CD		RTRWH	PT									
21	Uttar Pradesh	CD/NB/CP	DW/ TW/ RS	RTRWH(area in sqkm)	PT						Pond			
22	Uttarakhand	CD		RTRWH	PT						Chalkhal	CT		
23	West Bengal	Check dam		RTRWH (Munc/Cor.)+ RTRWH (Cen.Town)	PT in CT & MC	Gabion /Contour bund		injection wells	Sub-Surface Dyke		REET with RS	DW Recharge		

Table 7.2 Grouping of AR Structures

S.No	State	CD	RS	RTRWH	PT	Gabion	DS	Injection wells	SSD	SS Dev / WS Dev	Others			
24	UT-Andaman & Nicobar Islands	Check dam		RTRWH	PT	Gabion /Contour bund			SSD	Springshed Dev with CAT and Micro- WS Mgt	REET with RS			
25	UT-Chandigarh		RS											
26	UT-DNH	CD		RTRWH	PT						Urban Runoff Harvesting			
27	UT-Daman & Diu			RTRWH										
28	UT- Jammu & Kashmir			RTRWH		Gabion/ NB/SS Bhandara				Diversion of flows from Perennial Nalas/Springs	Rev & Res. Pond	Artificial Glaciers		
29	UT-Lakshadweep			RTRWH										
30	UT-Puducherry	CD/NB	RS/BW		PP						FP/RP	RT	RTW	
31	UT-Ladhak					Gabion				SS Development		Artificial Glaciers		

Table 7.3 Number of Artificial Recharge Structures												
S.No	State	**CD**	**RS**	**RTRWH**	**PT**	**Gabbion**	**DS**	**Injection wells**	**SSD**	**SS Dev / WS Dev**	**Others**	**Total**
1	Andhra Pradesh	13143	26209	263694	13085	0	0	0	0	0	0	316131
2	Bihar	122	5682	50000	428	0	12679	13811	0	0	8415	91137
3	Chhattisgarh	0	25687	118339	3426	0	0	0	0	0	30989	178441
4	Delhi	12	22706	304500	0	0	0	0	0	0	0	327218
5	Goa	0	0	0	0	0	0	0	0	0	931	931
6	Gujarat	3985	8607	1320947	701	0	0	0	0	0	2072	1336312
7	Haryana	335	44392	304377	0	0	0	0	0	0	393811	742915
8	Himachal Pradesh	2290	556	1050	0	108118	851	133	460	0	784	114242
9	Jharkhand	36062	1268	521692	5173	0	0	0	0	0	27455	591650
10	Karnataka	50527	436	0	9918	0	0	0	0	0	344	61225
11	Kerala	1260	0	482788	1395	196116	0	5	121	0	67943	749628
12	Madhya Pradesh	76002	76002	408938	12309	0	0	0	0	0	152085	725336
13	Maharashtra	19243	838	5646772	7188	0	0	0	0	0	8995	5683036
14	NE States	18821	0	15700	0	18835	0	0	0	11531	473149	538036
15	Odisha	1292	550	15700	1111	0	0	0	1051	0	2782	22486
16	Punjab	85	79839	551308	0	0	0	13410	0	0	455920	1100562
17	Rajasthan	32744	231	0	63158	0	0	0	0	0	674067	770200
18	Sikkim	380	0	1500	0	450	0	0	125	540	340	3335
19	Tamilnadu	7180	70460	0	2397	0	0	0	0	0	7685	87722
20	Telangana	11552	22188	555093	10636	0	0	0	0	0	0	599469
21	Uttar Pradesh	5582	5582	0	493	0	0	0	0	0	12011	23668
22	Uttarakhand	2870	0	5543	810	0	0	0	0	0	6300	15523
23	West Bengal	453	0	6740	8551	1136	0	8403	568	0	16914	42765
24	UT-Lakshadweep	0	0	9597	0	0	0	0	0	0	0	9597
25	UT-Puducherry	71	283	0	14	0	0	0	0	0	203	571
26	UT-DNH	49	0	12109	17	0	0	0	0	0	30	12205
27	UT-Chandigarh	0	10300	0	0	0	0	0	0	0	0	10300
28	UT-Jammu & Kashmir	0	0	1150	0	245	0	0	0	230	560	2185
29	UT-Ladakh	0	0	0	0	46	0	0	0	15	231	292
30	UT-Andaman & Nicobar Islands	350	0	2250	1000	150	0	0	100	170	0	4020
31	UT-DIU & Daman	0	0	14006	0	0	0	0	0	0	0	14006
	Total	284410	401816	10613793	141810	325096	13530	35762	2425	12486	2344016	14175144

Note
CD-Check dam, RS-Rechareg Shaft, RTRWH-Roof Top Rainwater Harvesting, PT=Percolation Tank, DS- Desilting, SSD- Sub-Surafce Dyke, SS Dev/WS Dev-Springshed Development/Wateshed Development activities, Others - Other Structures
Note: The cost of RTRWH has been estimated on the basis of cost per unit area of roof top in UP, Goa & Karnataka and has not been included in no of structures but included in cost. Similarly, in case of Rajasthan, CAT is given as cost per unit area and hence not included in number but included in cost.

Fig 7.1 Number of Artificial Recharge Structures proposed in the Master Plan

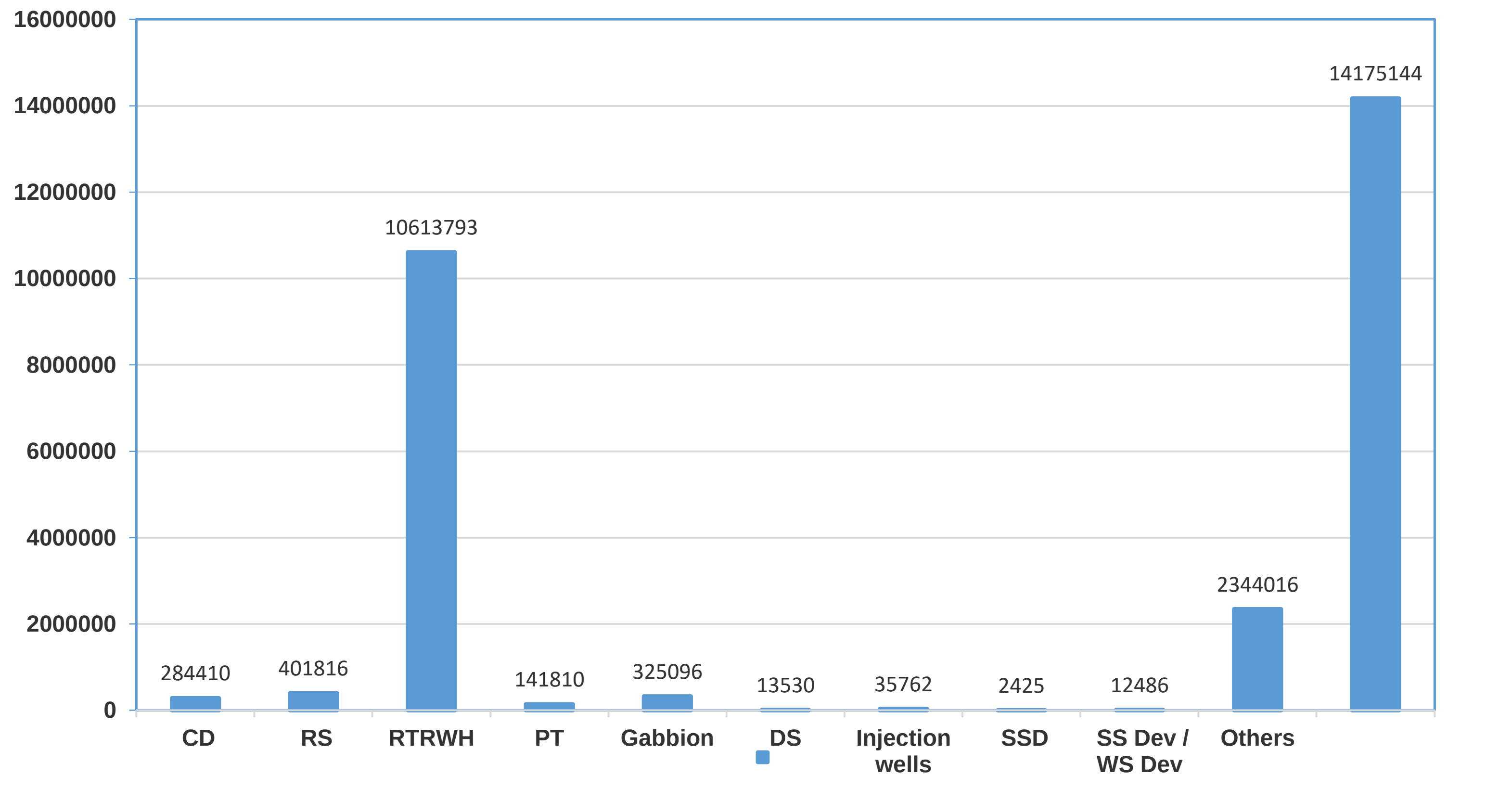


Table 7.4 Cost Estimate of Artificial Recharge (Rs in Cr)

S.No	State	CD	RS	RTRWH	PT	Gabion	DS	Injection wells	SSD	SS Dev / WS Dev	Others	Total
2	Andhra Pradesh	1051.44	524.18	527.39	1701.05	0.00	0.00	0.00	0.00	0.00	0.00	3804.06
3	Bihar	24.40	284.10	500.00	128.40	0.00	994.10	552.44	0.00	0.00	123.00	2606.44
4	Chhattisgarh	0.00	1284.35	591.70	1370.40	0.00	0.00	0.00	0.00	0.00	440.37	3686.82
5	Delhi	2.40	681.18	1522.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2206.08
6	Goa	0.00	0.00	146.54	0.00	0.00	0.00	0.00	0.00	0.00	279.30	425.84
7	Gujarat	278.95	430.35	2641.89	70.10	0.00	0.00	0.00	0.00	0.00	41.44	3462.73
8	Haryana	156.50	1331.76	913.13	0.00	0.00	0.00	0.00	0.00	0.00	1969.06	4370.45
9	Himachal Pradesh	256.48	29.19	36.75	0.00	540.59	55.32	2.00	17.48	0.00	117.60	1055.40
10	Jharkhand	2163.72	63.40	1304.23	1551.90	0.00	0.00	0.00	0.00	0.00	274.55	5357.80
11	Karnataka	5052.70	6.54	2870.02	1983.60	0.00	0.00	0.00	0.00	0.00	68.80	9981.66
12	Kerala	289.80	0.00	724.18	320.85	338.30	0.00	0.36	20.87	0.00	1565.46	3259.82
13	Madhya Pradesh	4560.12	760.02	817.88	2461.80	0.00	0.00	0.00	0.00	0.00	1926.72	10526.54
14	Maharashtra	2947.89	60.82	16940.31	10210.41	0.00	0.00	0.00	0.00	0.00	674.63	30834.06
15	NE States	3341.15	0.00	1683.49	0.00	472.58	0.00	0.00	0.00	1320.83	1071.73	7889.77
16	Odisha	64.60	11.00	204.10	222.20	0.00	0.00	0.00	105.10	0.00	194.65	801.65
17	Punjab	34.00	2395.17	1653.92	0.00	0.00	0.00	410.86	0.00	0.00	2279.60	6773.55
18	Rajasthan	1964.64	4.62	0.00	1894.74	0.00	0.00	0.00	0.00	0.00	15454.10	19318.10
19	Sikkim	34.00	0.00	75.00	0.00	5.25	0.00	0.00	3.13	27.00	54.50	198.87
20	Tamilnadu	1077.00	704.60	0.00	599.25	0.00	0.00	0.00	0.00	0.00	82.29	2463.14
21	Telangana	924.16	443.76	1110.20	1382.68	0.00	0.00	0.00	0.00	0.00	0.00	3860.80
22	UT-Andaman & Nicobar Islands	52.50	0.00	149.99	100.00	2.25	0.00	0.00	2.50	27.50	0.00	334.73
23	UT-Chandigarh	0.00	875.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	875.50
24	UT-DNH	7.54	0.00	36.33	24.99	0.00	0.00	0.00	0.00	0.00	2.25	71.11
25	UT-Jammu & Kashmir	0.00	0.00	120.75	0.00	128.63	0.00	0.00	0.00	24.15	33.60	307.13
26	UT-Ladakh	0.00	0.00	0.00	0.00	24.15	0.00	0.00	0.00	1.58	43.86	69.59
27	UT-Lakshadweep	0.00	0.00	57.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	57.58
28	UT-Puducherry	10.65	2.83	0.00	3.50	0.00	0.00	0.00	0.00	0.00	3.91	20.89
29	Uttar Pradesh	1116.40	83.73	2057.22	295.80	0.00	0.00	0.00	0.00	0.00	3603.30	7156.45
30	Uttarakhand	8.61	0.00	27.72	0.57	0.00	0.00	0.00	0.00	0.00	3.68	40.57
31	West Bengal	6.80	0.00	67.02	687.68	5.68	0.00	252.09	5.68	0.00	673.23	1698.17
	UT-DIU & Daman	0.00	0.00	14.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14.41
	Total	25426.44	9977.10	36794.23	25009.92	1517.42	1049.42	1217.74	154.76	1401.05	30981.61	133529.69

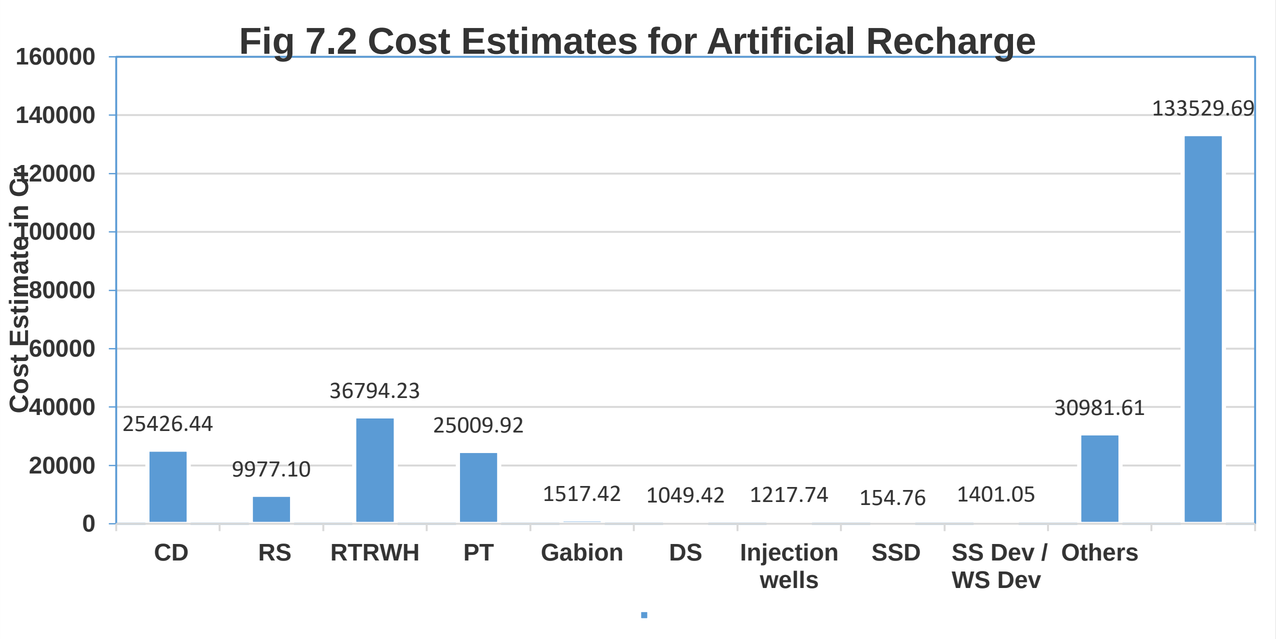


Table 7.5 Cost Estimate for Artificial Recharge in Urban & Rural Areas (Rs in Cr)					
S.No	State	Rural	Urban	Total	%
1	Andhra Pradesh	3276.67	527.39	3804.06	3%
2	Bihar	2106.44	500.00	2606.44	2%
3	Chhattisgarh	3095.12	591.70	3686.82	3%
4	Delhi	683.58	1522.50	2206.08	2%
5	Goa	279.30	146.54	425.84	0%
6	Gujarat	820.84	2641.89	3462.73	3%
7	Haryana	3457.32	913.13	4370.45	3%
8	Himachal Pradesh	1018.65	36.75	1055.40	1%
9	Jharkhand	4053.57	1304.23	5357.80	4%
10	Karnataka	7111.64	2870.02	9981.66	7%
11	Kerala	2535.64	724.18	3259.82	2%
12	Madhya Pradesh	9708.66	817.88	10526.54	8%
13	Maharashtra	13893.74	16940.31	30834.06	23%
14	NE States	6206.28	1683.49	7889.77	6%
15	Odisha	597.55	204.10	801.65	1%
16	Punjab	5119.63	1653.92	6773.55	5%
17	Rajasthan	19318.10	0.00	19318.10	14%
18	Sikkim	123.87	75.00	198.87	0%
19	Tamilnadu	2463.14	0.00	2463.14	2%
20	Telangana	2750.60	1110.20	3860.80	3%
21	UT-Andaman & Nicobar Islands	184.75	149.99	334.73	0%
22	UT-Chandigarh	875.50	0.00	875.50	1%
23	UT-DNH	34.78	36.33	71.11	0%
24	UT-Jammu & Kashmir	186.38	120.75	307.13	0%
25	UT-Ladakh	69.59	0.00	69.59	0%

Table 7.5 Cost Estimate for Artificial Recharge in Urban & Rural Areas (Rs in Cr)

S.No	State	Rural	Urban	Total	%
26	UT-Lakshadweep	0.00	57.58	57.58	0%
27	UT-Puducherry	20.89	0.00	20.89	0%
28	Uttar Pradesh	5099.23	2057.22	7156.45	5%
29	Uttarakhand	12.86	27.72	40.57	0%
30	West Bengal	1631.15	67.02	1698.17	1%
31	UT-DIU & Daman	0.00	14.41	14.41	0%
	Total	96735.45	36794.23	133529.69	
		72%	28%		

Anticipated Benefits

Groundwater System is a dynamic system with multiple inlets and outlets, all may or may not be active at a given time. The openness of the system to multiple, simultaneous recharge and discharge active points render the system more complex to define the anticipated benefits from the managed aquifer recharge. Thus, anticipated benefits include the indirect accrued benefits, in addition to rise in water level and can be grouped into following categories

1. **Water level related benefits**
   Rise in water level
   Arresting of Declining water level (rate/absolute Value)
2. **Well yield related benefits- Sustainability of Ground water structures**
   Wells provide water in lean months.
   Longer duration of pumping or increase in number of pumping days.
   Reduced pumping hours but constant command area
3. **Cropped Area related benefits**
   Increase in the area covered by water intensive crops
   More area with the same crop coverage
   In spite of having a monsoon failure, the cropped area remains the same
4. **Other Fringe Benefits**
   Green vegetation cover may increase in the zone of benefit and also along the periphery of the structures due to increase in soil moisture.
   Quality of ground water may improve due to dilution.

CHAPTER 8.0

8.0 STATE WISE ARTIFICIAL RECHARGE PLANS

8.1 ANDHRA PRADESH

Andhra Pradesh State is the 7th largest state in India covering geographical area of 1.63 Lakh Km^2 and lies between NL 12° 37' and 19° 09' and EL 76° 45' and 84° 47'. The State is bordered on the east by Bay of Bengal (~970 km), south by Tamilnadu and Karnataka, west by Karnataka and Telangana and north by Telangana, Chhattisgarh and Orissa states. The State is divided into 13 districts and 670 revenue mandals with 17398 revenue villages. Total population of the state (2011 census) is ~4.96 crores out of which 90 % lives in rural area and 10% in urban area. Andhra Pradesh is mainly drained by Godavari and Krishna Rivers and their tributaries in the northern, central parts and Pennar River drains the southern parts. There are 3 major basins and 11 medium river basins in the state. The normal annual rainfall of the state is 950 mm. The annual (2018) rainfall ranges from 391 mm in Anantapur district (deficit by 32%) to 1301 mm (excess by 12%) in Srikakulam district. Major part of the State is underlain by gneissic complex with a structural fill of sedimentary formations and basin-fill of meta-sedimentary formations.

8.1.1 Identification of Area

The area suitable for ground water augmentation through artificial recharge has been demarcated based on the analysis of average post-monsoon depth to water level data of the observation wells for the period 2009-2018 and the existing data on artificial recharge structures constructed under various schemes of Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) and Integrated Watershed Management Programs (IWMP) by Rural Development department, Govt. of Andhra Pradesh. Accordingly, an area of 83,914 sq.kms is identified which is spread over in 395 mandals in 13 districts of the State. The remaining area of 21,883 sq.kms comprises of 138 mandals have water level less than 5 m bgl and an area of 30,712 sq.kms comprises of 137 mandals have sufficient number of existing artificial recharge structures hence, no scope for taking up artificial recharge.

8.1.2 Sub Surface Storage Space:

The availability of unsaturated sub surface volume of aquifers in each district is computed as the product of area, thickness of aquifer zone between 5 m. bgl and the average post-monsoon water level. The unsaturated sub surface zone is estimated as 7,97,434 MCM. The available unsaturated volume for recharge is estimated by multiplying the unsaturated sub surface volume with specific yield of the aquifers. The available unsaturated volume for recharge is 15,948 MCM in the State. The water required to saturate the aquifer up to 5 m bgl is calculated as 21212 MCM considering 77% of the efficiency of the structures. (Table 8.1.1)

8.1.3 Source Water Availability

The source water availability is estimated from the rain fall and run off correlations. The runoff was calculated by taking into account of normal monsoon rainfall of the mandal and corresponding runoff yield from Strange Table for average catchment type. Out of the total run off available in the mandal, only 20% is considered for recommendation of artificial recharge structures considering the riparian rights and other practical considerations for recommending the artificial recharge structures. Though there is 15948 MCM unsaturated volume in the aquifer is available for recharge, only **1246.95 MCM of** surplus run off is available for recharge the aquifers. The storage required for existing 36,955 no. of artificial recharge structures (25,598 check dams and 11,397 percolation tanks) constructed by State Govt. departments under different IWMP and MNREGS schemes is deducted to arrive the balance surplus run off availability for recommending the additional feasible artificial recharge structures.

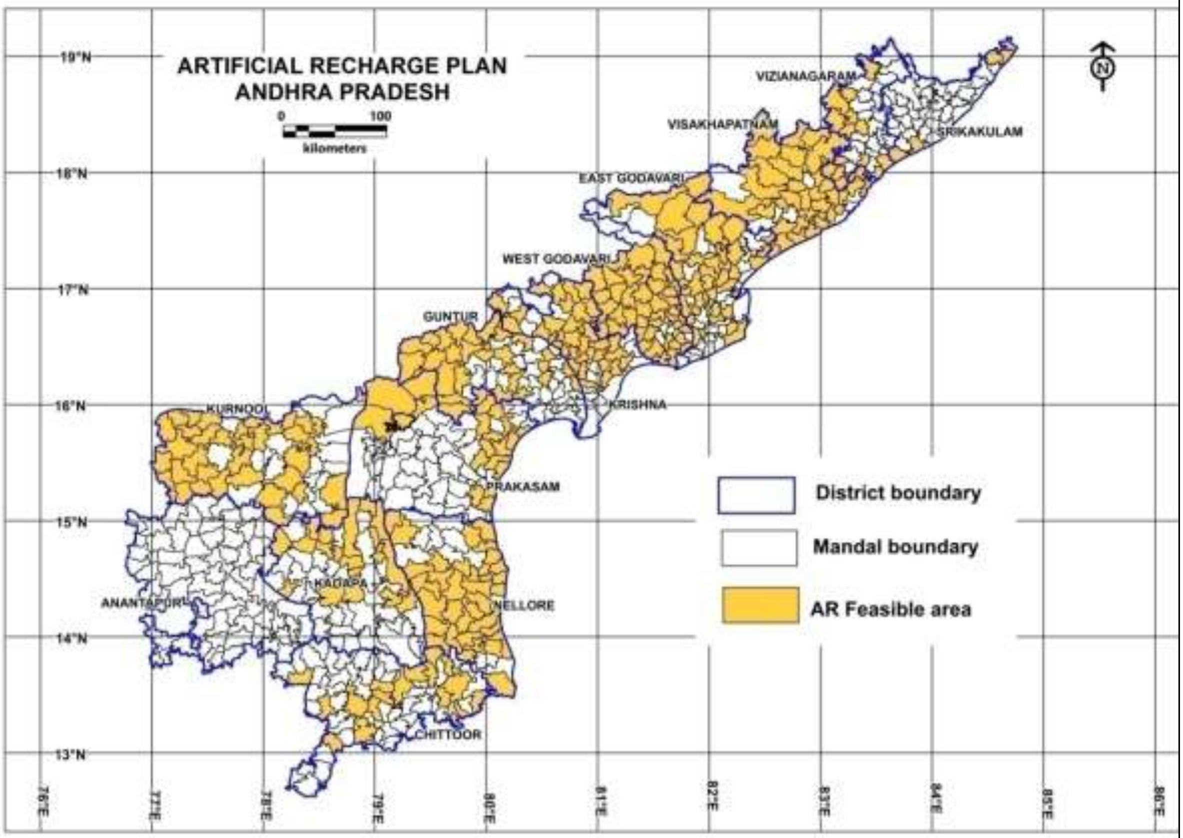


Fig-8.1.1 Area identified for Artificial Recharge

Table-8.1.1 Scope of Artificial Recharge in Andhra Pradesh

S. No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Anantapur	19130.00	17101.03	274942.43	5498.85	7313.47	102.00
2	Chittoor	15151.00	3984.57	53802.87	1076.06	1431.16	40.92
3	East Godavari	12805.18	6184.20	35839.06	716.78	953.32	203.01
4	Guntur	11391.06	5863.79	40363.93	807.28	1073.68	63.70
5	Kadapa	15350.00	4821.57	67046.56	1340.93	1783.44	45.70
6	Krishna	8727.00	5664.70	35600.19	712.00	946.96	135.79
7	Kurnool	17658.00	10064.51	62822.65	1256.45	1671.08	206.19
8	Nellore	13076.05	8623.62	42371.28	847.43	1127.08	40.23
9	Prakasam	17625.27	5161.14	60801.26	1216.03	1617.31	32.70
10	Srikakulam	5839.39	763.53	6121.77	122.44	162.84	32.53
11	Visakhapatnam	11161.00	5405.53	24183.26	483.67	643.27	169.90
12	Vizianagaram	6539.03	2592.57	8477.21	169.54	225.49	108.03
13	West Godavari	8506.68	7683.42	85061.49	1701.23	2262.64	66.25
	Total	**162959.68**	**83914.18**	**797433.95**	**15948.68**	**21211.74**	**1246.95**

8.1.4 Artificial Recharge Structures and Cost Estimate

The State is underlain mainly by hard rock aquifer system. In hard rock areas surface water spread techniques like percolation tanks and check dams are most appropriate. The number of Artificial Recharge Structures feasible has been recommended in areas, by considering the available surplus yield. The total number of Check dams and Percolation Tanks are recommended by taking 5 fillings for Check dams and 1.5 fillings for Percolation Tanks. Accordingly, a total of 26,228 number of artificial recharge structures (13085 number of percolation tanks, 13143 number of check dams) are recommended for 83914.18 sq.kms spread over in 395 mandals of 13 districts of the State. In addition to this 26,209 recharge shafts/Recharge wells are recommended to construct in the recommended Check dams and Percolation tanks for effective recharge. The unit cost of construction of Check Dam is Rs. 8 Lakhs and Percolation Tank is Rs. 13 Lakhs and Recharge Shaft is Rs. 2 Lakhs. The total outlay is estimated to be about Rs. 3276.67 Cr for the artificial recharge structures in the state (Table 8.1.2).

8.1.5 Roof Top Rain Water Harvesting in Urban Areas

As per the statistical data (2016-17) of Govt. of Andhra Pradesh, the total number of urban households is 36.53 Lakhs in 13 districts of the State. Out of total population, about 30% resides in the urban areas. The WALTA act, Govt. of Andhra Pradesh is mandated to construct roof top rain water harvesting structures for the buildings with roof area is 200 sq. m and above. The approximate cost for construction of roof top rain water harvesting has been assessed to be Rs. ~20,000/- for a 200 sq.m building. Out of 36.53 Lakhs households in the urban areas, it is assumed that 15% of households with roof area of ~200 sq.m and the total cost for the roof top rain water harvesting estimated to be Rs. **527.00 cr** for taking up **263694** RTRWH structures. It will conserve ~26 MCM of rain water considering the normal rainfall and 80% efficiency of the system, which either can be stored and recharged depending upon the hydro geological feasibility (Table-2).

In addition to this, there are 61528 no. of School buildings, 3000 hostel buildings, 4717 college buildings, 2722 hospital buildings, 12,658 no. of industries, 10376 post office buildings and 2384 telephone exchange buildings in the State, where roof top rain water harvesting can be taken up.

8.1.6 Total Cost

The total cost estimate for artificial recharge in Andhra Pradesh is Rs **3804.06 Cr** with a break up of Rs **3276.67 Cr** for rural areas & Rs **527.39 Cr** for urban areas.

Table 8.1.2 Artificial Recharge and Cost Estimate

		Number of Structures				Unit Cost of Structures				Cost of Structures				
S.No	District	CD	RTRWH	PT	Recharge Shaft	CD	RTRWH	PT	Recharge Shafts	CD	RTRWH	PT	Recharge Shaft	Total Cost (Lakh)
1	Anathapur	900	32480	600	3449	8.0	0.2	13.0	2.0	7200.00	6495.90	7800.00	6898.00	28393.90
2	Chittoor	277	32837	276	553	8.0	0.2	13.0	2.0	2216.00	6567.42	3588.00	1106.00	13477.42
3	East Godavari	1824	0	2112	1968	8.0	0.2	13.0	2.0	14592.00	0.00	27456.00	3936.00	45984.00
4	Guntur	921	13068	917	1838	8.0	0.2	13.0	2.0	7368.00	2613.69	11921.00	3676.00	25578.69
5	Kadapa	355	28957	353	708	8.0	0.2	13.0	2.0	2840.00	5791.41	4589.00	1416.00	14636.41
6	Krishna	1733	4148	1726	3459	8.0	0.2	13.0	2.0	13864.00	829.56	22438.00	6918.00	44049.56
7	Kurnool	2002	30711	1993	3995	8.0	0.2	13.0	2.0	16016.00	6142.11	25909.00	7990.00	56057.11
8	Nellore	499	5397	497	996	8.0	0.2	13.0	2.0	3992.00	1079.46	6461.00	1992.00	13524.46
9	Prakasam	300	12571	299	599	8.0	0.2	13.0	2.0	2400.00	2514.27	3887.00	1198.00	9999.27
10	Srikakulam	145	0	145	290	8.0	0.2	13.0	2.0	1160.00	0.00	1885.00	580.00	3625.00
11	Visakhapatnam	2402	103525	2391	4793	8.0	0.2	13.0	2.0	19216.00	20705.00	31083.00	9586.00	80590.00
12	Vizianagaram	795	0	791	1586	8.0	0.2	13.0	2.0	6360.00	0.00	10283.00	3172.00	19815.00
13	West Godavari	990	0	985	1975	8.0	0.2	13.0	2.0	7920.00	0.00	12805.00	3950.00	24675.00
	Total	13143	263694	13085	26209					105144.00	52418.00	52738.82	170105.00	380405.82

8.2 BIHAR

The state of Bihar, located in the eastern part of the country, is endowed with fertile soil and abundant water resources aided by a good monsoon rainfall of about 1000 mm. The state encompassing a geographical area of 94,163 sq. km. is underlain by extensive water bearing formations down to hundreds of meters depth, particularly in the northern parts and the parts adjoining the Ganga River. These alluvial deposits are represented by alternating, regionally extensive, layers of sands of various grade separated by clay layers, forming prolific aquifer system. However, due to deficit rainfalls during recent years in the state, coupled with proliferation of ground water development, specially agri-irrigation sector,resulted in to substantial decline in ground water level in the State. With this scenario at hand, Master Plan for Artificial Recharge to Ground Water in Bihar has been prepared with prime concern of revival of surface water bodies as the revitalized surface water bodies will recharge groundwater reservoir and their network will provide farmers an alternative irrigation option, free from over dependence on groundwater.

8.2.1 Identification of Areas

Identification of the area suitable for artificial recharge has been done on the basis of depth of post-monsoon water level and ground water level trend. Using GIS tools, post-monsoon (November, 2019) depth-to-water level map and long-term (2007-2017) trend of ground water level map has been superimposed over administrative boundary to identify feasible areas for recharge. For this purpose, depth-to-water level contour maps are prepared based on combined datasets of CGWB and MWRD, Govt. of Bihar. Using the prepared map, feasible areas are identified (Fig 8.2.1), subject to fulfilling the below mentioned conditions.

- Areas showing water levels between 3 and 6 m bgl and declining trend of > 10 cm /yr;
- Areas with Depth-to-Water levels between 6 and 9 m bgl and declining trend;
- Areas with Depth-to-Water levels > 9 m bgl with or without declining trend.
- Additionally, “Semi-Critical”, “Critical” or “Over Exploited” Blocks from GWRA-2017 has also been considered for artificial recharge.

8.2.2 Subsurface Storageand Water Requirement

Storage space available for recharge *i.e.* net unsaturated volume in identified areas is determined by computation of average depth of the unsaturated zone below 3 m bgl and then multiplied by area considered for recharge. Further, norm-based specific yield values, based upon nature of aquifer material, are multiplied to arrive at volume of water required for artificial recharge for each identified area. Gross volume of source water required for artificial recharge is estimated considering average recharge efficiency of 65%, as clay dominated younger alluvium is present at top of stratigraphic horizon in major parts of the State. Volume of source water required for artificial recharge purpose is calculated by multiplying a factor of 1.54 (*i.e.* reciprocal of 0.65). Sub-surface storage potential in the state, thus estimated, is 8751 MCM as in 2017. Gross volume of source water required, to fill up the space is 13476 MCM (Table 8.2.1).

8.2.3 Source Water Availability

Availability of non-committed source water for the purpose of artificial recharge to groundwater is the primary concern during the preparation of the plan, as data availability for surplus runoff is only river-basin or sub-basin wise. and cannot be directly correlated with identified feasible areas for artificial recharge. In earlier estimation, basin wise surface water availability with 75% dependability has been utilized from 2nd Bihar State Irrigation Commission Report (1994). However, the commission noted that for South Bihar, rainfall can be directly correlated with river discharge, where as for North Bihar, snow-melt component is so high in southerly flowing rivers, that rainfall component is insignificant and cannot be directly correlated with river discharge

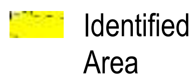


Fig 8.2.1 Area identified for Artificial Recharge

The report indicates that river basin catchments of Bihar contribute about 28.8 BCM towards surface water resource which is about 9.26% of total surface water resource of the State. Hence, in the context of the state of Bihar, considering entire non-monsoon rainfall as committed, excess monsoon rainfall can be safely harnessed to replenish groundwater table without affecting surface water resource. For the present plan, 60% of the normal monsoon rainfall for identified feasible areas is considered as available non- committed surface runoff**.** District-wise list of identified areas, computed storage volumes and non-committed source water are tabulated in Table 8.2.1.

Table 8.2.1 Scope of Artificial Recharge in Bihar

S.No	State	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Bihar	Araria	2789.37	0.00	0.00	0.00	0.00	2558.05
2	Bihar	Arwal	636.83	171.86	444.10	35.53	54.72	404.15
3	Bihar	Aurangabad	3302.84	999.55	10242.30	425.41	655.13	2396.33
4	Bihar	Banka	3019.54	1028.28	6077.80	199.14	306.67	1950.14

S.No	State	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
5	Bihar	Begusarai	1891.31	234.55	808.20	64.66	99.58	1177.03
6	Bihar	Bhabhua	3362.06	1262.09	19332.20	905.00	1393.70	2260.88
7	Bihar	Bhagalpur	2602.55	430.51	4185.70	218.63	336.69	1725.92
8	Bihar	Bhojpur	2275.30	1007.76	1360.10	108.81	167.57	1471.31
9	Bihar	Buxar	1623.82	441.42	1827.30	146.19	225.13	974.07
10	Bihar	Darbhanga	2504.29	260.70	1955.20	156.42	240.88	1651.29
11	Bihar	East Champaran	3958.87	204.96	734.30	58.75	90.48	3000.58
12	Bihar	Gaya	4985.86	2697.74	37714.80	1210.42	1864.05	3320.41
13	Bihar	Gopalganj	2019.13	1112.82	689.90	55.20	85.01	1404.56
14	Bihar	Jamui	3098.26	2021.84	21743.30	1024.74	1578.11	2007.14
15	Bihar	Jehanabad	932.57	932.57	2113.20	169.06	260.36	594.50
16	Bihar	Katihar	3009.91	1902.66	2512.20	200.98	309.51	2233.00
17	Bihar	Khagaria	1485.72	13.99	77.60	6.21	9.57	1021.70
18	Bihar	Kishanganj	1911.43	0.00	0.00	0.00	0.00	2371.34
19	Bihar	Lakhisarai	1227.74	360.20	3579.60	166.52	256.44	799.26
20	Bihar	Madhepura	1788.40	607.98	382.60	30.61	47.14	1283.77
21	Bihar	Madhubani	3486.45	0.00	49.10	0.00	0.00	2552.07
22	Bihar	Munger	1395.50	345.84	3881.80	193.02	297.26	948.28
23	Bihar	Muzaffarpur	3042.77	1086.77	2439.20	195.14	300.52	2060.67
24	Bihar	Nalanda	2349.96	1467.83	8945.10	471.56	726.20	1399.74
25	Bihar	Nawada	2486.57	1112.18	13543.00	582.05	896.36	1592.35
26	Bihar	Patna	3200.84	1010.52	3131.60	250.53	385.82	1916.98
27	Bihar	Purnia	3202.39	692.62	846.90	67.75	104.34	2583.08
28	Bihar	Rohtas	3839.26	1225.12	22739.90	1027.45	1582.27	2717.04
29	Bihar	Saharsa	1661.28	0.00	0.00	0.00	0.00	1322.79
30	Bihar	Samastipur	2612.87	881.33	3640.20	291.22	448.48	1763.20
31	Bihar	Saran	2629.57	405.56	670.10	53.61	82.56	1710.47
32	Bihar	Sheihkpura	688.09	382.30	1917.70	153.42	236.27	448.38
33	Bihar	Sheohar	442.99	0.00	0.00	0.00	0.00	360.86
34	Bihar	Sitamarhi	2185.20	168.94	305.80	24.46	37.67	1638.67
35	Bihar	Siwan	2223.07	481.47	246.50	19.72	30.38	1497.40
36	Bihar	Supaul	2410.26	0.00	0.00	0.00	0.00	1972.48
37	Bihar	Vaishali	1995.18	1007.61	2982.00	238.56	367.38	1288.11
38	Bihar	West Champaran	4344.38	0.00	0.00	0.00	0.00	3974.03
Total			**92622.43**	**25959.57**	**181119.30**	**8750.77**	**13476.25**	**66352.03**

8.2.4 Artificial Recharge and Cost Estimates

Rural Areas

Considering hydrogeological diversities among different areas of State of Bihar, a simplified and generalised norm has been adopted where design and efficiency of individual artificial recharge structure has been defined specific to the existing terrain types in the State. Terrain-wise norms adopted along with unit cost estimates for different types of structures are given in Table 8.2.2. Emphasis has been given on renovation of traditional *Ahar - Pyne*System(alluvial contour bunding), which is very common in South Bihar. These structures, if revitalized would assist immensely in water conservation as groundwater recharge in South Bihar. On the other hand in North Bihar, de-silting of *Mauns* (Ox-bow Lake) has been emphasized to restore the natural recharge areas. However, as there is no existing database on location and condition of the *Ahar - Pyne* System, further, 10 km length of existing structure has been considered per 100 sq. km. of net-cropped area, only for South Bihar districts.

Table 8.2.2 Details of Norms adopted for Artificial Recharge Structures in Bihar

Terrain Type	Recharge Structure Type	Structure ID	Recharge Percentage	Storage Capacity (MCM)	Number of Filling	Dimension	Unit Cost (in lakhs) (Approx)
Hard Rock Area	Percolation Tank	PT (H)	20%	2.0	01	100 m x 4.5 m (03 Sq. Km Catchment)	30.0
	Gully Plug	GP	20%	0.05	05	10 m x 2 m	0.40
	Contour Bunding& Trenching	CB &T (H)	40%	0.05	05	300 – 400 m	2
	Check Dam	CD	30%	0.20	02	15 m x 3 m	20.0
Marginal Alluvial Area	NalaBunding	NB	20%	0.05	05	15 m x 2 m	1.0
	Contour Bunding& Trenching	CB &T (H	)20%	0.05	05	300 – 400 m	2.0
	Recharge Shaft	RS	25%	0.05	01	5 m x 5 m x 10 m / 60 days Op. period	5.0
	Percolation Tank	PT (M)	35%	2.50	01	100 m x 4.5 m (04 Sq. Km Catchment)	30.0
Alluvial Area	De-silting of existing tank /pond /talao	DS-Tank	50%	0.20	02	100 m x 80 m x 6 m	5.0
	De-silting of Mauns (Ox-bow lake)	DS-Mauns	<1%	6.00	01	10 – 500 ha /100 ha	100.0 /100 ha
	Injection Well in Village Tank	Inj. Wells	10%	0.03	02	100 m x 100 m x 3 m Tank with 40 m Boring	4.0
	Renovation of traditional Ahar-Pyne System	Revival of Ahar-Pyne	40%	0.10	01	As per Existing Structure / Km	20.0 / Km
Urban Areas	Roof-top Rain Water Harvesting Structures	RTRWH	80%	0.00009	01	100 m^2 (Roof) with 40 m Boring	1.0
	De-silting and revival of existing ponds	Revival of UWB	20%	0.006	02	50 m x 20 m x 6 m	10.0

The proposed plan envisages utilization of 13476 MCM of source water for recharge purpose through different structures. On the basis of the norm, number of structures has been worked out based on gross storage capacity of individual structure. District-wise numbers of various types of artificial recharge structures and cost Estimate in Bihar are given in Table – 8.2.3. As per estimate, 163 Percolation Tank, 2608 each of Gully Plug & Contour Bunding - Trenching, and 122 Check Dam may be constructed in hilly areas of Bihar. In adjoining marginal alluvial areas, 357 NalaBunding, 2842 Contour Bunding& Trenching, 5682 Recharge Shaft and 265 Percolation Tank may be created to enhance groundwater recharge. On the other hand, in vast alluvial tract of Bihar, augmentation of groundwater resource may be achieved through renovation of natural and man-made surface water structures. It is proposed that, De-silting of existing 10658 village tanks /ponds /talaos, De-silting of 44 Sq. km of *mauns* (Ox-bow lake), Injection Well creation in 13811 Village Tanks, and Renovation of 2045 km of traditional *ahar-pyne* System may result in expected rise in water table. However, actual numbers of structures implementable may vary significantly based on scale of implementation.District-wise and type-wise cost estimates are given in Table – 8.2.3. Total cost of work has been estimated to be Rs. 2606.44 crore.

Table 8.2.3 Artificial recharge and Cost Estimates in Bihar

Number of Structures

S. No	District	PT (H)	GP	CB &T (H)	CD	NB	CB &T (M)	RS	PT (M)	DS-Tank	DS-Mauns	Inj. Wells	Revival of Ahar-Payne	RTRWH	Revival of UWB
1	Araria	0	0	0	0	0	0	0	0	0	0	0	0	500	5
2	Arwal	0	0	0	0	1	9	17	1	31	0	41	42	300	2
3	Aurangabad	8	131	131	6	21	165	330	15	602	0	802	188	1500	6
4	Banka	8	121	121	6	7	59	118	6	216	0	288	118	300	3
5	Begusarai	0	0	0	0	2	16	31	1	57	0	75	0	4000	14
6	Bhabhua	29	471	471	22	37	293	586	27	1069	0	1425	156	200	1
7	Bhagalpur	4	62	62	3	5	43	86	4	157	0	210	126	1500	7
8	Bhojpur	0	0	0	0	3	26	52	2	95	0	127	185	2000	8
9	Buxar	0	0	0	0	4	35	70	3	128	0	171	138	500	2
10	Darbhanga	0	0	0	0	5	38	75	4	137	0	182	0	1500	7
11	East Champaran	0	0	0	0	2	14	28	1	51	20	69	0	3500	12
12	Gaya	37	592	592	28	101	807	1613	76	2941	0	3921	169	2500	9
13	Gopalganj	0	0	0	0	2	13	26	1	48	0	64	0	1000	5
14	Jamui	16	264	264	12	26	206	413	19	752	0	1003	44	400	5
15	Jehanabad	0	0	0	0	5	41	81	4	148	0	197	55	800	4
16	Katihar	0	0	0	0	6	48	96	5	176	9	234	0	2000	7
17	Khagaria	0	0	0	0	0	1	3	0	5	0	7	0	200	1
18	Kishanganj	0	0	0	0	0	0	0	0	0	0	0	0	1000	7
19	Lakhisarai	3	44	44	2	4	33	67	3	122	0	162	73	1000	5
20	Madhepura	0	0	0	0	1	7	15	1	27	0	36	0	800	4
21	Madhubani	0	0	0	0	0	1	2	0	3	0	5	0	700	3
22	Munger	3	43	43	2	5	40	80	4	145	0	194	45	1000	4
23	Muzaffarpur	0	0	0	0	6	47	94	4	171	6	228	0	1500	7
24	Nalanda	6	90	90	4	12	100	199	9	363	0	484	152	2500	11
25	Nawada	13	212	212	10	27	216	432	20	787	0	1049	107	1000	5
26	Patna	0	0	0	0	8	60	120	6	219	0	292	157	8000	27
27	Purnia	0	0	0	0	2	16	33	2	59	0	79	0	2000	13

Cost of Structures (Lakh)

S. No	District	PT (H)	GP	CB &T (H)	CD	NB	CB &T (M)	RS	PT (M)	DS-Tank	DS-Mauns	Inj. Wells	Revival of Ahar-Payne	RTRWH	Revival of UWB	Total Cost (Lakh)
1	Araria	0	0	0	0	0	0	0	0	0	0	0	0	500	50	550.0
2	Arwal	0	0	0	0	1	18	85	30	155	0	164	840	300	20	1613.0
3	Aurangabad	240	52.4	262	120	21	330	1650	450	3010	0	3208	3760	1500	60	14663.4
4	Banka	240	48.4	242	120	7	118	590	180	1080	0	1152	2360	300	30	6467.4
5	Begusarai	0	0	0	0	2	32	155	30	285	0	300	0	4000	140	4944.0
6	Bhabhua	870	188.4	942	440	37	586	2930	810	5345	0	5700	3120	200	10	21178.4
7	Bhagalpur	120	24.8	124	60	5	86	430	120	785	0	840	2520	1500	70	6684.8
8	Bhojpur	0	0	0	0	3	52	260	60	475	0	508	3700	2000	80	7138.0
9	Buxar	0	0	0	0	4	70	350	90	640	0	684	2760	500	20	5118.0
10	Darbhanga	0	0	0	0	5	76	375	120	685	0	728	0	1500	70	3559.0
11	East Champaran	0	0	0	0	2	28	140	30	255	2000	276	0	3500	120	6351.0
12	Gaya	1110	236.8	1184	560	101	1614	8065	2280	14705	0	15684	3380	2500	90	51509.8
13	Gopalganj	0	0	0	0	2	26	130	30	240	0	256	0	1000	50	1734.0
14	Jamui	480	105.6	528	240	26	412	2065	570	3760	0	4012	880	400	50	13528.6
15	Jehanabad	0	0	0	0	5	82	405	120	740	0	788	1100	800	40	4080.0
16	Katihar	0	0	0	0	6	96	480	150	880	900	936	0	2000	70	5518.0
17	Khagaria	0	0	0	0	0	2	15	0	25	0	28	0	200	10	280.0
18	Kishanganj	0	0	0	0	0	0	0	0	0	0	0	0	1000	70	1070.0
19	Lakhisarai	90	17.6	88	40	4	66	335	90	610	0	648	1460	1000	50	4498.6
20	Madhepura	0	0	0	0	1	14	75	30	135	0	144	0	800	40	1239.0
21	Madhubani	0	0	0	0	0	2	10	0	15	0	20	0	700	30	777.0
22	Munger	90	17.2	86	40	5	80	400	120	725	0	776	900	1000	40	4279.2
23	Muzaffarpur	0	0	0	0	6	94	470	120	855	600	912	0	1500	70	4627.0
24	Nalanda	180	36	180	80	12	200	995	270	1815	0	1936	3040	2500	110	11354.0
25	Nawada	390	84.8	424	200	27	432	2160	600	3935	0	4196	2140	1000	50	15638.8
26	Patna	0	0	0	0	8	120	600	180	1095	0	1168	3140	8000	270	14581.0
27	Purnia	0	0	0	0	2	32	165	60	295	0	316	0	2000	130	3000.0

S. No	District	Number of Structures														Cost of Structures (Lakh)														
		PT (H)	GP	CB &T (H)	CD	NB	CB &T (M)	RS	PT (M)	DS-Tank	DS-Mauns	Inj. Wells	Revival of Ahar-Payne	RTRWH	Revival of UWB	PT (H)	GP	CB &T (H)	CD	NB	CB &T (M)	RS	PT (M)	DS-Tank	DS-Mauns	Inj. Wells	Revival of Ahar-Payne	RTRWH	Revival of UWB	Total Cost (Lakh)
28	Rohtas	36	578	578	27	40	320	639	30	1166	0	1554	249	1000	9	1080	231.2	1156	540	40	640	3195	900	5830	0	6216	4980	1000	90	25898.2
29	Saharsa	0	0	0	0	0	0	0	0	0	0	0	0	500	2	0	0	0	0	0	0	0	0	0	0	0	0	500	20	520.0
30	Samastipur	0	0	0	0	9	70	140	7	255	9	340	0	200	1	0	0	0	0	9	140	700	210	1275	900	1360	0	200	10	4804.0
31	Saran	0	0	0	0	2	13	26	1	47	0	63	0	1000	7	0	0	0	0	2	26	130	30	235	0	252	0	1000	70	1745.0
32	Sheihkpura	0	0	0	0	5	37	74	3	134	0	179	41	800	4	0	0	0	0	5	74	370	90	670	0	716	820	800	40	3585.0
33	Sheohar	0	0	0	0	0	0	0	0	0	0	0	0	100	1	0	0	0	0	0	0	0	0	0	0	0	0	100	10	110.0
34	Sitamarhi	0	0	0	0	1	6	12	1	21	0	29	0	800	4	0	0	0	0	1	12	60	30	105	0	116	0	800	40	1164.0
35	Siwan	0	0	0	0	1	5	9	0	17	0	23	0	500	3	0	0	0	0	1	10	45	0	85	0	92	0	500	30	763.0
36	Supaul	0	0	0	0	0	0	0	0	0	0	0	0	700	4	0	0	0	0	0	0	0	0	0	0	0	0	700	40	740.0
37	Vaishali	0	0	0	0	7	57	115	5	209	0	278	0	1000	4	0	0	0	0	7	114	575	150	1045	0	1112	0	1000	40	4043.0
38	West Champaran	0	0	0	0	0	0	0	0	0	0	0	0	1200	9	0	0	0	0	0	0	0	0	0	0	0	0	1200	90	1290.0
	Total	163	2608	2608	122	357	2842	5682	265	10358	44	13811	2045	50000	232	4890	1043.2	5216	2440	357	5684	28410	7950	51790	4400	55244	40900	50000	2320	260644.2

Urban Areas

In urban areas, two aspects are considered, viz., revival of urban water bodies and roof top rainwater harvesting.

Revival of Urban Water Bodies

As per Census (2011), Bihar has 2325 Sq. km of urban area with a population density of 5058 persons per sq. km with anurbanization rate of 11.3 %. Though urbanization is in low key, population growth in existing urban areas is exceeding its holding capacity leading to encroachment of municipal / government owned water bodies and change in land characterization in privately owned water bodies. Based on considerationthat at least one surface water body exists in 10 sq. km urban area, district-wise number of existing surface water bodies in urban parts of Bihar has been worked out along with cost estimate. Total cost for the works will involve revival of 232 existing surface water bodies with an estimated cost of Rs. 23.2 cr (Table 8.2.3).

Roof-Top Rain Water Harvesting

As per Census (2011), Bihar has about 40,000 Govt. buildings, institutions, schools, hospitals, shopping complexes, warehouses *etc.* in urban and municipal areas of the state. At present, the number may be assumed at 70000. These, buildings may be adopted for implementation of first phase roof-top rainwater harvesting, as on an average these buildings should have large roof area. On the other hand, as per Census (2011), Bihar has 1,77,44,046 residential houses in both urban and rural setup. Considering 50% of urban houses and 10% of rural houses qualify for roof-top rainwater harvesting, there are about twenty lakh (20 lakh) such houses in the state. Considering average monsoon rainfall of 1000 mm for the state and 80% efficiency of the system with about 100 m^2 of roof-area, the state has potential to augment 216 MCM of rain water to groundwater resources through roof-top rainwater harvesting. First phase implementation of roof-top rainwater harvesting has a potential to recharge 31.5 MCM of rain water to groundwater resources. Total cost for the first phase work has been estimated to be Rs. 500 crore (Table 8.2.3)

8.2.5 Total Cost

Prepared AR master plan identifies water scarce areas and proposes terrain specific structure to create additional surface water bodies as well as for augmentation of groundwater. The total cost estimate for artificial recharge in Bihar is Rs 2606.44 Cr with a break up of Rs 2106.44 Cr for rural areas & Rs 500.00 Cr for urban areas.

8.3 CHHATTISGARH

Chhattisgarh State has been formed after bifurcation of Madhya Pradesh on 1st November, 2000, covering an area of 1,35,600 sq km. The population of the state is 25.54 million (Census 2011) with density of population as 189 per sq km. The average annual rainfall of the state is 1,356 mm. The state has 3 administrative divisions, 27 districts and 146 development blocks. There are 19,567 populated villages and 114 cities in the state. About 63140.00 sq km area of the state is covered by forest. The agricultural land and irrigated land in the state is 59030.00 sq km and 15020.00 sq km respectively (Directorate of Economics & Statistics, Chhattisgarh, 2017-18). The state comprises of Mahanadi and Godavari basins with small parts of Ganga, Narmada and Swarnarekha basins. These basins can be subdivided into 74 major watersheds, 8 watersheds of Son and Narmada falling partly in the adjoining Madhya Pradesh state.

8.3.1 Identification of the Area

Depth to water level recorded during post-monsoon (November 2018) period and decadal post monsoon water level trend (November 2009 to 2018) have been considered to identify the areas for recharge, as the natural recharge is not enough to compensate the ground water withdrawal. The data of monitoring stations of both CGWB & State Groundwater department have been used in the exercise. A total area of 25667.94sq.km. shows declining trend in ground water levels. 123 watersheds have been identified in Chhattisgarh in which declining trend of more than 0.1 m/yr has been recorded (**Fig 8.3.1).** These watersheds have been identified for construction of suitable artificial recharge structures for augmenting the available ground water resources.

8.3.2 Sub-Surface Storage Space and Water Requirement

To estimate the available sub surface storage space, a map has been prepared on the basis of post monsoon depth to water level of November 2018. The post monsoon average depth to water level is predominantly in the range of 3 to 6 m below ground level. Based on this map, the volume of unsaturated zone available for recharge (up to 3 m below ground level) has been calculated for each of the block. A total 58237.38 MCM volume of unsaturated zone has been estimated for the Chhattisgarh state. The requirement of water to fully saturate the vadose zone up to 3 m below ground level has been worked out for each watershed at 75% efficiency considered for recharge structures. The total requirement of water for saturating the sub-surface storage works out to be 1370.05 MCM for the entire state (**Table-8.3.1)**.

Table 8.3.1 Scope of Artificial Recharge in Chhattisgarh

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Balod	2808.74	1112.67	3364.41	77.64	103.26	284.63
2	Baloda Bazar	4994.40	1096.09	1994.52	31.54	41.95	341.13
3	Balrampur	7139.20	676.51	1316.61	17.67	23.50	218.97
4	Bastar	6129.98	1121.42	1682.12	23.80	31.66	507.65
5	Bemetara	2854.81	2190.46	10214.85	212.02	281.98	560.34
6	Bijapur	6612.48	810.84	1216.26	21.00	27.93	276.04
7	Bilaspur	5815.87	1897.64	4549.48	73.15	97.29	585.27
8	Dantewada	3410.50	77.80	116.70	1.08	1.43	26.22
9	Dhamtari	4081.93	996.69	3269.16	58.15	77.33	326.21
10	Durg	2319.99	1107.44	2386.16	41.15	54.73	283.29

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
11	Gariaband	5822.66	448.39	734.67	12.49	16.61	158.98
12	Janjgir-Champa	4229.46	207.55	311.32	4.42	5.88	64.44
13	Jashpur	6457.41	963.92	1760.06	18.98	25.25	377.50
14	Kanker	6434.48	148.89	223.33	4.10	5.45	54.34
15	Kawardha	4447.05	545.01	1924.04	42.37	56.35	136.36
16	Kondagaon	3860.27	909.76	1364.63	26.00	34.59	323.36
17	Korba	7145.44	846.84	1587.13	19.96	26.55	275.16
18	Koriya	5977.70	1081.91	1786.02	31.20	41.49	358.22
19	Mahasamund	4963.00	1517.26	2912.00	55.93	74.39	532.72
20	Mungeli	2750.36	942.30	1928.03	23.96	31.86	285.16
21	Narayanpur	6913.16	0.00	0.00	0.00	0.00	0.00
22	Raigarh	6836.35	2146.83	3673.68	51.32	68.26	982.92
23	Raipur	2891.98	1546.39	2656.03	55.40	73.68	469.15
24	Rajnandgaon	6680.17	1000.84	2357.91	37.35	49.67	250.99
25	Sukma	5635.79	671.50	1007.25	12.72	16.92	386.54
26	Surajpur	2787.20	1326.70	3018.42	62.17	82.69	451.03
27	Surguja	5191.15	276.29	882.59	14.55	19.35	93.01
	Total	135191.53	25667.94	58237.38	1030.12	1370.05	8609.63

8.3.3 Source Water Availability

The availability of surplus monsoon runoff has been estimated for 123 identified watersheds mainly on the basis of NWDA data and State Irrigation Department. The total availability of source water for recharge works out to be 8609.63 MCM, which far exceeds the total requirement to create the sub-surface storage. However, for each watershed the requirement vis-a-vis the availability (surplus run off) has been taken care and the least of the two has been considered as available source water for harnessing in artificial recharge structures. The total quantum of source water which can be utilized for creation of sub-surface storage works out to be 1370.05 MCM for all the 123 identified watersheds**.**

8.3.4 Recharge Structures and Cost Estimates

The suitable artificial recharge structures in the state are gully plugs, gabion structures, contour bunds in the upper reaches of the watersheds, percolation tanks, nala bunds in the runoff zones and recharge shafts, gravity head wells in downstream areas. The main artificial recharge structures proposed are given below along with the estimated number of feasible structures and their cost.

Percolation Tanks

Percolation tank is the main artificial recharge structure proposed for effective utilization of the surplus monsoon runoff. In hard rock areas only 50% of the total estimated surplus surface water resources have been considered for storage in the percolation tanks. As per the hydrogeological conditions in Chhattisgarh, an average percolation tank has filling capacity of 0.10 MCM. It can actually store 200% of its capacity due to multiple filling during the monsoon.

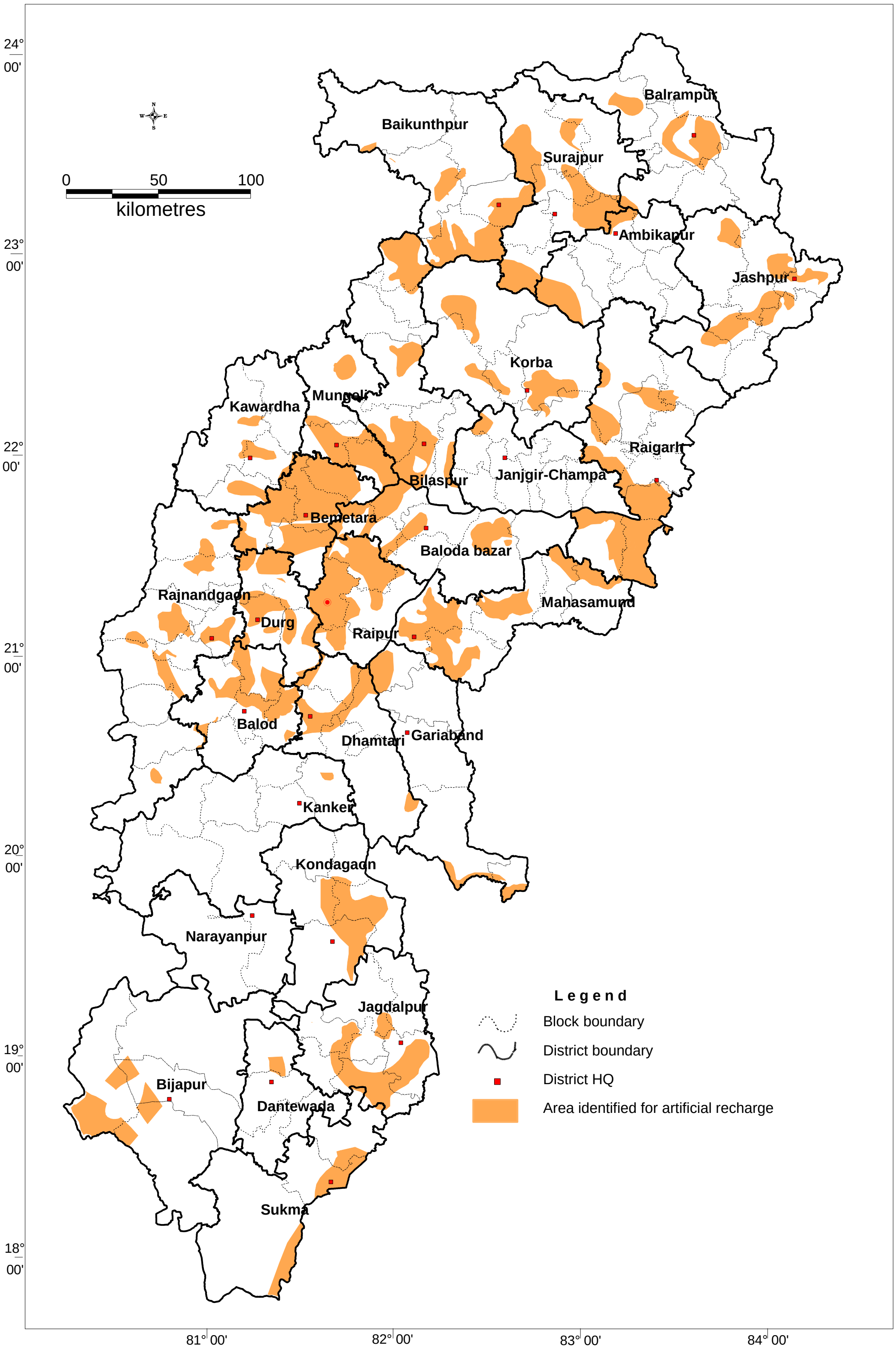


Fig 8.3.1 Area identified for artificial recharge

Thus an average gross storage capacity of 0.20 MCM has been considered. The average cost of such structure has been considered as Rs.40 lakh. The number of feasible percolation tank in each identified watershed has been calculated and presented in Table-8.3.2 The total percolation tanks feasible in Chhattisgarh are 3426 costing Rs. 1370.4 crore.

Nala Bunds

There is a large scope for constructing Nala bunds/Cement plugs in various second and third order streams of the state. About 25% of surplus monsoon runoff can be utilized by recharge through these structures. The average capacity of Nala bunds/Cement plugs has been considered as 0.03 MCM. The average cost of each structure has been taken as Rs.3 lakh. It is estimated that 11417 Nala bund/Cement plugs can be constructed in the state at the cost of 342.5 crore (Table-8.3.2).

Recharge Shafts & Gravity Head Recharge Wells

These structures are feasible in villages and urban pockets. About 15% of the surplus monsoon runoff can be utilized through these structures. The average recharge capacity through recharges shafts, gravity head recharge through dug wells during an operational period of 60 days in monsoon and post monsoon period is considered as 0.008 MCM. The average cost of structure may be taken as Rs.5.0 Lacs. The number of structures and their cost for each identified watershed is calculated and presented in Table 8.3.2. For the entire State the feasible structures are 25687 costing Rs.1284.4 crore.

Gully Plugs, Contour Bunds, Gabion Structures

These are mainly soil conserving structures help to increase the soil moisture with limited recharge to ground water. It is estimated that 10% of total water available for recharge can be utilized through these structures, which have an average storage capacity of 0.007 MCM. The average cost of each structure is taken as Rs 50, 000/. The structures feasible in each identified watershed has been estimated and presented in Table 8.3.2. For the entire State feasible structures total up to 19572 costing Rs 97.9 crore.

8.3.5 Roof Top Rain Water Harvesting

There are 114 urban areas in Chhattisgarh, with total number of houses around 11,83,390. Due to scarcity of water, individual houses in most of the urban areas have gone for construction of bore wells/ dug wells in unplanned way, resulting in lowering of water levels and dwindling of yield/drying up of wells. The availability of rooftop in urban areas is an attractive solution for the collection of rainwater during monsoons and recharging to the ground water reservoir. An attempt has been made to study the feasibility of roof top rainwater harvesting in urban areas of the State. Considering the varied hydrogeological and other situations of space availability, even if 10% of the houses with an average roof area of 50 sq. meter are considered, a total roof area of 5.91 sq. km is available to collect the rainfall. Considering the average annual normal rainfall in each urban area, the total volume of rainwater, which can be collected on roofs, has been worked out, only 85 % of this volume of rainwater has been considered as available source water for recharging ground water. The total available water from roof top rainwater harvesting worked out to 6.812 MCM. The average expenditure on providing the necessary arrangements through the fittings, filter etc to divert the roof water to the existing ground water structure (tube well/dug well) has been considered as Rs.50,000/- per house. The total cost for roof top rainwater harvesting in 1,18,339 houses of the 114 cities of Chhattisgarh declared as standard urban areas is worked out to be Rs.591.69 crore.

8.3.6 Total Cost Estimates

The estimated cost for artificial Recharge and rainwater harvesting works out to Be 3686.82 Cr, out of which cost for artificial recharge in Rural areas works out to be 3095.12 Cr and in urban areas is of the order of Rs 591.69 Cr.

Table 8.3.2 Artificial Recharge Structures & Cost Estimates

S.No	District	Number of Structures					Unit Cost of Structures(in Lakhs)					Cost of Structures (in Lakhs)					
		RS/GHRW	PT	GP/CB/ GS	NB/CP/ KT Bhandara	RTRWH	RS/GHRW	PT	GP/CB/ GS	NB/CP/ KT Bhandara	RTRWH	RS/GHRW	PT	GP/CB/ GS	NB/CP/ KT Bhandara	RTRWH	Total Cost (Lakh)
1	BALOD	1936	258	1475	860	2468	5.0	40.0	0.5	3.0	0.5	9680.00	10320.00	737.50	2580.00	1234.00	24551.50
2	BALODA BAZAR	786	105	599	350	3422	5.0	40.0	0.5	3.0	0.5	3930.00	4200.00	299.50	1050.00	1711.00	11190.50
3	BALRAMPUR	441	59	336	196	472	5.0	40.0	0.5	3.0	0.5	2205.00	2360.00	168.00	588.00	236.00	5557.00
4	BASTAR	594	79	452	264	3040	5.0	40.0	0.5	3.0	0.5	2970.00	3160.00	226.00	792.00	1520.00	8668.00
5	BEMETARA	5287	705	4028	2350	1380	5.0	40.0	0.5	3.0	0.5	26435.00	28200.00	2014.00	7050.00	690.00	64389.00
6	BIJAPUR	524	70	399	233	647	5.0	40.0	0.5	3.0	0.5	2620.00	2800.00	199.50	699.00	323.50	6642.00
7	BILASPUR	1824	243	1390	811	3414	5.0	40.0	0.5	3.0	0.5	9120.00	9720.00	695.00	2433.00	1707.00	23675.00
8	DANTEWADA	27	4	20	12	1640	5.0	40.0	0.5	3.0	0.5	135.00	160.00	10.00	36.00	820.00	1161.00
9	DHAMTARI	1450	193	1105	644	3250	5.0	40.0	0.5	3.0	0.5	7250.00	7720.00	552.50	1932.00	1625.00	19079.50
10	DURG	1026	137	782	456	23739	5.0	40.0	0.5	3.0	0.5	5130.00	5480.00	391.00	1368.00	11869.50	24238.50
11	GARIABAND	311	42	237	138	913	5.0	40.0	0.5	3.0	0.5	1555.00	1680.00	118.50	414.00	456.50	4224.00
12	JANJGIR-CHAMPA	110	15	84	49	4442	5.0	40.0	0.5	3.0	0.5	550.00	600.00	42.00	147.00	2221.00	3560.00
13	JASHPUR	473	63	361	210	1654	5.0	40.0	0.5	3.0	0.5	2365.00	2520.00	180.50	630.00	827.00	6522.50
14	KANKER	102	14	78	45	4038	5.0	40.0	0.5	3.0	0.5	510.00	560.00	39.00	135.00	2019.00	3263.00
15	KAWARDHA	1057	141	805	470	1915	5.0	40.0	0.5	3.0	0.5	5285.00	5640.00	402.50	1410.00	957.50	13695.00
16	KONDAGAON	648	86	494	288	1288	5.0	40.0	0.5	3.0	0.5	3240.00	3440.00	247.00	864.00	644.00	8435.00
17	KORBA	498	66	379	221	9986	5.0	40.0	0.5	3.0	0.5	2490.00	2640.00	189.50	663.00	4993.00	10975.50
18	KORIYA	778	104	593	346	4508	5.0	40.0	0.5	3.0	0.5	3890.00	4160.00	296.50	1038.00	2254.00	11638.50
19	MAHASAMUND	1395	186	1063	620	2703	5.0	40.0	0.5	3.0	0.5	6975.00	7440.00	531.50	1860.00	1351.50	18158.00
20	MUNGELI	597	80	455	266	1360	5.0	40.0	0.5	3.0	0.5	2985.00	3200.00	227.50	798.00	680.00	7890.50
21	NARAYANPUR	0	0	0	0	491	5.0	40.0	0.5	3.0	0.5	0.00	0.00	0.00	0.00	245.50	245.50
22	RAIGARH	1280	171	975	569	5516	5.0	40.0	0.5	3.0	0.5	6400.00	6840.00	487.50	1707.00	2758.00	18192.50
23	RAIPUR	1382	184	1053	614	27227	5.0	40.0	0.5	3.0	0.5	6910.00	7360.00	526.50	1842.00	13613.50	30252.00
24	RAJNANDGAON	931	124	710	414	5913	5.0	40.0	0.5	3.0	0.5	4655.00	4960.00	355.00	1242.00	2956.50	14168.50
25	SUKMA	317	42	242	141	618	5.0	40.0	0.5	3.0	0.5	1585.00	1680.00	121.00	423.00	309.00	4118.00
26	SURAJPUR	1550	207	1181	689	1746	5.0	40.0	0.5	3.0	0.5	7750.00	8280.00	590.50	2067.00	873.00	19560.50
27	SURGUJA	363	48	276	161	549	5.0	40.0	0.5	3.0	0.5	1815.00	1920.00	138.00	483.00	274.50	4630.50
	Total	25687	3426	19572	11417	118339						128435	137040	9786	34251	59169.5	368681.5

RS/GHRW- Recharge Shafts & Gravity Head Recharge Wells

8.4 DELHI (NATIONAL CAPITAL TERRITORY)

National Capital Territory of Delhi occupies an area of 1483 Sq.km. and lies between 28° 24'15'' & 28° 53'00''N latitudes and 76° 50'24" & 77°20' 30" E longitudes. Area is covered under Survey of India Toposheet Nos. 53D and 53H. For administrative purposes, NCT Delhi is divided into 11 districts and 33 Tehsils/Sub-divisions. The ground water availability in the territory is controlled by the hydrogeological conditions characterized by occurrence of different geological formations, viz., Quartzite (Delhi Ridge) covering an area of 145 sq. km and Older/Younger Alluvium covering an area of 1338 sq. km. The river Yamuna is the main drainage flowing North-South direction and forms about 97 sq. km flood plain area. The normal annual rainfall of NCT Delhi 611.8 mm out of which 540 mm receives during monsoon period. 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. 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.

8.4.1 Identification of Area

The area characterized by post monsoon water level (2018) >5m bgl and declining trend of water level have been identified for artificial recharge and is of the order of 824.5 sq.km and shown in Fig 8.4.1

Fig 8.4.1 Area identified for Artificial Recharge in NCT of Delhi

8.4.2 Sub-Surface Storage Space and Water Requirement

The volume of unsaturated sub surface zone beneath 5m bgl is given by the product of area and thickness. It is of the order of 12479.01 MCM in NCT Delhi. The volume available for artificial recharge is given by the product of volume of unsaturated zone and specific yield and is estimated as 982.48 MCM. An efficiency of 75% is observed for the artificial recharge structures and hence the water required to saturate the aquifer up to 5m bgl is of the order of 982.49 MCM. (Table 8.4.1)

Table 8.4.1Scope of Artificial Recharge in NCT of Delhi

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Central	79.00	23.00	69.00	5.66	7.53	4.32
2	East	32.44	22.00	169.18	13.87	18.45	2.58
3	New Delhi	160.53	113.00	2232.88	189.79	252.43	12.81
4	North	293.12	143.00	209.78	17.83	23.72	20.22
5	North East	38.00	8.50	3.91	0.33	0.44	1.45
6	North West	155.07	28.00	0.00	0.00	0.00	0.00
7	Shahdara	36.92	16.00	90.40	7.68	10.22	2.92
8	South	163.27	147.00	5664.35	283.22	376.68	13.05
9	South East	81.09	55.00	708.95	35.45	47.15	6.41
10	South West	285.72	226.00	2905.46	319.60	425.07	21.59
11	West	134.60	43.00	425.10	109.05	145.04	9.27
12	Nazul Land	26.56	0.00	0.00	0.00	0.00	0.00
Total		**1486.32**	**824.50**	**12479.01**	**982.48**	**1306.73**	**94.62**

8.4.3 Source Water Availability

The average annual rain fall of the state is 611.8 mm, of which 533.1 mm occurs during monsoon period (June to September). Delhi mostly being Urban area, the area feasible for artificial recharge is only 843 Sq Km out of which 190Sq km of roof area, 81Sq Km of paved area and the balance 572 Sq Km is open area . Considering 80 % runoff coefficient for roofed area, 60% for paved area and 30% for open, the runoff availability for Delhi state is assessed as 175 MCM. The surplus monsoon runoff available from Yamuna is 282 MCM. Thus a total of 457 MCM surplus runoff is available for recharge to ground water. As the recharge areas are at higher elevations, the surplus water of Yamuna river cannot be diverted under gravity to these areas. However, the water can be transported to Chhatarpur Basin characterized by deeper water level and can be recharged through percolation ponds or recharge wells. Presently considering only the available surface runoff amounting to 175 MCM, the committed supply is of 52 MCM and only the balance of 123 MCM is available for recharge. In the present circumstances only 20% of the uncommitted surplus run off amounting to 24MCM can be utilized for artificial recharge to ground water as the most the area is urban and entire rainwater cannot be a harvested due to outflow into sewers and other losses.

8.4.4 Recharge Structures and Cost Estimates

Based on the available scientific data generated by Central Ground Water Board over the years and based on the scope of artificial recharge, three types of structures are considered, viz., Recharge Trench with or without recharge shaft, RTRWH in urban area and check dams in ridge area.

In parks and gardens, recharge trenches and recharge shafts are proposed to be constructed. Roof top rain water harvesting structures are proposed in areas where feasible. Congested areas like Chandni Chowk, Shahdara, SeelamPur, Seema Puri, part of Darya Ganj etc., where plot sizes are very small and/ or open land is not available for construction of recharge facility have been excluded. Area falling under Yamuna flood plain has also been excluded as the water level is very shallow and it is proposed that excess flood water may be transported to Chhatarpur Basin, where water level is deeper and can also accommodate the recharged water. Check dams have been proposed to be constructed in hilly areas. A total of 22706 recharge trenches with recharge shafts, 304500 roof top rain water harvesting structures and 12 check dams are proposed to be constructed. The details of artificial recharge and its cost estimate is given as Table 8.4.2.

Table 8.4.2 Artificial Recharge in NCT of Delhi

District	No of Structures			Unit Cost of Structures (Lakh)			Cost of Structures (Lakh)			Total Cost (Lakh)
	CD	RS & RT	RTRWH	CD	RS & RT	RTRWH	CD	RS & RT	RTRWH	
Central	1	884	2627	20.00	3.00	0.50	20.00	2652.00	1313.50	3985.50
East	0	281	23461	20.00	3.00	0.50	0.00	843.00	11730.50	12573.50
New Delhi	6	6684	59878	20.00	3.00	0.50	120.00	20052.00	29939.00	50111.00
North	0	456	7000	20.00	3.00	0.50	0.00	1368.00	3500.00	4868.00
North East	0	113	0	20.00	3.00	0.50	0.00	339.00	0.00	339.00
North West	0	0	0	20.00	3.00	0.50	0.00	0.00	0.00	0.00
Shahdara	0	363	20906	20.00	3.00	0.50	0.00	1089.00	10453.00	11542.00
South	5	5700	37734	20.00	3.00	0.50	100.00	17100.00	18867.00	36067.00
South East	0	420	0	20.00	3.00	0.50	0.00	1260.00	0.00	1260.00
South West	0	6721	72816	20.00	3.00	0.50	0.00	20163.00	36408.00	56571.00
West	0	1084	80078	20.00	3.00	0.50	0.00	3252.00	40039.00	43291.00
Nazul Land	0	0	0	20.00	3.00	0.50	0.00	0.00	0.00	0.00
Total	12	22706	304500				240	68118	152250	220608

The artificial recharge to groundwater in NCT of Delhi is of the order of 2206.08 Cr, which includes construction of CD, Recharge Trench with Recharge Shaft and Roof Top Rainwater harvesting structures.

8.5 GOA

Goa state is situated in West Coast of India having geographical area of 3702 sq km. It is divided into two districts and 12 taluks. About 218 sq km falls in command area, while 1561 sq.km falls in non command area and 430 sq km falls in poor ground water quality area. The state receives more than 3000 mm of annual rainfall. The state is rich in water resources, however, hydrogeological and physiographical conditions in the state do not permit large scale surface and ground water storage. The steep gradient of the terrain and also in groundwater system, both surface water and groundwater flows out towards sea, resulting in drying of of wells and scarcity in summer.

8.5.1 Identification of Areas

The area for artificial recharge to ground water have been identified on the basis of post monsoon water level data (2018) and declining trend in water level for the past ten years (decadal) and areas with surplus water availability. The area identified for artificial recharge to ground water is 1268 sq. kms (Fig 8.5.1).

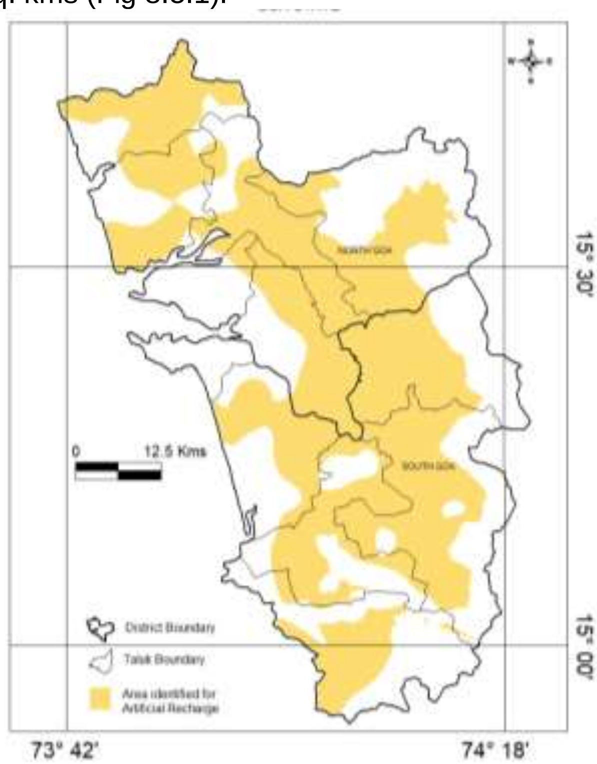


Fig 8.5.1 Area identified for Artificial Recharge in Goa

Table 8.5.1 Scope of Artificial Recharge in Goa

S.No	State	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Availabe Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Goa	North Goa	1755.90	685.00	7638.57	465.25	618.78	191.85
2	Goa	South Goa	1946.08	582.84	5392.08	161.76	215.14	201.31
		Total	3701.98	1267.84	13030.65	627.01	833.93	393.16

8.5.2 Subsurface Space & Source Water Availability

The thickness of available unsaturated zone (below 3 m bgl) is estimated by considering the different ranges of water level. The volume unsaturated sub surface zone is estimated by multiplying the thickness and the area and is of the order of 13030.65 MCM. The volume available for artificial recharge is given by the product of unsaturated zone and specific yield and is of the order of 627.041 MCM. Considering an efficiency of 75% of these artificial recharge structures, water required for artificial recharge works out to be 833.93 MCM (Table .8.5.1)

8.5.3 Source Water Availability

Base flow occurs during the non-monsoon period. The decline of water level can be reduced by arresting base flow by suitable water conservation and artificial recharge structures. This also helps to recharge the aquifer system during summer months thereby to sustain the ground water abstraction structures. Annual surface run off in the state is 8811 MCM. A part of this run off is being harnessed through major and medium irrigation projects and the rest goes to sea as run off. The surplus available for recharge is 393.16 MCM (Table .8.5.1).

8.5.4 Recharge Structures and Cost Estimates

Bhandaras and vented dams are suitable structures in the state. These structures may be able to harvest the surplus run off and hence has been proposed in the State of at an estimated cost of Rs 279.30 cr (Table 8.5.2).

Table 8.5.2 Artificial Recharge in Goa

		Number of Structures	Unit Cost of Structures (Lakh)	Cost of Structures(Lakh)	
S.No	District	VD/CD	VD/CD	VD/CD	Total Cost (Lakh)
1	North Goa	463	30.0	13890.00	13890.00
2	South Goa	468	30.0	14040.00	14040.00
	Total	931		27930	27930

8.5.5 Roof Top Rain Water Harvesting

It has been assessed that roof top rainwater harvesting can be adopted in 45794 houses, government buildings, institutes, etc. in urban and municipal area of the state suitable for artificial recharge in first phase. It will harness 27.43 MCM rainwater to augment groundwater resources considering normal rainfall for the state and 80% efficiency of the system. The cost of roof top rainwater harvesting of a buildings having roof and paved areas of ~200 sq.m has been assessed to be Rs. 30000/- and for bigger building having more than 200 sq.m will be Rs. 70000/- (On an average 500 sq.m is taken). The total cost for the rooftop rainwater harvesting for the state has been estimated to be Rs. 14654 lakhs in the first phase considering 5% of the total buildings having larger roofs.

8.5.6 Total Cost

The total cost of artificial recharge for the State of Goa is of the order of Rs 425.84 Cr, out of which, cost estimate for Rural area is of the order of Rs 279.30 Cr and Urban area is 146.54 Cr.

8.6 GUJARAT

The State of Gujarat located in western part of India has an area of 1,96,024 Sq.Km. with the longest coastline of 1600 km. There are 18,225 villages and 348 towns with a population of 60,439,692 (2011 census). The droughts are frequent in major part of Gujarat. The annual rainfall shows steep reduction from 2000 mm in extreme south (Dangs and Valsad districts) to 300 mm in Kachchh district. Gujarat has three distinct physiographic areas, viz., main land Gujarat, Saurashtra and Kachchh regions. Gujarat is covered by number of large and small river basins, which are characterized by represent varied and complex hydrogeological, agro-climatic and hydrological features.

8.6.1 Identification of Area

The post monsoon (2009-18) decadal average depth to water level and post monsoon decadal water level trend (2009-18) have been considered for identifying the area for artificial recharge with the following criteria.

Area with water level between 6-9 m bgl & declining trend > 0.10 m / year
Area with water level between 6 -9 m bgl & declining trend 0 to 0.10 m / year
Area with water level > 9 m bgl & declining trend > 0.10 m / year
Area with water level > 9 m bgl & declining trend 0 to 0.10 m / year

A total of 53,123 sq. km area spread over thirty-three district having water level & trend as above is given as Fig 8.6.1 & in Table 8.6.1.

8.6.2 Sub-Surface Storage Space and Water Requirement

The thickness of available unsaturated zone (below 6 mbgl) is considered for computing the volume of unsaturated zone for recharge. The product of the area and thickness provides the volume of unsaturated zone below 6m bgl which is of the order of 252703.26 MCM. The product of specific yield and the unsaturated volume provide the volume available for recharge and is of the order of 14825.31 MCM. Considering the efficiency of the artificial recharge structures as 75%, the volume of water required to saturate has been worked out and is found to be 19717.6 MCM (Table 8.6.1).

8.6.3 Source Water Availability

The availability of source water, one of the prime requisites of artificial recharge has been adopted as per data of Narmada, Water Resources, Water Supply & Kalpsar Department, Government of Gujarat (www.guj-nwrws.gujarat.gov.in), which has adopted basin approach. Broadly, the data of each basin takes into account of committed runoff, provision for future planning and surplus water available. Accordingly, accounting for gross storage capacity of existing all irrigations dams / reservoir and proposed allocation for various schemes, surplus runoff has been worked out for 4 main physiographic regions of the state. This availability so worked out for entire 4 regions has been further redistributed on prorate basis for different districts within the respective regions for planning of Artificial Recharge. The total surplus water available for planning of artificial recharge in the state is 6194.42 MCM/yr. Considering the various types of artificial recharge structures constructed up to 2020, the balance surplus run off has been calculated to be 4144.27 MCM. However as per the data provided by the State Water Resources Department an additional 315 MCM of surplus surface water is provisioned for artificial recharge through recharge shafts and existing defunct tube wells which can be used as injection wells. Hence the total balance runoff available is calculated to be 4459.26 MCM. (Table 8.6.1).

8.6.4 Recharge Structures and Cost Estimates

In hard rock areas with moderate relief, weirs/check dams are considered feasible, whereas, in plateau and plain areas occupied by hard rock, percolation tanks are considered appropriate. In semi-consolidated formation weirs/check dams are considered feasible. In the areas occupied by alluvium percolation tanks are considered appropriate.

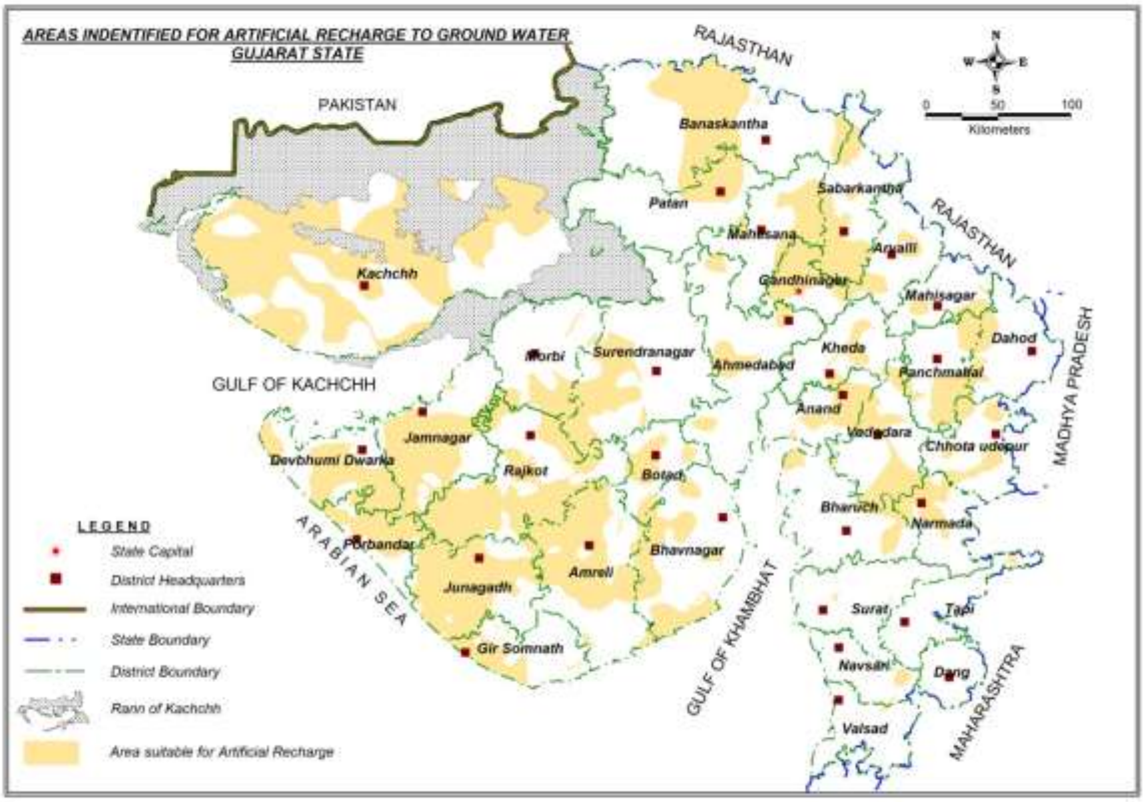


Fig 8.6.1 Area identified for Artificial Recharge in Gujarat

Table 8.6.1 Scope of Artificial Recharge in Gujarat

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Ahmedabad	7018.65	751.13	2901.69	435.25	578.88	15.00
2	Amreli	7375.45	3974.12	19794.54	593.84	789.81	15.00
3	Anand	2826.48	890.67	4538.49	544.62	724.34	20.00
4	Arvalli	3219.67	491.13	2120.28	84.81	112.80	15.00
5	Banaskantha	10405.32	3752.91	22187.73	1775.02	2360.78	20.00
6	Bharuch	5240.59	677.84	2685.84	322.30	428.66	985.83
7	Bhavnagar	6693.00	2129.10	10161.30	304.84	405.44	20.00
8	Botad	2561.12	827.59	4338.87	130.17	173.13	15.00
9	Chhota udepur	3460.30	808.89	2853.54	114.14	151.81	15.00
10	Dahod	3649.80	497.31	2044.26	61.33	81.57	15.00
11	Dang	1708.25	0.00	0.00	0.00	0.00	293.32
12	Devbhumi Dwarka	4075.27	2208.00	8835.30	530.12	705.06	15.24
13	Gandhinagar	2165.84	1268.71	7122.93	1068.44	1421.03	10.00
14	Gir Somnath	3762.95	883.10	3132.30	93.97	124.98	26.79
15	Jamnagar	6019.51	3302.20	12218.70	366.56	487.52	10.00
16	Junagadh	5027.60	4045.25	19333.05	579.99	771.39	15.00
17	Kachchh	19506.50	8777.60	45262.80	3621.02	4815.96	4.16
18	Kheda	3366.26	471.75	1805.91	216.71	288.22	10.00
19	Mahesana	4409.57	1193.55	6273.27	940.99	1251.52	20.00
20	Mahisagar	2494.46	316.49	1353.78	108.30	144.04	20.00
21	Morbi	4803.71	922.74	3814.56	114.44	152.21	21.20
22	Narmada	2760.68	850.54	4053.54	121.61	161.74	459.04

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
23	Navsari	2199.52	121.63	397.80	11.93	15.87	401.14
24	Panchmahal	3225.70	1235.76	5873.46	176.20	234.35	15.00
25	Patan	5731.04	1091.31	6423.33	770.80	1025.16	15.00
26	Porbandar	2261.95	1485.72	6691.86	200.76	267.01	30.67
27	Rajkot	7473.83	4707.87	18531.42	555.94	739.40	15.00
28	Sabarkantha	3953.39	1703.82	9950.73	398.03	529.38	15.00
29	Surat	4111.14	22.13	75.69	0.91	1.21	789.62
30	Surendranagar	9218.12	2140.40	9566.70	478.34	636.19	17.85
31	Tapi	3130.55	52.17	156.51	4.70	6.25	601.53
32	Vadodara	4096.10	1507.10	8159.10	97.91	130.22	20.00
33	Valsad	3256.87	14.66	43.98	1.32	1.76	497.87
	Total	161209.19	53123.19	252703.26	14825.31	19717.66	4459.26

Taking into consideration the existing artificial recharge structures suitable in the district area and available balance runoff additional artificial recharge structures are proposed (Table 8.6.2). For the present planning average cost of structure has been adopted from the guidelines laid down by Govt. of Gujarat. The cost of project is estimated to be Rs. 3462.73 crores for constructing various structures as indicated in table 8.6.2.

Roof Top Rain Water Harvesting in Urban Area

Gujarat is considered as a drought prone state and up to March 2019, 8911 villages and 165 towns have been covered for piped water supply (http://www.sardarsarovardam.org/water-supply-policy). There are still some urban pockets in Gujarat State depend heavily on ground water for drinking water supplies and groundwater levels are declining. Rainwater harvesting can be used to supplement the water supply and at the same time arrest the declining water levels.

The suitable method for artificial recharge in urban area is to harvest the rainwater from roof tops. Depending on hydrogeological condition, the harvested water can be stored and used directly or can be recharged or the combination of storage and recharge. As per 2011 census 31 urban centers have been identified where the population exceeds 1 Lakh (Table 7). There are about 251.82 Lakh people reside in the urban areas of the State. There are about 52.83 Lakh households in such centers and considering about 25% houses are suitable for harvesting and considering 40 sq.m. as typical house hold roof top area the total area available for harvesting (90% of total roof top) has been estimated to be 475.54 Lakh sq m. The source water available for harvesting has been taken as 60% of normal rainfall in the urban centre after making allowance for storm rain etc., Thus, the total source water available for harvesting has been estimated as 26.3 MCM/yr. The Average cost of making the roof top harvesting arrangements for storing it at surface and recharging to ground water is @ Rs. 20,000/- per house. Thus, the cost of roof top harvesting for 13.20 lakh houses of the state is estimated as Rs. 2641.89 crores (Table 8.6.2)

8.6.5 Total Cost

The total cost for proposed artificial recharge is Rs 3462.73 Cr, out of which Rs 820.84 Cr is in rural areas and Rs 2641.89 Cr is urban areas.

Table 8.6.2 Artificial Recharge in Gujarat

S.No.	District	Number Of Structures					Unit Cost of Structures (Lakh)					Cost of Structures (Lakh)					
		CD	RTRWH	PT	Recharge Shaft	Recharge through defunct tube wells	CD	RTRWH	PT	Recharge Shaft	Recharge through defunct tube wells	CD	RTRWH	PT	Recharge Shaft	Recharge through defunct tube wells	Total Cost (Lakh)
1.	Ahmedabad	0	317408	0	245	255	7.0	0.2	10.0	5.0	2.0	0.00	63481.60	0.00	1225	510	65216.60
2.	Amreli	0	18949	0	493	7	7.0	0.2	10.0	5.0	2.0	0.00	3789.80	0.00	2465	14	6268.80
3.	Anand	0	32487	0	590	77	7.0	0.2	10.0	5.0	2.0	0.00	6497.35	0.00	2950	154	9601.35
4.	Arvalli	0		0	484	16	7.0	0.2	10.0	5.0	2.0	0.00	0.00	0.00	2420	32	2452.00
5.	Banaskantha	0	20493	0	0	666	7.0	0.2	10.0	5.0	2.0	0.00	4098.65	0.00	0	1332	5430.65
6.	Bharuch	0	29046	0		0	7.0	0.2	10.0	5.0	2.0	0.00	5809.25	0.00	0	0	5809.25
7.	Bhavnagar	0	59059	0	665	2	7.0	0.2	10.0	5.0	2.0	0.00	11811.75	0.00	3325	4	15140.75
8.	Botad	0		0	498	2	7.0	0.2	10.0	5.0	2.0	0.00	0.00	0.00	2490	4	2494.00
9.	Chhota udepur	0		0	478	22	7.0	0.2	10.0	5.0	2.0	0.00	0.00	0.00	2390	44	2434.00
10.	Dahod	0	8893	0	499	1	7.0	0.2	10.0	5.0	2.0	0.00	1778.50	0.00	2495	2	4275.50
11.	Dang	0	1203	0		0	7.0	0.2	10.0	5.0	2.0	0.00	240.50	0.00	0	0	240.50
12.	Devbhumi Dwarka	204		36			7.0	0.2	10.0	5.0	2.0	1428.00	0.00	360.00	0	0	1788.00
13.	Gandhinagar	0	15792	0	159	174	7.0	0.2	10.0	5.0	2.0	0.00	3158.40	0.00	795	348	4301.40
14.	Gir Somnath	359		63			7.0	0.2	10.0	5.0	2.0	2513.00	0.00	630.00	0	0	3143.00
15.	Jamnagar	0	31385	0	333		7.0	0.2	10.0	5.0	2.0	0.00	6276.90	0.00	1665	0	7941.90
16.	Junagadh	0	44906	0	498	2	7.0	0.2	10.0	5.0	2.0	0.00	8981.20	0.00	2490	4	11475.20
17.	Kachchh	56	39918	10		0	7.0	0.2	10.0	5.0	2.0	392.00	7983.55	100.00	0	0	8475.55
18.	Kheda	0	26791	0	156	177	7.0	0.2	10.0	5.0	2.0	0.00	5358.25	0.00	780	354	6492.25
19.	Mahesana	0	26986	0	546	121	7.0	0.2	10.0	5.0	2.0	0.00	5397.15	0.00	2730	242	8369.15
20.	Mahisagar	0		0	663	4	7.0	0.2	10.0	5.0	2.0	0.00	0.00	0.00	3315	8	3323.00
21.	Morbi	275		48		22	7.0	0.2	10.0	5.0	2.0	1925.00	0.00	480.00	0	44	2449.00
22.	Narmada	2150	3303	378		42	7.0	0.2	10.0	5.0	2.0	15050.00	660.60	3780.00	0	84	19574.60
23.	Navsari	212	22959	37		2	7.0	0.2	10.0	5.0	2.0	1484.00	4591.70	370.00	0	4	6449.70
24.	Panchmahal	0	16991	0	493	7	7.0	0.2	10.0	5.0	2.0	0.00	3398.15	0.00	2465	14	5877.15
25.	Patan	0	7024	0	334	166	7.0	0.2	10.0	5.0	2.0	0.00	1404.80	0.00	1670	332	3406.80
26.	Porbandar	411	15288	72			7.0	0.2	10.0	5.0	2.0	2877.00	3057.60	720.00	0	0	6654.60
27.	Rajkot	0	117906	0	499	1	7.0	0.2	10.0	5.0	2.0	0.00	23581.25	0.00	2495	2	26078.25
28.	Sabarkantha	0	18844	0	416	84	7.0	0.2	10.0	5.0	2.0	0.00	3768.75	0.00	2080	168	6016.75
29.	Surat	15	263707	3		4	7.0	0.2	10.0	5.0	2.0	105.00	52741.45	30.00	0	8	52884.45
30.	Surendranagar	203	25602	36		90	7.0	0.2	10.0	5.0	2.0	1421.00	5120.45	360.00	0	180	7081.45

S.No.	District	Number Of Structures					Unit Cost of Structures (Lakh)					Cost of Structures (Lakh)					
		CD	RTRWH	PT	Recharge Shaft	Recharge through defunct tube wells	CD	RTRWH	PT	Recharge Shaft	Recharge through defunct tube wells	CD	RTRWH	PT	Recharge Shaft	Recharge through defunct tube wells	Total Cost (Lakh)
31.	Tapi	78	4266	14		14	7.0	0.2	10.0	5.0	2.0	546.00	853.15	140.00	0	28	1567.15
32.	Vadodara	0	114877	0	558	109	7.0	0.2	10.0	5.0	2.0	0.00	22975.45	0.00	2790	218	25983.45
33.	Valsad	22	36864	4		5	7.0	0.2	10.0	5.0	2.0	154.00	7372.75	40.00	0	10	7576.75
		3985	**1320944.75**	**701**	**8607**	**2072**						**27895.00**	**264188.95**	**7010.00**	**43035**	**4144**	**346272.95**

Note: Most part of the Bharuch District shows predominantly rising trend both during pre-monsoon and post-monsoon period. Hence No AR structure is proposed.

8.7 HARYANA

Haryana state is located in the north western part of India. It has an areal extent of 44,241 sq.km. and forms 1.35 % of the geographical area of the country. Around 97% of the state area is plain and known as Indo-Gangetic plain. The state forms the part of Ganga & Indus basin. The normal annual rainfall varies from more than 1000 mm in the north east to less than 300 mm in the south west. In the south western parts of the state, drought is a common feature. In the north eastern and eastern parts of the State, fairly thick and regionally extensive confined/unconfined aquifers exist down to a depth of more than 300 m with yield prospects of about 150 m^3/hour. The alluvium down to 450 m below land surface has been explored in this part. In the south-western and the central parts of the State, moderately thick and regionally extensive confined/unconfined aquifers exist. The ground water here is generally saline at all levels except local patches. The yield prospects in this area are less than 50 m^3/hour. In the remaining areas moderately thick and regionally extensive aquifers exist and their yield prospects are 50-150 m^3/hour mainly due to limitation of depth as underlying ground water is saline. In the hard rock areas the ground water potentials are limited and there the yield prospects are 5 to 20 m^3/hour within weathered residuum and fractured zones.
Ground water resources of state have been estimated as on 31.03.2017. The Net annual replenishable ground water resource of state has been assessed to be 9.13 BCM against the withdrawal of 12.5 BCM. The average stage of ground water development in the state is has reached to 137%. Out of 128 blocks assessed, 78 fall under 'Over exploited' category, 3 in 'Critical', 21 as 'Semi critical' and 26 as 'Safe' category. The reason for this stage of ground water development is mainly because of decrease in ground water recharge due to reduced rainfall, urbanisations etc. These over-exploited aquifers require augmentation for sustaining the ground water abstraction structures.

8.7.1 Identification of Area

Based on the post monsoon depth to water level of the year 2018 and long term (2009-2018) ground water level trends, it has been estimated that approximately 39,381 sq. kms area is feasible for artificial recharge. (Fig 8.7.1). The area feasible for artificial recharge to ground water is demarcated based on criteria of depth to water level of more than 3 m bgl during post-monsoon season and continuous annual decline rate of more than 10 cm per annum.

8.7.2 Sub-Surface Storage Space and Water Requirement

The total volume of unsaturated strata is calculated by considering unsaturated thickness of aquifers on block-wise basis. The sub-surface storage potential is estimated by multiplying the volume of unsaturated aquifer by average specific yield i.e. 12%. The quantity of water required is estimated by considering the recharge efficiency of 75%. Sub surface storage potential of the state is estimated as 77,964 MCM during post-monsoon season of 2018. The sub-surface storage potential estimated during post-monsoon season of 2012 is about 54175 MCM. Thus due to over-exploitation about 23789 MCM of volume of aquifer has been dewatered and used-up during the last 6 years. The quantity of water required for filling the sub-surface storage potential (unsaturated zone) is approximately 103693 MCM. District-wise break up is given in the Table.8.7.1.

8.7.3 Source Water Availability

The quantity of non-committed surplus surface water in the Haryana state has been estimated to be only 679.26 MCM(as per the data available from the state government) against the requirement of 103693 MCM.Thus, the source water for recharge in the State of Haryana can be surplus canal flow, runoff generated in large Farms and rainwater from roof top. The surplus water from canal are proposed to be used for recharging through canal, while the runoff generated from farm land to be used for farm ponds and by making provision for rooftop rainwater harvesting. Total surface runoff from farms to be recharged through farm ponds/percolation ponds is 3294 MCM considering 10% of total area of the district is suitable for constructing farm ponds. The rooftop rainfall runoff available for recharging purpose is estimated as 24.52 MCM considering 10% households have roof top area of about 200 sq.mt.

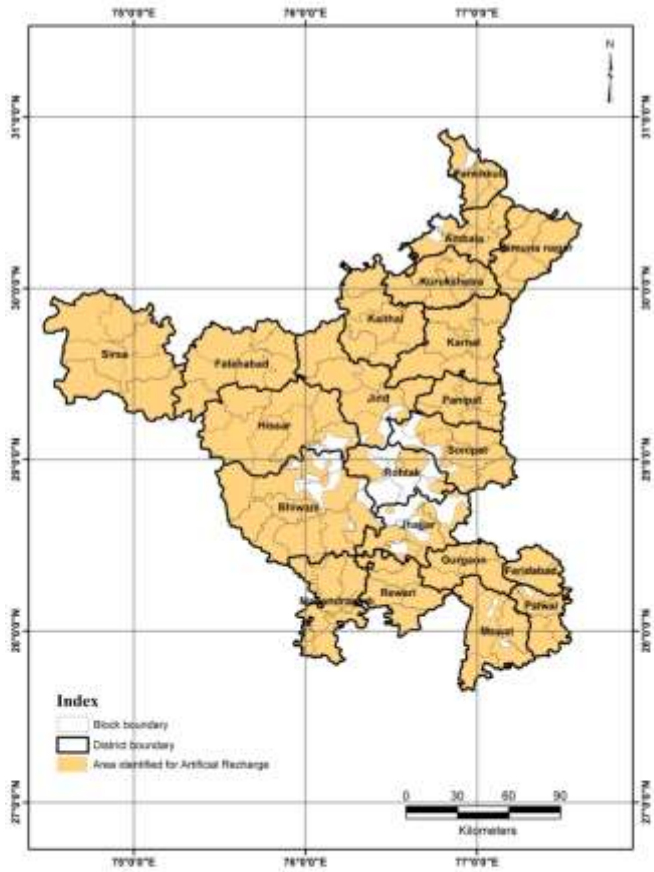


Fig 8.7.1 Area identified for Artificial Recharge in Haryana

Table 8.7.1 Scope of Artificial Recharge in Haryana

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Ambala	1485.00	1484.97	11539.48	1384.74	1841.70	12.01
2	Bhiwani	3248.00	2483.91	47002.36	5640.28	7501.58	62.46
3	Charkhi Dadri	1380.00	1244.26	26826.91	3219.23	4281.57	0.00
4	Faridabad	789.00	789.24	12636.83	1516.42	2016.84	9.95
5	Fatehabad	2538.00	2537.72	31526.82	3783.22	5031.68	62.35
6	Gurgaon	1198.00	1197.83	29134.28	3496.11	4649.83	30.57
7	Hissar	4071.00	3481.75	23189.85	2782.78	3701.10	26.32
8	Jhajjar	1924.00	825.23	1588.39	190.61	253.51	18.87
9	Jind	2766.00	2588.32	38436.73	4612.41	6134.50	37.82
10	Kaithal	2287.00	2287.45	57817.21	6938.06	9227.63	85.44
11	Karnal	2488.00	2487.97	52413.00	6289.56	8365.11	30.26
12	Kurukshetra	1667.00	1667.18	63831.49	7659.78	10187.51	49.07

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
13	Mahendragarh	1943.00	1943.33	70192.51	8423.10	11202.73	68.31
14	Mewat	1645.00	1414.64	12049.73	1445.97	1923.14	14.00
15	Palwal	1245.00	893.81	4768.89	572.27	761.11	18.34
16	Panchkula	898.00	898.15	8216.12	985.93	1311.29	8.01
17	Panipat	1266.00	1268.43	16381.59	1965.79	2614.50	17.10
18	Rewari	1527.00	1503.71	29497.85	3539.74	4707.86	54.15
19	Rohtak	1676.00	721.28	3497.65	419.72	558.23	0.00
20	Sirsa	4283.00	4282.72	71242.25	8549.07	11370.26	55.11
21	Sonipat	2193.00	1655.67	21580.57	2589.67	3444.26	17.22
22	Yamunanagar	1724.00	1723.63	16331.92	1959.83	2606.58	1.90
	Total	44241.00	39381.20	649702.44	77964.29	103692.51	679.26

8.7.4 Recharge Structure and Cost Estimates

The major proposed recharge structures in the state are Farm ponds, injection wells and horizontal trench with or without recharge shafts. The average cost of a recharge shaft to recharge 0.015 MCM water annually will be around Rs. 3.0 lakh and of check dam to recharge 0.04 MCM annually will be around Rs. 50 lakhs in Aravali hills and Rs. 40 lakhs in Siwaliks. Average cost of construction of farm ponds is about 0.50 lakh and recharge pit in individual houses and cluster of houses will be 0.30 lakhs. It is recommended to construct about 335 number of check dams, 44392 number of Recharge shafts with recharge tube wells near the percolations ponds and adjacent to the canals to utilize the surplus surface runoff, 393811 number of farm ponds in the agricultural lands and 304377 number of roof top rain water harvesting structures in the urban and rural areas to divert the runoff from the roof top area. The total cost of all types of recharge structures required to recharge will be around Rs. 4370.45 crores. The district wise number of structures feasible and cost estimates is given in table 8.7.2.

8.7.5 Roof Top Rain Water Harvesting in Villages

It has been assessed that roof top rainwater harvesting can be adopted in 30 lakh houses with 200 Sq.mt roof area, government buildings, institutes etc. in urban and municipal area of the state suitable for artificial recharge in the first phase. It will harness 24.5 MCM rain water to augment groundwater resources considering normal rainfall for the state and 80% efficiency of the system. The cost of roof top rain water harvesting of a buildings having roof and paved areas of ~ 200 sq.m in a cluster of 4-6 houses has been assessed to be Rs. 30,000/- and for bigger building having more than 1000 sq.m will be Rs. 1.0 lakh. The total cost for the roof top rain water harvesting for the state has been estimated to be Rs. 913 crore. Apart from this, another 75,000 structures for government/institutional buildings are recommended.

8.7.6 Recharge From Farm Areas in Villages Through Farm Ponds

It is proposed to harness the runoff available from the agricultural lands and farms located in rural area through Farm ponds. The runoff generated which can be utilsed for recharge purpose has been estimated by considering the 10% of total area of the districts occupied by large farms where farm ponds can be constructed for recharge purpose. It is estimated that about 393811 number of farm ponds can be constructed to recharge about 3294.17 MCM of water. The estimated cost of constructing the farm ponds @ rate of 0.50 lakhs per farm pond is about 1969 crores.

8.7.7 Artificial Recharge from Sewage Water

Besides rainfall, ample scope exists to recharge treated sewage water, which is disposed away from the town without any purposeful gain. At present, in majority of the towns sewage water is subjected to primary treatment only. In certain towns, the sewage water is subjected to secondary treatment. The towns where treated sewage water is available are Panipat, Karnal, Faridabad, Yamunanagar, Gurgaon, Sonepat etc. The total capacity of the plants installed for treatment in these towns is 0.325 MCM per day. Therefore, total treated water availability per year is 118.6 MCM. The treated water may be gainfully utilized by storing the water in percolation ponds where ground water levels are deep and allowing the water seep into the ground through a thick layer of unsaturated zone so that the pollutants may get attenuated in unsaturated zone. About 1000 percolation ponds are recommended in the state. The total cost of these structures will be Rs 2500 lacs @ Rs 2.50 lakh per structure. Besides this, there are about 48 urban agglomerations which are located in the area suitable for artificial recharge. The total population of these towns is around 13 lakhs. The sewage generated from these towns is around 45.5 MCM annually. The sewage in these towns is subjected to primary treatment only, which is not suitable for artificial recharge. If sewage in these towns is given secondary/tertiary treatment, it may be utilized for artificial recharge in proximity of the towns. Three pond domestic waste water (only bathroom water and kitchen waste water) treatment system are recommended to be constructed in the villages to treat the bathroom water and use the same for irrigational requirements is recommended so that the stress on ground water can be reduced.

8.7.8 Total Cost

There are some major changes in the revised Master Plan to that of 2013. These changes are mainly due to revision of recharge structures as recommended in ground water management plans prepared during the NAQUIM Plan. Farm Ponds which were not recommended in 2013 Master plan have been incorporated in this Mater Plan as per the recommendations of NAQUIM Project. The rooftop rain water harvesting structures were also revised based on the NAQUIM Project management Plans. Thus the cost of taking up artificial recharge in rural and urban areas will be revised and will be Rs 4370.45 crores for all types of recharge structures (Table 8.7.2). Cost does not include the ponds recommended for treated waste water.

Table 8.7.2 Artificial Recharge Structures and Cost Estimates in Haryana

S. No	District	Number of Structures				Unit Cost of Structures (Lakh)				Cost of Structures(Lakhs)				
		CD	RS	FP	RTRWH	CD	RS	FP	RTRWH	CD	RS	FP	RTRWH	Total Cost
1	Ambala	25	734	14850	11770	40	3	0.5	0.3	1000	2202	7425.00	3531.00	11186.20
2	Bhiwani	25	4097	24839	24814	40	3	0.5	0.3	1000	12291	12419.50	7444.20	21102.80
3	Charkhi Dadri	0	0	12443	0	40	3	0.5	0.3	0	0	6221.50	0.00	6221.50
4	Faridabad	25	597	7892	6337	50	3	0.5	0.3	1250	1791	3946.00	1901.10	6038.70
5	Fatehabad	0	4157	25377	14514	40	3	0.5	0.3	0	12471	12688.50	4354.20	18289.80
6	Gurgaon	50	1905	11978	8868	50	3	0.5	0.3	2500	5715	5989.00	2660.40	9240.90
7	Hissar	0	1755	34818	22565	40	3	0.5	0.3	0	5265	17409.00	6769.50	24705.00
8	Jhajjar	0	1258	8252	13650	40	3	0.5	0.3	0	3774	4126.00	4095.00	8598.40
9	Jind	0	2521	25883	19088	40	3	0.5	0.3	0	7563	12941.50	5726.40	19424.20
10	Kaithal	0	5696	22875	15802	40	3	0.5	0.3	0	17088	11437.50	4740.60	17886.90
11	Karnal	0	2017	24880	19859	40	3	0.5	0.3	0	6051	12440.00	5957.70	19002.80
12	Kurukshetra	0	3271	16672	13082	40	3	0.5	0.3	0	9813	8336.00	3924.60	13241.90
13	Mahendragarh	50	4421	19433	14712	50	3	0.5	0.3	2500	13263	9716.50	4413.60	15476.40
14	Mewat	25	867	14146	13998	50	3	0.5	0.3	1250	2601	7073.00	4199.40	11542.50
15	Palwal	25	1156	8938	12970	50	3	0.5	0.3	1250	3468	4469.00	3891.00	8716.80
16	Panchkula	50	401	8981	4615	40	3	0.5	0.3	2000	1203	4490.50	1384.50	6015.30
17	Panipat	0	1140	12684	12188	40	3	0.5	0.3	0	3420	6342.00	3656.40	10340.40
18	Rewari	50	3477	15037	13030	50	3	0.5	0.3	2500	10431	7518.50	3909.00	12490.60
19	Rohtak	0	0	7213	11745	40	3	0.5	0.3	0	0	3606.50	3523.50	7130.00
20	Sirsa	0	3674	42827	18350	40	3	0.5	0.3	0	11022	21413.50	5505.00	28020.70
21	Sonipat	0	1148	16557	18755	40	3	0.5	0.3	0	3444	8278.50	5626.50	14249.40
22	Yamunanagar	10	100	17236	13665	40	3	0.5	0.3	400	300	8618.00	4099.50	12751.50
	Total	335	44392	393811	304377					15650	133176	196905.50	91313.10	437044.60

8.8 HIMACHAL PRADESH

Himachal Pradesh is one of the northern most states with an area of 55673 sq. km. The major river systems of the region are the Chenab, the Ravi, the Beas, the Sutlej, and the Yamuna. The catchments of these rivers are fed by snow and rainfall and are protected by fairly extensive cover of natural vegetation. The rainfall in the state varies from 900 to 2000 mm. In the high altitude areas where rainfall is as low as 200 - 800 mm, snow is the major source of precipitation. Average rainy/snowfall days varies from 50 - 75 /year.Rainfall though is abundant in South, South Eastern and Western Himachal Pradesh, but scanty in Northern districts.

All the traditional water harvesting practice developed is necessitated by the need, scarcity of water resources and terrain conditions. These practices differ depending upon the terrain. Roof top rain water harvesting is slowly becoming prevalent in State. All new government buildings have adopted rooftop rainwater harvesting in the state. During the Britishers time, roof top water after the first shower, was collected in small sub surface tanks for utilizing during the lean period. This practice was adopted by the Britishers in all the hill stations like Kasauli, Dagshai, Shimla, Dalhousieetc. All of this traditional water harvesting practice were maintained and used by the people themselves and are eco-friendly and socially accepted. However, most of these traditional practices has been abandoned or become defunct, on the advent of piped water supply in the State from various sources like springs, infiltration galleries, streams etc. Now there is an urgent need for the revival of our traditional water harvesting practices by adding modern technology inputs.

8.8.1 Identification of Area

The area for artificial recharge was identified based on long term decadal post monsoon depth to water levels(2009-18; November) and sub-regional issues and given as Fig 8.8.1. In valley area of state an area of 1,51,039Ha had been identified for artificial recharge in parts of 57 blocks of 10 districts of State, while outside the valley, 3958.4 sq. km area has been identified for artificial recharge in 12 districts of state. The area identified for artificial recharge has been marked as GW Recharge-Priority area in the Fig 8.8.1.

8.8.2 Sub-Surface Storage and Water Requirement

The thickness of available unsaturated zone (below 3 m bgl) is estimated by considering the mean water levels in the valleys below 3 mbgl. The volume of unsaturated zone is given by the product of thickness and area, while the volume of space available for artificial recharge is estimated by multiplying unsaturated zone volume by specific yield. Considering an efficiency of 75%, the volume of water required for artificial recharge is assessed. The volume of unsaturated zone is of the order of 16698 MCM, while the volume of space available for artificial recharge is 2671 MCM and water required for artificial recharge is 3553 MCM. (Table 8.8.1)

8.8.2 Source Water Availability

The State is having abundance of surface water sources, major rivers like the Chandra-Bhaga, the Beas and the Ravi are originating in the Central part of the State whereas Satluj and Yamuna rivers pass through the State. There is no shortage of water in the State, however, due to greater groundwater exploitation, the water levels are going deeper in valley areas. The data on quantum of Surfacerunoff, basin discharge, committed & non-committed runoff for the state of Himachal Pradesh is not available and since no shortage of water is felt, it is assumed that water is available for artificial recharge .

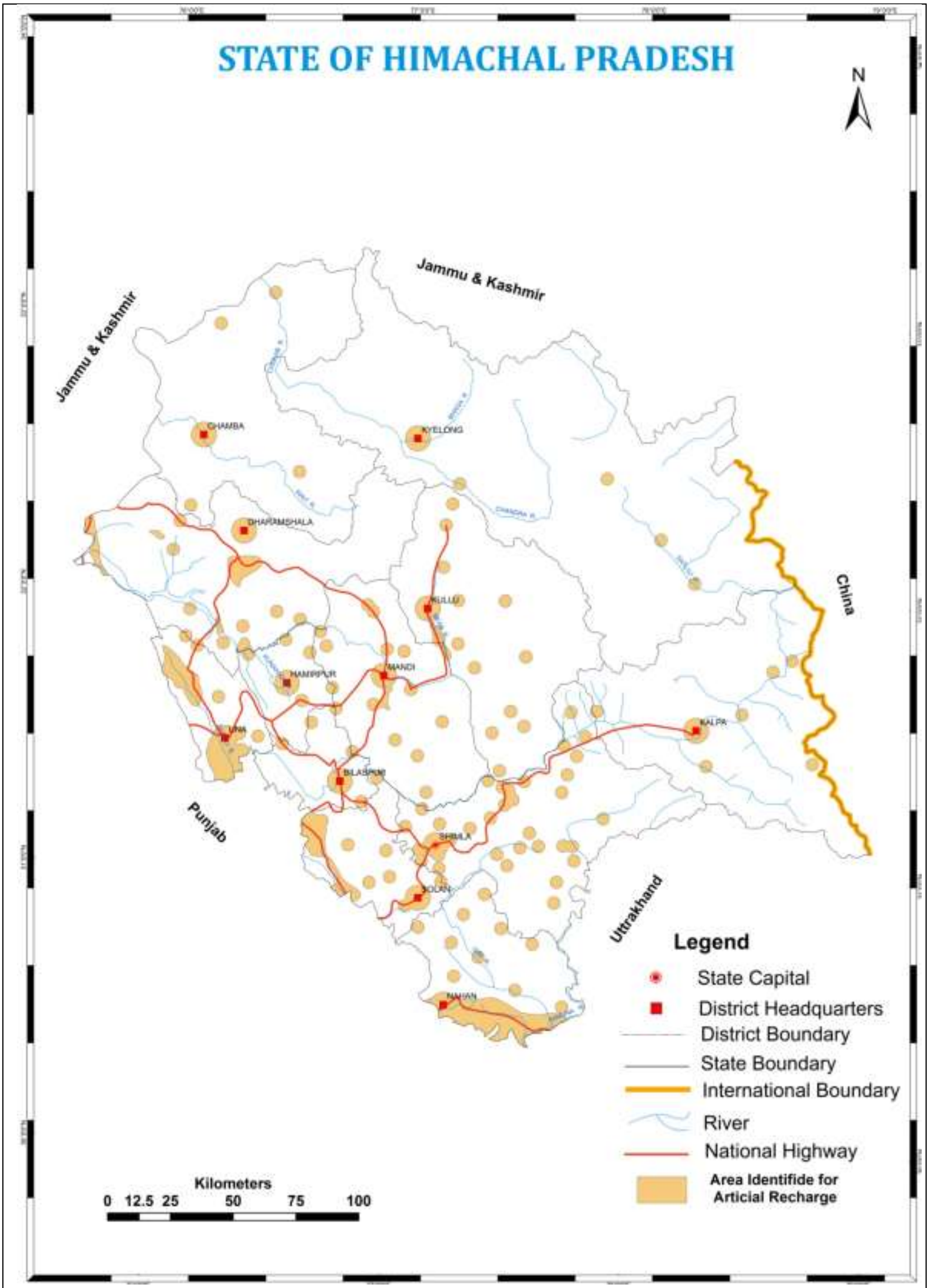


Fig 8.8.1 Area Identified for Artificial Recharge in Himachal Pradesh

Table 8.8.1 Scope of Artificial Recharge in Himachal Pradesh

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)
1	Bilaspur	1167.00	143.20	0.00	0.00	0.00
2	Chamba	6528.00	157.10	0.00	0.00	0.00
3	Hamirpur	1118.00	171.10	0.00	0.00	0.00
4	Kangra	5739.00	963.60	4176.56	668.25	888.77
5	Kinnaur	6401.00	194.30	0.00	0.00	0.00
6	Kullu	5503.00	359.30	0.00	0.00	0.00
7	Lahaul&Spiti	11685.00	163.20	0.00	0.00	0.00
8	Mandi	3950.00	475.80	166.25	26.60	35.38
9	Shimla	5131.00	682.30	0.00	0.00	0.00
10	Sirmaur	2825.00	716.60	4046.85	647.50	861.17
11	Solan	1936.00	425.30	4147.34	663.57	882.55
12	Una	1540.00	1017.00	4161.20	665.79	885.50
	Total	53523.00	5468.80	16698.20	2671.71	3553.38

8.8.3 Artificial Recharge & Cost Estimate

In most of the areas in the hilly region, there is a tradition to divert stream flow by making full use of slope for irrigating the fields by short approach channels locally called Kulhs. In high hill areas, spring water is being utilized for irrigation. In the lower areas of Siwaliks where perennial water sources are limited, ponds/tanks locally called Talabs are the major source of water supplies. These Talabs are generally constructed adjacent to the rivulets or in low topography areas for collection of rain waters. Almost all the villages in Hamirpur, Bilaspur, Sirmaur, Solan, Una and Kangra districts have such talabs. In general, Modification of Village Ponds/Tanks, Recharge Shaft, Injection well, Sub-surface dykes& Roof Top Rainwater Harvesting Structures are considered in valley areas, while Gabbion, Check dams / Nala Bunds / Cement Plug& Roof Top Rainwater Harvesting Structures are considered in hilly areas. The number of different artificial recharge structures proposed depending on physiography/lithological variation in the states are provided in table 8.8.2.Details of Artificial recharge structures and the cost estimates are given in table 8.8.2.

Roof Top Rain Water Harvesting

In hilly and urban areas, the roof top rain water can be conserved and used for recharge of ground water. This approach requires connecting the outlet pipes from roof top to divert the water to either existing wells/tubewells/borewell or specially designed wells. The urban housing complexes or institutional buildings have large roof area and can be utilizing for harvesting roof top rain water to recharge aquifer in urban areas.

8.8.4 Total Cost

The total cost of artificial recharge for the State of Himachal Pradesh is of the order of Rs 1055.40 Cr, out of which, cost estimate for Artificial recharge structures is of the order of Rs 1018.65 Crand rooftop rainwater harvesting in Urban area is 36.75 Cr.

Table 8.8.2 Artificial Recharge Structures in Himachal Pradesh

S.No	RTRWH / Artificial Recharge Structures Proposed	MAJOR PHYSIOGRAPHIC / LITHOLOGICAL UNITS (Total Geographical Area 55673 sq. km)									Total No. of Structures	Total Cost (Rs. In Lakh)
		Valley Fills (Area: 3475 sq. km)			Siwaliks / Semi – Consolidated / Low Hill Ranges/ (Area: 10104 sq. km)			Igneous / Crystallines / Consolidated / High Hill Ranges (Area: 42094 sq. km)				
		No. of Proposed structures	Unit cost (Lakh)	Total Cost (Lakh)	No. of Proposed Structures	Unit cost (Lakh)	Total Cost (Lakh)	No. of Proposed structures	Unit cost (Lakh)	Total Cost (Lakh)		
1	Gabion Structures	0	0.50	0.00	22980	0.50	11490.00	85138	0.50	42569.00	108118	54059.00
2	Check dams / Nala Bunds / Cement Plug	0	11.20	0.00	1323	11.20	14817.60	967	11.20	10830.40	2290	25648.00
3	Sub-surface dykes	394	3.80	1497.20	66	3.80	250.80	0	3.80	0.00	460	1748.00
4	Check dam cum sub surface dykes	784	15.00	11760.00	0	15.00	0.00	0	15.00	0.00	784	11760.00
5	Modification of village Tanks	304	6.50	1976.00	16	6.50	104.00	18	6.50	117.00	338	2197.00
6	Modification of village Ponds	299	6.50	1943.50	152	6.50	988.00	62	6.50	403.00	513	3334.50
7	Recharge shaft	348	5.25	1827.00	208	5.25	1092.00	0	5.25	0.00	556	2919.00
8	Injection well	131	1.50	196.50	2	1.50	3.00	0	1.50	0.00	133	199.50
9	Roof top rain water Harvesting	0	3.50	0.00	525	3.50	1837.50	525	3.50	1837.50	1050	3675.00
TOTAL		2260		19200.20	25272		30582.90	86710		55756.90	114242	105540.00

Table 8.8.3District wise Artificial Recharge Structures & Cost Estimates in Himachal Pradesh

S.No	District	Number of Structures								Cost of Structures (Lakh)								
		Gabbion	Check dams / Nala Bunds / Cement Plug	Sub-surface dykes	Check dam cum sub surface dykes	Modification of village tanks/Ponds	Recharge shaft	Injection well	Roof top rain water harvesting	Gabbion	Check dams / Nala Bunds / Cement Plug	Sub-surface dykes	Check dam cum sub surface dykes	Modification of village tanks/Ponds	Recharge shaft	Injection well	Roof top rain water harvesting	Total Cost
1	Bilaspur	3208	172	71	24	64	23	4	100	1604.00	1926.40	269.80	360.00	416.00	120.75	6.00	350.00	5052.95
2	Chamba	12856	190	10	20	9	17	4	50	6428.00	2128.00	38.00	300.00	58.50	89.25	6.00	175.00	9222.75
3	Hamirpur	3264	178	13	26	83	23	5	100	1632.00	1993.60	49.40	390.00	539.50	120.75	7.50	350.00	5082.75
4	Kangra	8778	390	135	270	162	194	44	200	4389.00	4368.00	513.00	4050.00	1053.00	1018.50	66.00	700.00	16157.50
5	Kinnaur	12502	125	15	30	5	15	6	25	6251.00	1400.00	57.00	450.00	32.50	78.75	9.00	87.50	8365.75
6	Kullu	10776	108	11	22	16	12	5	50	5388.00	1209.60	41.80	330.00	104.00	63.00	7.50	175.00	7318.90
7	Lahaul&Spiti	27370	274	15	30	6	15	6	25	13685.00	3068.80	57.00	450.00	39.00	78.75	9.00	87.50	17475.05
8	Mandi	8530	210	35	50	56	42	7	100	4265.00	2352.00	133.00	750.00	364.00	220.50	10.50	350.00	8445.00
9	Shimla	10122	160	35	42	80	7	3	100	5061.00	1792.00	133.00	630.00	520.00	36.75	4.50	350.00	8527.25
10	Sirmaur	4810	212	42	84	100	74	17	100	2405.00	2374.40	159.60	1260.00	650.00	388.50	25.50	350.00	7613.00
11	Solan	3412	134	23	76	248	45	10	100	1706.00	1500.80	87.40	1140.00	1612.00	236.25	15.00	350.00	6647.45
12	Una	2490	137	55	110	22	89	22	100	1245.00	1534.40	209.00	1650.00	143.00	467.25	33.00	350.00	5631.65
	Total	108118	2290	460	784	851	556	133	1050	54059.00	25648.00	1748.00	11760.00	5531.50	2919.00	199.50	3675.00	105540.00

8.9 JHARKHAND

The state of Jharkhand covers an area of 79710 sqkm, lies between North latitude 21°58’ and 25°18’ and 83°22’ and 87°57’ East longitude. The state is divided into 24 districts and 260 community development blocks. As per census 2011, the Population of the state is 32988134, of which about 30% of total population is tribal.The total rural population is 25055073 while the urban population is 7933061.The annual normal rainfall of the state is 1301 mm.The entire state is characterized by land of great inequalities, succession of plateaus, hills, valleys, scarps ridges with altitude varying from 40 m to more than 1300 m above mean sea level. The state is covered under three major river basins, viz, Lower Ganga, Subarnarekha and Brahmani. The state is underlain by diverse rock types of different geological ages ranging from Archaean to Recent. The major rock types are igneous and metamorphic rocks covering nearly 85 percent of the geographical area of the state.

8.9.1 Identification of Area

The area identified for artificial recharge has been made based on post monsoon depth to water level (Nov 2018) more than 3m bgl with declining trend of more than 0.1 m/yr (2009 – 2018). In addition, area with water level more than 9m bgl and OCS blocks in the State have been considered and identified area is shown as priority area in Fig 8.9.1.

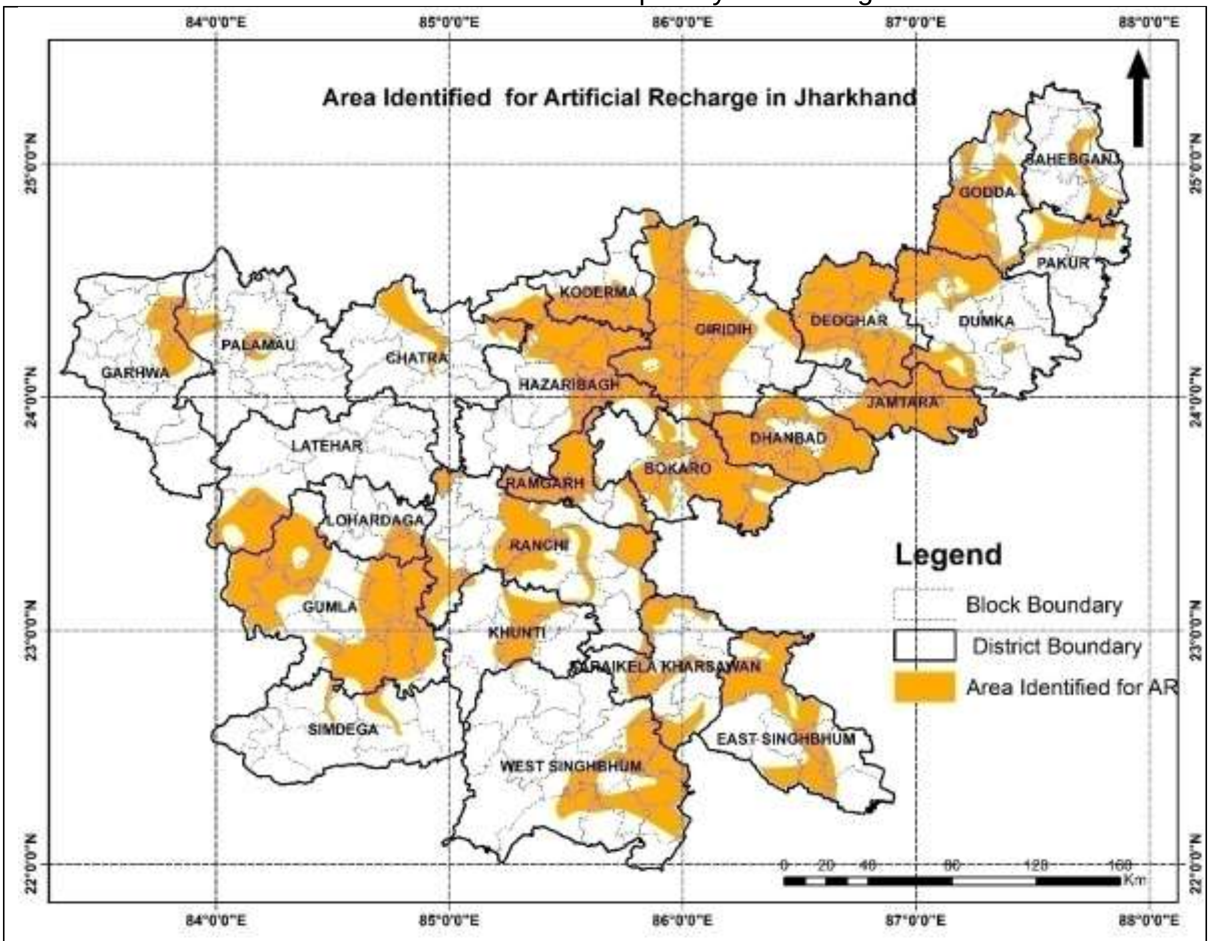


Fig 8.9.1 Area Identified in Jharkhand

8.9.2 Subsurface Storage and Source Water Requirement

The volume of unsaturated zone available for recharge in identified areas is determined by computation of average depth of the unsaturated zone below 3 m bgl and then multiplied by area considered for recharge. It is of the order of 56498 MCM. The volume available for artificial recharge is estimated by multiplying the volume of unsaturated zone with respective specific yield of the formation and is of the order of 1324 MCM. Based on the experiences in the State, an efficiency of these artificial recharge structures is considered as 60% and accordingly the water required for artificial recharge is assessed and is of the order of 2197.47 MCM. (Table 8.9.1)

8.9.3 Source Water Availability

In the absence of data, the yield from the catchment has been computed using Strange's table and 30% of the monsoon rain fall has been considered. Further, data on committed run off is not available and hence 50% of the estimated run off has been considered available for artificial recharge. The district wise source water availability has been provided in Table 8.9.1.

Table-8.9.1 Scope of Artificial Recharge in Jharkhand

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Availabe Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Bokaro	2859.00	1686.77	2563.89	51.28	85.12	238.92
2	Chatra	3932.00	545.82	1888.54	37.77	62.70	101.83
3	Deoghar	2551.00	1922.16	5055.28	101.11	167.84	295.57
4	Dhanbad	2252.00	1663.32	3542.87	70.86	117.62	277.61
5	Dumka	3716.00	1252.34	2742.62	82.28	136.58	247.18
6	East Singhbhum	3633.00	1480.52	3553.25	71.06	117.97	337.47
7	Garhwa	4045.00	441.66	998.15	19.96	33.14	76.67
8	Giridih	5085.00	2902.94	5138.20	205.53	341.18	308.07
9	Godda	2111.00	1309.60	2750.16	55.00	91.31	268.82
10	Gumla	5347.00	3358.94	4769.69	95.39	158.35	638.61
11	Hazaribagh	4310.00	1843.79	4554.16	91.08	151.20	351.68
12	Jamtara	1804.00	1374.12	2006.22	40.12	66.61	209.99
13	Khunti	6209.00	575.79	466.39	18.66	30.97	109.69
14	Koderma	1497.00	757.75	1159.36	34.78	57.74	144.57
15	Latehar	3613.00	593.71	1442.72	28.85	47.90	62.69
16	Lohardaga	1492.00	299.30	655.47	19.66	32.64	50.58
17	Pakur	1806.00	318.26	639.70	19.19	31.86	63.23
18	Palamu	4517.00	431.17	1164.16	23.28	38.65	76.70
19	Ramgarh	1396.00	1039.00	2794.91	55.90	92.79	167.38
20	Ranchi	4963.00	1897.29	3434.09	68.68	114.01	309.07
21	Sahibganj	1702.00	339.63	448.31	26.90	44.65	58.74
22	SaraikelaKharsawan	2725.00	869.82	1182.96	35.49	58.91	172.75
23	Simdega	3752.00	181.73	170.83	3.42	5.67	34.67
24	West Singhbhum	5292.00	1662.88	3375.65	67.51	112.07	295.58
	Total	80609.00	28748.31	56497.57	1323.78	2197.47	4898.06

8.9.4 Proposed Recharge Structures and Cost Estimates

Based on the geomorphology and hydrogeology, the type of structures has been identified and considering the gross capacity and multiple fillings, the numbers of structures have been estimated based on the availability of surplus source water availability (Table 8.9.2).

Table-8.9.2 Artificial recharge in Jharkhand

S. No	District	Number of Structures					Unit Cost of Structures (Lakh)					Cost of Structures (Lakh)					
		NB/CD/GP	PT	Recharge shaft	RTRWH area 300 to 1000 sq. m.	RTRWH area more than 1000 sq. meter	NB/CD/GP	PT	Recharge shaft	RTRWH area 300 to 1000 sq. m.	RTRWH area more than 1000 sq. meter	NB/CD/GP	PT	Recharge shaft	RTRWH area 300 to 1000 sq. m.	RTRWH area more than 1000 sq. meter	Total Cost
1	Bokaro	1418	226		64559	3398	6.0	30.0		0.25	1.0	8508.00	6780.00		16139.75	3398.00	34825.75
2	Chatra	1044	166		3753	198	6.0	30.0		0.25	1.0	6264.00	4980.00		938.25	198.00	12380.25
3	Deoghar	2797	446		15925	838	6.0	30.0		0.25	1.0	16782.00	13380.00		3981.25	838.00	34981.25
4	Dhanbad	1960	312		101246	5329	6.0	30.0		0.25	1.0	11760.00	9360.00		25311.50	5329.00	51760.50
5	Dumka	2276	363		5954	313	6.0	30.0		0.25	1.0	13656.00	10890.00		1488.50	313.00	26347.50
6	East Singhbhum	1966	156	589	88499	4658	6.0	30.0	5.0	0.25	1.0	11796.00	4680.00	2945.00	22124.75	4658.00	46203.75
7	Garhwa	552	88		4526	238	6.0	30.0		0.25	1.0	3312.00	2640.00		1131.50	238.00	7321.50
8	Giridih	5134	819		12247	645	6.0	30.0		0.25	1.0	30804.00	24570.00		3061.75	645.00	59080.75
9	Godda	1521	121	456	4047	213	6.0	30.0	5.0	0.25	1.0	9126.00	3630.00	2280.00	1011.75	213.00	16260.75
10	Gumla	2639	421		4226	222	6.0	30.0		0.25	1.0	15834.00	12630.00		1056.50	222.00	29742.50
11	Hazaribagh	2519	402		16860	887	6.0	30.0		0.25	1.0	15114.00	12060.00		4215.00	887.00	32276.00
12	Jamtara	1110	177		5118	269	6.0	30.0		0.25	1.0	6660.00	5310.00		1279.50	269.00	13518.50
13	Khunti	516	82		3097	163	6.0	30.0		0.25	1.0	3096.00	2460.00		774.25	163.00	6493.25
14	Koderma	962	153		8366	440	6.0	30.0		0.25	1.0	5772.00	4590.00		2091.50	440.00	12893.50
15	Latehar	798	127		3442	181	6.0	30.0		0.25	1.0	4788.00	3810.00		860.50	181.00	9639.50
16	Lohardaga	544	86		3797	200	6.0	30.0		0.25	1.0	3264.00	2580.00		949.25	200.00	6993.25
17	Pakur	530	84		4587	241	6.0	30.0		0.25	1.0	3180.00	2520.00		1146.75	241.00	7087.75
18	Palamau	644	102		13654	719	6.0	30.0		0.25	1.0	3864.00	3060.00		3413.50	719.00	11056.50
19	Ramgarh	1546	246		27546	1450	6.0	30.0		0.25	1.0	9276.00	7380.00		6886.50	1450.00	24992.50
20	Ranchi	1900	303		83177	4378	6.0	30.0		0.25	1.0	11400.00	9090.00		20794.25	4378.00	45662.25
21	Sahebganj	744	59	223	10591	557	6.0	30.0	5.0	0.25	1.0	4464.00	1770.00	1115.00	2647.75	557.00	10553.75
22	SaraikelaKharsawan	981	78		18345	966	6.0	30.0		0.25	1.0	5886.00	2340.00		4586.25	966.00	13778.25
23	Simdega	94	7		2825	146	6.0	30.0		0.25	1.0	564.00	210.00		706.25	146.00	1626.25
24	West Singhbhum	1867	149		15305	806	6.0	30.0		0.25	1.0	11202.00	4470.00		3826.25	806.00	20304.25
	Total	36062	5173	1268	521692	27455						216372.00	155190.00	6340.00	130423.00	27455.00	535780.00

Rooftop Rainwater Harvesting in Urban Areas

There is a great potential for roof top harvesting in urban areas of the state of Jharkhand. All the district headquarters are considered for roof top rainwater harvesting and ground water augmentation. There are 1062557 and 1525412 of houses in ***24 districts*** headquarter as per 2001 and 2011 census respectively. Considering the growth rate about 44 % between 2001 &2011, the projected number of house in 2021 will be 2196593. It is considered that 25 % of the 2196593 houses i.e. about 5.5 Lakh house are proposed for rooftop rainwater harvesting. As per Ranchi Rainwater Harvesting Regulation implemented by Ranchi Municipal Corporation, houses with 300 square meter of roof area or more are to be taken into consideration for roof top rain water harvesting. The cost of roof top rainwater harvesting of a roof area 300 square meters or above is estimated as Rs.1305 crores for 5.22 lakh buildings (75% of total number buildings) taking the unit cost as Rs.25,000/-. The cost of the rest 5% building having more than 1000 square meters roof area(27455 nos) will be Rs. 274.55 crores taking unit cost of Rs. 1.0 lakh per building.

8.9.5 Total Cost Estimates

The total cost of artificial recharge for the State of Jharkhand is of the order of Rs 5357.80 Cr, out of which, cost estimate for Rural area is of the order of Rs 4053.57 Cr and Urban area is 1304.23 Cr.

8.10 KARNATAKA

Karnataka state is located in south western part of India with a population of 61,130,704 and population density of 319 per sq.km (Census 2011). It covers an area of 1,91,791 sq.km and divided into 30 districts and 176 taluks for administrative convenience.Humid to semi-arid climatic conditions prevail in the state. Normal annual rainfall varies from 573 to 4119 mm and bulk of the annual rainfall is received during the south-west and north-east monsoons.
Karnataka State can be is divided into four regions, from physiography point of view., Coastal belt, Malnad region, Northern Maidan region and Southern Maidan region. The western Ghats which runs North-South forms the principal water divide in the state, giving rise to West and East flowing rivers of Karnataka. The Sharavati, the Kalinadi, the Netravati, the Varahi, the Bedti and Aghanashini are some of the important rivers which originate from the Western Ghats and flow westerly and join the Arabian Sea. The Krishna River system covers an area 1,13,271 sq.km and drains 59.06 percent of Karnataka State followed by the Cauvery River system which drains 34,273 sq.km covering 17.87 percent. The west flowing rivers drain 26,214 sq.km area of the state covering 13.68 percent. Other river systems cover appreciably small areas.
Karnataka State is underlain by rock types ranging in age from Archaean to Recent. Major portion of the State is covered by Peninsular Gneisses, Granites and Dharwar Schists of Archaean age. Groundwater occurs under unconfined condition in weathered residuum and under semi confined to confined condition in deeper fractures. In general, weathered residuum extends down to 30m bgl and fractures are encountered down to 200m bgl, Quality of ground water in general is good and potable in the state except for higher concentration of fluoride and nitrates in select districts.

8.10.1 Identification ofArea

The area characterized by depth to water level more than 3m bgl during the year 2018 post-monsoon period and declining decadal water level trend is considered for artificial recharge. In addition, areas with poor quality of water has also been considered for effecting improvement through dilution and areas with stage of groundwater extraction more than 100% has also been considered for augmentation (Fig.8.10.1).

8.10.2 Subsurface Storage Space

The thickness of unsaturated zone up to the depth of 3m, for each category of depth to water level has been worked out and volume of unsaturated zone has been estimated. The volume of space available for artificial recharge is given by the product of specific yield and volume of unsaturated zone and is found to be of the order of 10234 MCM. Considering the efficiency of 75%, water required for artificial recharge is assed as 13611 MCM (Table 8.10.1)

Table 8.10.1 Scope of Artificial Recharge in Karnataka

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Availabe Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Bagalkote	6593.00	5594.00	22888.59	457.77	608.84	541.53
2	Bangalore(r)	2294.00	1725.00	7438.19	148.76	197.86	197.86
3	Ramanagaram	3558.00	2786.00	6561.32	131.23	174.53	174.53
4	Bangalore(u)	2208.00	1606.00	3972.73	79.45	105.67	105.67
5	Belgaum	13461.00	9696.00	31618.36	632.37	841.05	825.83
6	Bellary	7379.00	5561.00	17695.60	353.91	470.70	470.70
7	Bidar	5458.00	4712.00	21654.90	433.10	576.02	557.20
8	Bijapur	10530.00	10037.00	30421.08	608.42	809.20	809.20

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Availabe Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
9	Chamrajangar	5685.00	5322.00	29380.40	587.61	781.52	581.61
10	Chikmagalur	7234.00	4776.00	9355.98	187.12	248.87	248.87
11	Chitradurga	8360.00	7429.00	40773.83	815.48	1084.58	1084.58
12	D. kannada	4494.00	2910.00	8505.36	170.11	226.24	226.24
13	Davangere	5914.00	3627.00	8687.25	173.75	231.08	231.08
14	Dharwar	4263.00	3294.00	19324.83	386.50	514.04	499.76
15	Gadag	4657.00	4506.00	31713.59	634.27	843.58	788.51
16	Gulbarga	10951.00	7948.00	13971.10	279.42	371.63	371.63
17	Yadgir	5223.00	2661.00	7476.30	149.53	198.87	198.87
18	Hassan	6837.00	5933.00	20708.79	414.18	550.85	550.85
19	Haveri	4851.00	4287.00	23045.28	460.91	613.00	613.00
20	Kodagu	4096.00	3377.00	12604.86	252.10	335.29	160.78
21	Chikballapur	4255.00	3362.00	14593.99	291.88	388.20	388.20
22	Kolar	3985.00	2350.00	9012.58	180.25	239.73	239.73
23	Koppal	5559.00	4052.00	21680.45	433.61	576.70	527.67
24	Mandya	4991.00	2697.00	6762.45	135.25	179.88	179.88
25	Mysore	6331.00	3921.00	13194.47	263.89	350.97	350.97
26	Raichur	8386.00	4238.00	8132.27	162.65	216.32	216.32
27	Shimoga	8465.00	5874.00	19608.57	392.17	521.59	521.59
28	Tumkur	10596.00	7865.00	27350.27	547.01	727.52	713.37
29	U. Kannada	10242.00	7835.00	14058.54	281.17	373.96	245.54
30	Udupi	3575.00	3472.00	9495.11	189.90	252.57	252.57
	Total	190431.00	143453.00	511687.03	10233.74	13610.88	12874.17

8.10.3 Source Water Availability

Monsoon rainfall run off is the only source water for artificial recharge in the state. Non-committed monsoon runoff is taken based on "Theme paper on water Vision 2050 Indian water resources of NWDA" and apportioned to various districts (Table 8.10.1).

8.10.4 Artificial Recharge & Cost Estimates

The surface water spreading structures, viz., percolation tank, check dam, Recharge shaft, sub-surface dyke and vented dams (Dakshina Kannada District) are considered in the State. The number of structures are proposed considering the existing structures constructed through various scheme in the State. The estimated cost of artificial recharge structures in Karnataka State works out to be Rs. 7111.64 Cr (table 8.10.2).

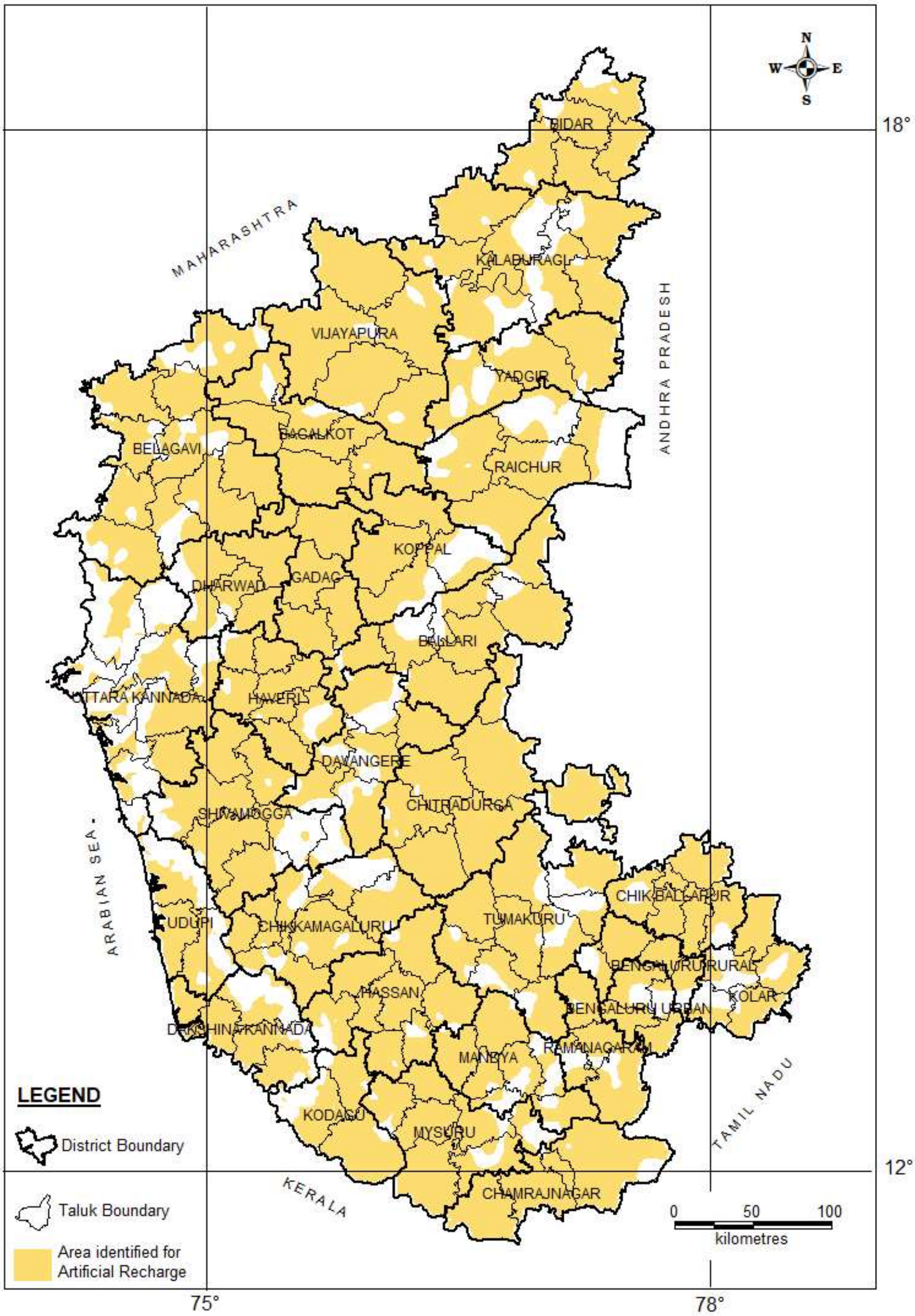


Fig 8.10.1 Area identified for Artificial Recharge in Karnataka

Table 8.10.2 Artificial Recharge in Karnataka

S.No	District	Number of Structures				Unit Cost of Structures (Lakh)				Cost of Structures(Lakh)				
		CD	RS	PT	SSD & CD Cum SSD	CD	RS	PT	SSD & CD Cum SSD	CD	RS	PT	SSD & CD Cum SSD	Total Cost
1	Bagalkote	1990	0	487	14	10.0	1.5	20.0	20.0	19900.00	0.00	9740.00	280.00	29920.00
2	Bangalore(r)	832	0	178	5	10.0	1.5	20.0	20.0	8320.00	0.00	3560.00	100.00	11980.00
3	Ramanagaram	130	0	128	5	10.0	1.5	20.0	20.0	1300.00	0.00	2560.00	100.00	3960.00
4	Bangalore(u)	559	8	95	3	10.0	1.5	20.0	20.0	5590.00	12.00	1900.00	60.00	7562.00
5	Belgaum	3700	0	741	22	10.0	1.5	20.0	20.0	37000.00	0.00	14820.00	440.00	52260.00
6	Bellary	2244	0	177	13	10.0	1.5	20.0	20.0	22440.00	0.00	3540.00	260.00	26240.00
7	Bidar	1869	0	452	15	10.0	1.5	20.0	20.0	18690.00	0.00	9040.00	300.00	28030.00
8	Bijapur	1698	0	727	22	10.0	1.5	20.0	20.0	16980.00	0.00	14540.00	440.00	31960.00
9	Chamrajangar	2896	101	466	16	10.0	1.5	20.0	20.0	28960.00	151.50	9320.00	320.00	38751.50
10	Chikmagalur	1103	9	141	7	10.0	1.5	20.0	20.0	11030.00	13.50	2820.00	140.00	14003.50
11	Chitradurga	4143	0	802	29	10.0	1.5	20.0	20.0	41430.00	0.00	16040.00	580.00	58050.00
12	D. kannada	144	0	204	6	10.0	1.5	20.0	20.0	1440.00	0.00	4080.00	120.00	5640.00
13	Davangere	479	0	81	6	10.0	1.5	20.0	20.0	4790.00	0.00	1620.00	120.00	6530.00
14	Dharwar	2421	30	448	13	10.0	1.5	20.0	20.0	24210.00	45.00	8960.00	260.00	33475.00
15	Gadag	3879	0	710	21	10.0	1.5	20.0	20.0	38790.00	0.00	14200.00	420.00	53410.00
16	Gulbarga	995	7	300	10	10.0	1.5	20.0	20.0	9950.00	10.50	6000.00	200.00	16160.50
17	Yadgir	855	0	179	5	10.0	1.5	20.0	20.0	8550.00	0.00	3580.00	100.00	12230.00
18	Hassan	2557	8	365	15	10.0	1.5	20.0	20.0	25570.00	12.00	7300.00	300.00	33182.00
19	Haveri	2496	0	325	16	10.0	1.5	20.0	20.0	24960.00	0.00	6500.00	320.00	31780.00
20	Kodagu	815	21	145	4	10.0	1.5	20.0	20.0	8150.00	31.50	2900.00	80.00	11161.50
21	Chikballapur	1544	0	36	10	10.0	1.5	20.0	20.0	15440.00	0.00	720.00	200.00	16360.00
22	Kolar	669	0	211	6	10.0	1.5	20.0	20.0	6690.00	0.00	4220.00	120.00	11030.00
23	Koppal	1548	0	475	14	10.0	1.5	20.0	20.0	15480.00	0.00	9500.00	280.00	25260.00
24	Mandya	817	0	162	5	10.0	1.5	20.0	20.0	8170.00	0.00	3240.00	100.00	11510.00
25	Mysore	1804	61	312	9	10.0	1.5	20.0	20.0	18040.00	91.50	6240.00	180.00	24551.50
26	Raichur	972	34	195	6	10.0	1.5	20.0	20.0	9720.00	51.00	3900.00	120.00	13791.00
27	Shimoga	2241	80	381	14	10.0	1.5	20.0	20.0	22410.00	120.00	7620.00	280.00	30430.00
28	Tumkur	2783	62	637	19	10.0	1.5	20.0	20.0	27830.00	93.00	12740.00	380.00	41043.00
29	U. Kannada	1203	11	131	7	10.0	1.5	20.0	20.0	12030.00	16.50	2620.00	140.00	14806.50
30	Udupi	1141	4	227	7	10.0	1.5	20.0	20.0	11410.00	6.00	4540.00	140.00	16096.00
	Total	50527	436	9918	344					505270	654	198360	6880	711164

Roof Top Rain Water Harvesting

It has been assessed that roof top rain water harvesting can be adopted in 8.9 lakh houses, government buildings, institutes etc., in urban and municipal areas of the state suitable for artificial recharge in the first phase. It will harness 149.64 MCM rainwater to augment ground water resources considering normal rainfall for the state and 80% efficiency of the system. The cost of roof top rainwater harvesting of a building having roof and paved area of ~ 200 sq.m has been assessed to be Rs. 30000/- and for bigger buildings having more than 200 sq.m. will be Rs. 70000/-. The total cost for the roof top rain water harvesting for the state has been estimated to be Rs. 2870.02 Cr in the first phase considering 5% of the total buildings having largerroofs.

8.10.5 Total Cost

The total cost of artificial recharge for the State of Karnataka is of the order of Rs 9981.66 Cr, out of which, cost estimate for Rural area is of the order of Rs 7111.64 Cr and Urban area is 2870.02 Cr.

8.11 NORTH EASTERN STATES

CGWB, North Eastern Region, Guwahati covers the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland and Tripura. The region is mainly a hilly terrain except the vast alluvial plains of Brahmaputra and Barak Rivers in Assam and small intermontane valleys scattered in other states of the region. In spite of copious rainfall, many parts of the region face scarcity of drinking water, especially during lean period. As per 2011 Census, the details of area, number of administrative units and population of North Eastern States are given below in table - 8.11.1.

Table. 8.11.1 Vital Statistics of North Eastern States (Census 2011)

State	Area (Km^2)	No. of districts	Population	Inhabited villages
Assam	78438	27	26655528	26395
Arunachal Pradesh	83743	16	109768	5589
Manipur	22327	9	2293896	2582
Meghalaya	22429	7	2964007	6839
Nagaland	16579	11	1988636	1428
Mizoram	21081	8	689756	830
Tripura	10486	4	3671032	875
TOTAL	2,55,083	82	38372623	44538

Ground water occurs in alluvial terrain under unconfined to semi-confined conditions and depth to water level rests mostly within 5 meter. In the foot hill belt of Arunachal Pradesh bordering Assam, depth to water level rests within 12 m. In the southern part of Arunachal Pradesh, in parts of Manipur, Mizoram, Nagaland, Tripura and West Garo Hills, Tipam Sandstone Formation form potential aquifers. The hard rock terrain includes high hill ranges of Arunachal Pradesh, high land plateau of Meghalaya, Karbi-Anglong, N.C. Hills and inselberg areas of Assam.

8.11.1 Scope of Artificial Recharge

The areas receive a good amount of rainfall and thus the aquifers are naturally replenished every year. Based on depth to water level map of the region, it is observed that artificial recharge measures are not required. However, localized requirement cannot be denied. Considering the physiography, rainfall, hydrogeological setup and in consultation with state govt. the type and number of structures have been determined and cost worked out on the basis of rates of respective State Government (Table 8.11.2).

Table 8.11.2 Scope of Artificial Recharge

Type of Structure	No. of Structures	Unit Cost (Lakhs)	Total Cost (Lakh)
Arunachal Pradesh			
Farm pond	5000	4	20000
Check dam	10000	15	150000
Gabion structure	5000	1.0	5000
Earthen Contour Bund	200000	0.005	1000
Staggered trenches	11000	0.005	55
Assam			
Farm pond	10000	4	40000
Renovation of existing water bodies	30000	0.3	9000
Check dam	5000	15	75000
Gabion structure	5000	0.5	2500
Earthen Contour Bund	200000	0.005	1000

Type of Structure	No. of Structures	Unit Cost (Lakhs)	Total Cost (Lakh)
Staggered trenches	10000	0.005	50
Manipur			
Check dam	2000	25	50000
Gabion	1000	3	3000
Renovation of existing water bodies	1000	0.5	500
Farm Ponds	3500	8	28000
Meghalaya			
Farm ponds	500	4	2000
Renovation of existing water bodies	100	0.5	50
Check dam	600	20	12000
Gabion structure	800	2	1600
Mizoram			
Check dam	500	25	12500
Gabion	1000	2	2000
Nagaland			
Check dam	700	49	34300
Gabion	1000	4.64	4640
Nala Bund	1000	2.0	2000
Restoration of traditional wells	1000	3.50	3500
Tripura			
Gabion	35	0.5	17.5
Contour bund	14	0.05	0.7
Check dam	21	15	315
Modification of village tanks	35	0.5 to 1.0	17.5
Total Cost			**460045.7**

8.11.2 Roof Top Rain Water Harvesting:

The North Eastern Region of India is characterized as the highest rainfall region of the country. However, the water availability for domestic use, animal and crop production is negligible not only during lean period but also during rainy season. Dwindling discharge in many natural water sources in the hills results in water scarcity in the hilltops. To address these issues, states may identify areas of water scarcity, especially in the villages located in the hilltops and formulate schemes for augmenting water supply by means of rainwater harvesting.

Average annual rainfall of North Eastern States varies from 1450mm to 3000mm. An attempt has been made to assess the scope of rainwater harvesting in schools and health centers in the North Eastern States and thereby cost involved (Table.8.11.3, 8.11.4 & 8.11.5).

Table 8.11.3 Scope of Rooftop Rainwater Harvesting in Schools

State	No. of Schools			Schools with drinking water facility	Schools without/partially covered with drinking water facility can be covered through RTRH	Total roof area (m2) considering average 100 m^2 roof area /school	Average annual rainfall (in m)	75% of average rainfall (m)	Volume of water can be harvested (m^3)
	Rural	Urban	Total						
Assam	67106	3936	71042	59221	11821	1182139	2.18	1.64	1938708
Arunachal Pradesh	3618	429	4047	3264	783	78350	3.00	2.25	176287

State	No. of Schools			Schools with drinking water facility	Schools without/partially covered with drinking water facility can be covered through RTRH	Total roof area (m2) considering average 100 m^2 roof area /school	Average annual rainfall (in m)	75% of average rainfall (m)	Volume of water can be harvested (m^3)
	Rural	Urban	Total						
Manipur	4301	692	4993	4423	570	57020	1.45	1.09	62152
Meghalaya	13504	1010	14514	9251	5263	526278	2.20	1.65	868358
Nagaland	2354	472	2826	2209	617	61663	2.09	1.57	96811
Mizoram	2553	1272	3825	3528	297	29720	2.15	1.61	47850
Tripura	4446	398	4844	4310	534	53381	2.25	1.69	90214
TOTAL	97882	8209	106091	86205	19886	1988551	2.19		3280380

Source: No. of Schools “School Education in India” by National University of Educational Planning and Administration & MOHRD, Govt. of India

Table 8.11.4 Scope of Rooftop Rainwater Harvesting in Health Centre

State	No. of Health Centre		Total roof area (m^2) considering average 140 m^2 roof area /health centre		Average annual rainfall (in m)	75% of average rainfall (m)	Volume of water can be harvested (m^3)	
	Rural	Urban	Rural	Urban			Rural	Urban
Assam	4725	38	661500	5320	2.18	1.64	1084860	8724.8
Arunachal Pradesh	455	14	63700	1960	3.00	2.25	143325	4410
Manipur	452	8	63280	1120	1.45	1.09	68975.2	1220.8
Meghalaya	547	13	76580	1820	2.20	1.65	126357	3003
Mizoram	436	10	61040	1400	2.09	1.57	95832.8	2198
Nagaland	482	11	67480	1540	2.15	1.61	108642.8	2479.4
Tripura	892	17	124880	2380	2.25	1.69	211047.2	4022.2
TOTAL	3264	73	456960	10220			1839040	26058

Source: No. of Health Centre "Rural Health Statistics 2014-15", Ministry of Health & Family Welfare

Table 8.11.5 Cost Estimates for RTRWH in North Eastern States

States	RTRWH for Number of schools	RTRWH for Health Centers	Unit Cost for RTRWH (Lakh)	Total Cost (Lakh)
Assam	11821	4763	3.00	49752
Arunachal Pradesh	783	469	2.97	3718.44
Manipur	570	460	2.97	3059.10
Meghalaya	5263	560	17.5	101902.50
Nagaland	617	493	3.40	3774.00
Mizoram	297	446	2.50	1857.50
Tripura	534	909	2.97	4285.71
TOTAL	19885	8100		168349.25
Note: Unit Cost could not be obtained for Arunachal Pradesh, Manipur, Meghalaya & Tripura, for which average of Assam, Mizoram & Nagaland is taken				

8.11.3 Development of Springs

The emergence of spring is very common in seven North Eastern States. The age-old method of fetching water from springs for domestic purposes is still prevalent in both urban and rural areas. These springs can be developed scientifically for providing safe drinking water to the rural populace. It is often reported that spring discharge is diminishing day by day and needs proper attention. Artificial recharge through construction of recharge pit, contour/ staggered trenches in the spring catchment area and protection of the spring catchment will help to maintain sustainability of springs.

It is estimated that there are about 11,531 numbers of villages with availability of springs in the region (Source: No. of villages with springs:Report of Working Group I Inventory and Revival of Springs in the Himalayas for Water Security https://niti.gov.in/writereaddata/files/document_publication/doc1.pdf)

Considering at least one spring per village and average discharge of 0.6 lpm, it is estimated that 3,63,6416 m^3 water can be conserved annually and can be supplied for 1,66,046 populace for drinking and other purposes (Table 8.11.6 & 8.11.7). However, actual number springs available in each state is yet to be worked out.

Table 8.11.6 Scope of water conservation from Spring in the North Eastern States

State	Area (km^2)	No. of villages with springs	Average discharge considered (lpm)	Total annual discharge (m3/year)	Population can be covered annually @60 lpcd
Assam	78438	2997	0.6	945134	43157
Arunachal Pradesh	83743	2086	0.6	657841	30038
Manipur	22327	1405	0.6	443081	20232
Meghalaya	22429	3810	0.6	1201522	54864
Mizoram	16579	453	0.6	142858	6523
Nagaland	21081	639	0.6	201515	9202
Tripura	10486	141	0.6	44466	2030
TOTAL	2,55,083	11,531		3,63,6416	1,66,046

8.11.7 Cost Estimates for Spring Development

State	No. of villages with springs	Unit Cost (Lakh)	Total Cost (Lakh)
Assam	2997	11.67	34974.99
Arunachal Pradesh	2086	10.00	20860.00
Manipur	1405	11.67	16396.35
Meghalaya	3810	11.67	44462.70
Mizoram	453	12.00	5436.00
Nagaland	639	13.00	8307.00
Tripura	141	11.67	1645.47
TOTAL	11,531		132082.51
Note: Unit Cost could not be obtained for Assam, Manipur, Meghalaya & Tripura, Hence, average value of Arunachal Pradesh, Nagaland & Tripura has been used for these States			

8.11.4 Total Cost

The total cost towards artificial recharge works out to be Rs 7889.77 Cr, out of which the cost towards artificial recharge structures is Rs 4885.46 Cr, RWH in schools and Health centre is Rs 1683.49 Cr and for spring Development is Rs 1320.83 CR.

8.12 KERALA

Kerala State is a narrow stretch of land covering an area of 38,863 sq.km. in the southernmost part of India, has been subdivided into 14 districts, 75 taluks, 152 blocks and 941 panchayats for administrative convenience. The total population of the state as per 2011 census is 3,33,87,677 with a density of about 859 persons per sq.km. Thiruvananthapuram, with a population density of 1509 persons per sq.km is the most densely populated district in Kerala followed by Alappuzha and Kozhikode with 1501 and 1318 persons per sq.km. Kerala receives rainfall from both south west and north east monsoons. The precipitation is highest in the Western Ghats and the lowest in the vicinity of Palghat gap. Kuttiyadi basin in northern Kerala experiences the highest rainfall of 3934 mm, while Pambar (Amaravathi) basin, which is a rain shadow area, records the lowest annual rainfall of 1367 mm. Kerala State is drained by 41 west flowing rivers and 3 east flowing rivers. The *Bharathapuzha*, *Periyar* and *Pamba* are the most important rivers draining the State. The run-off estimated in the state is about 70165 MCM out of which 42772 MCM is considered to be utilizable (CGWB, 2013).

8.12.1 Identification of Area

Area suitable for ground water augmentation through artificial recharge has been demarcated based on the analysis of available data on depth to water level and long-term water level trends. Average Post-monsoon depth to water level data in the observation wells for the period 2014-18 and water level trends for the period 2009-2018 have been used for the analysis, based on which an area of about 11,957sq.km, excluding reserved forests has been identified as suitable for implementation of artificial recharge (Fig. 8.12.1).

8.12.2 Sub Surface Storage Space and Water Requirement

In order to estimate the sub-surface storage space available for recharge, area suitable for artificial recharge based on deep (>6m) and declining ground water level trends and average post-monsoon water levels were demarcated in each district. The availability of sub-surface storage space in each district is then computed as the product of area feasible and thickness of aquifer zone between 3m bgl and the average post-monsoon water level. The net quantum of source water required to saturate the aquifer up to 3m bgl was then computed as the product of the storage space available, the average specific yield of the aquifer material and the recharge efficiency of the structures. As per the calculation, the volume of unsaturated zone available for recharge below 3m is 810MCM and the quantum of source water required to saturate the available space is 1080 MCM (Table 8.12.1).

8.12.3 Source Water Availability

The data on surface water resources available in various basins in the State were provided by the state government agencies. The data available for each basin includes committed runoff and surplus water available for future planning. The availability of source water was worked out by adding the amount of surface water provided for future planning and surplus available. The availability so worked out for the entire basins were then apportioned for the districts in the basin and then again apportioned for the area identified as suitable for recharge augmentation. The availability of surplus surface water available for recharge augmentation in identified areas for the state as a whole is of the order of 12,455 MCM.

Table 8.12.1 Scope of Artificial Recharge in Kerala

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Trivandrum	2192.00	1046.00	4803.00	120.07	160.09	767.00
2	Kollam	2491.00	1132.00	3124.00	78.10	104.13	790.00
3	Alappuzha	1414.00	137.00	0.00	0.00	0.00	0.00
4	Pathanamthitta	2637.00	486.00	914.00	22.85	30.46	627.00
5	Kottayam	2208.00	399.00	498.00	14.45	19.27	262.00
6	Ernakulam	3068.00	651.00	645.00	19.34	25.78	791.00
7	Idukki	4358.00	234.00	182.00	2.73	3.64	336.00
8	Thrissur	3032.00	1164.00	2306.00	57.64	76.85	1068.00
9	Palakkad	4480.00	858.00	1425.00	21.37	28.50	868.00
10	Malappuram	3550.00	1835.00	5690.00	85.35	113.80	1056.00

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
11	Kozhikode	2344.00	691.00	1465.00	27.84	37.12	623.00
12	Wayanad	2131.00	1050.00	3613.00	108.38	144.50	2189.00
13	Kannur	2966.00	1125.00	3824.00	76.48	101.98	1514.00
14	Kasaragod	1992.00	1149.00	7031.00	175.77	234.36	1564.00
	Total	38863.00	11957.00	35520.00	810.36	1080.48	12455.00

8.12.4 Recharge Structures and Cost Estimates

The areas have been grouped into hard rock and alluvial areas. Surface spreading techniques such as check dams, percolation ponds, gully plugs and nalah bunds; ground water conservation structures such as sub-surface dykes, soil and water conservation methods such as contour bunds have been considered as appropriate structures for ground water augmentation in the State, depending upon topography and hydrogeological setup. Based on the geomorphological and hydrogeological settings, the feasibility of artificial recharge through different structures has been assessed. The number of structures of each category required to facilitate the recharge in each district has been computed accordingly. The net number of recharge structures in the state has been finalized based on NAQUIM studies wherever aquifer mapping is completed. About 50% of the districts in the state has been mapped under NAQUIM and the number of artificial recharge structures feasible in these districts has been arrived at by utilizing the optimum number of structures suggested as outcome of the study. As per the data on water conservation activities provided by various agencies such as MGNREGA, Rural Development Board, Ground Water Department, Soil Conservation department etc, about 1.2cr artificial recharge structures of different types have already been constructed in various parts of state after 2013. The existing artificial recharge structures include check dams, contour bund, earthern bund, farm ponds, gully plug, percolation pond, rain pits, dug well recharge and roof top rain water harvesting.

Thus, taking into consideration of the existing structures, the final figure has been arrived by apportioning the number of structures to the standard unit volume/ capacity as per earlier studies of CGWB and is found to the tune of 3.3 lakh number of structures. Similarly, figures are arrived and projected in a similar manner to the remaining districts considering the geomorphology and hydrogeological set up. In view of the pattern of historical rainfall in Kerala, the structures proposed are expected to have 3 fillings a year and the total quantum of water recharged through each type of structure has been computed accordingly. The details of artificial recharge and its cost estimate are furnished in Table 8.12.2.

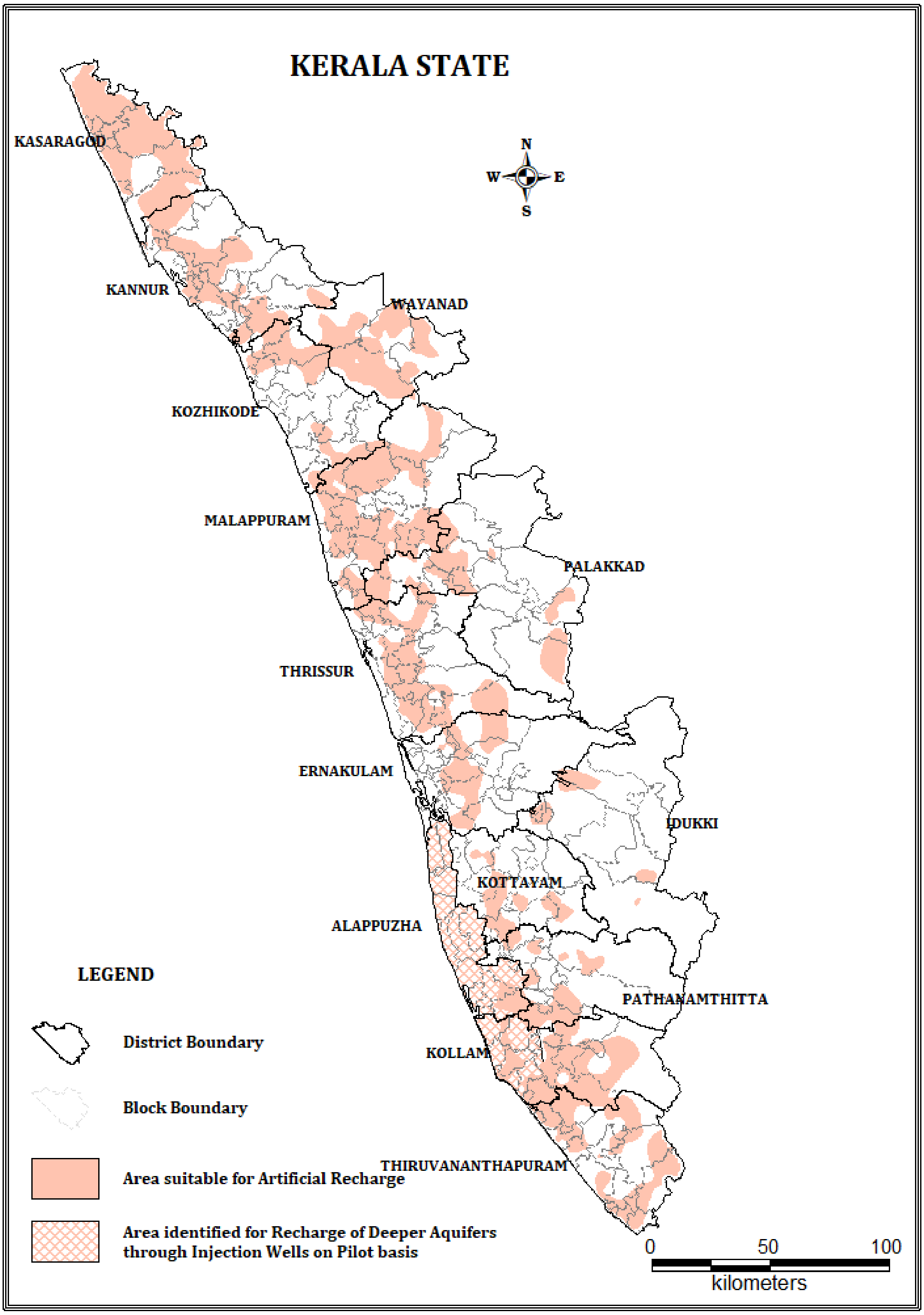


Fig 8.12.1 Identified Areas for Artificial Recharge

Table 8.12.2 Artificial Recharge Structures & Cost Estimates in Kerala

S. No	District	Number of Structures									Cost of Structures(Lakh)									
		CD	PP	CB	GP/Gabion	NB	injection wells	SSD	RTRWH	RTRWH in Commercial Buildings	CD	PP	CB	GP/Gabion	NB	injection wells	SSD	RTRWH	RTRWH in Commercial Buildings	Total Cost (Lakh)
1	Alappuzha	0	0	0	0	0	3	0	0	0	0.00	0.00	0.00	0.00	0.00	20.70	0.00	0.00	0.00	20.70
2	Ernakulam	65	25	171	111	110		10	104593	1	1495.00	575.00	393.30	19.15	253.00		172.50	15688.95	30.00	18626.90
3	Idukki	6	1	15	249	50		2	8193	0	138.00	23.00	34.50	42.95	115.00		34.50	1228.95	0.00	1616.90
4	Kannur	180	125	3000	15000	1250		10	27620	1	4140.00	2875.00	6900.00	2587.50	2875.00		172.50	4143.00	30.00	23723.00
5	Kasaragod	300	300	15000	40000	5250		20	14026	1	6900.00	6900.00	34500.00	6900.00	12075.00		345.00	2103.90	30.00	69753.90
6	Kollam	44	100	2176	13626	1929	2	5	64958	1	1012.00	2300.00	5004.80	2350.49	4436.70	14.95	86.25	9743.70	30.00	24978.89
7	Kottayam	39	20	171	148	71		5	16845	1	897.00	460.00	393.30	25.53	163.30		86.25	2526.75	30.00	4582.13
8	Kozhikode	50	60	2250	10000	1000		5	55826	1	1150.00	1380.00	5175.00	1725.00	2300.00		86.25	8373.90	30.00	20220.15
9	Malappuram	140	150	5250	25000	2500		10	35181	1	3220.00	3450.00	12075.00	4312.50	5750.00		172.50	5277.15	30.00	34287.15
10	Palakkad	58	72	200	700	2560		16	22084	1	1334.00	1656.00	460.00	120.75	5888.00		276.00	3312.60	30.00	13077.35
11	Pathanamthitta	58	53	360	2540	475		16	10295	0	1334.00	1219.00	828.00	438.15	1092.50		276.00	1544.25	0.00	6731.90
12	Thrissur	100	75	1000	6000	1500		4	80348	1	2300.00	1725.00	2300.00	1035.00	3450.00		69.00	12052.20	30.00	22961.20
13	Trivandrum	40	314	3585	47742	7560		8	40375	1	920.00	7222.00	8245.50	8235.50	17388.00		138.00	6056.25	30.00	48235.25
14	Waynad	180	100	7500	35000	3000		10	2444	0	4140.00	2300.00	17250.00	6037.50	6900.00		172.50	366.60	0.00	37166.60
	Total	1260	1395	40678	196116	27255	5	121	482788	10	28980.00	32085.00	93559.40	33830.01	62686.50	35.65	2087.25	72418.20	300.00	325982.01

Sl.No	Type of AR Structure	Unit Capacity	Unit Cost (Lakh)
1	Check Dam	0.033 MCM	23.0
2	Percolation Pond	0.033 MCM	23.0
3	Sub-surface dyke	0.003 MCM	17.25
4	Gully Plugs	0.0001 MCM	0.1725
5	Nalah Bunds/Gabions	0.00225 MCM	2.3
6	Contour Bund	0.00075 MCM	2.3
7	Injection Wells	100/200m depth	5.75/9.20
8	Rooftop Rainwater Harvesting	85 sq.m	0.15
9	Rooftop Rainwater Harvesting in commercial buildings	1000sq.m	30

8.12.5 Artificial Recharge of Deeper Aquifers

Deep confined aquifers in zones below 100m bgl constitute important sources of water supply in Alappuzha and Kollam districts of Kerala. Continued extraction of groundwater for various uses from these aquifers over the last several years has resulted in the decline of piezometric heads. Augmentation of recharge into these aquifers through suitable techniques will help to bring up the piezometric heads in these aquifers and in sustainable development of these aquifers (CGWB, 2013).

Based on the studies carried out by CGWB elsewhere in the country, injection wells for recharging surface runoff has been considered as the most suitable structures for artificial recharge of these aquifers. However, quantification of surface runoff required for recharge has not been computed for want of detailed information pertaining to the intake capacities of these aquifers and long-term decline of piezometric heads in the aquifers. In view of this, it is proposed to implement schemes for recharge augmentation of the deeper sedimentary aquifers in Alappuzha and Kollam districts on pilot basis. Injection wells can be constructed to a depth of 200 and 100m in specific location on pilot basis to check the extent of success. Based on the impact of pilot scheme, more recharge structures can be constructed.

8.12.6 Rooftop Rain Water and Runoff Harvesting In Urban Areas

Roof Top Rainwater Harvesting

There are 6 Corporations, 87 Municipal towns and 1 township in the State of Kerala. The total urban land area is 3640 sq.km with 15 lakh houses supporting population of 63 lakhs (Census, 2011). After excluding the area suitable for implementation of artificial recharge, the remaining 2360 sq.km with 9.75 lakh houses can be considered for roof top rain water harvesting (RWH). Since there are limitations to implement roof top rain harvesting in all houses due to geomorphological and hydrogeological setup, increase in vertical expansion, and constraints in lateral expansion of buildings in recent years, 50% of the available roof top area has been considered as suitable for rooftop rain water harvesting for storage. It figures out to be 4.8 lakh houses with population of 20 lakhs, 500 government buildings and around 50 commercial buildings with roof area more than 1000 sq.m.

The annual rainfall in urban area varies from 2267 mm to 3428 mm with an average annual rainfall of 3000 mm. After accounting for potential-evapotranspiration, precipitation of the order of about 1755 mm is available for conservation. It is estimated that a quantum of 57 MCM of rain water can be harvested from 4.8 lakh residential houses with an average roof area of 85 sq.m, which can be effectively utilized for storage through suitable roof top rainwater harvesting structures by considering 80% efficiency of the system. In view of space constrains and social acceptance, collection tanks with $2m^3$ will be ideal for individual households. Based on the land availability the size of the storage tanks can be increased up to $4m^3$. The average expenditure for providing necessary arrangements such as gutters, pipes along with storage tank for residential houses have been assessed as Rs. 15,000/- per unit and thus the total cost comes about Rs. 724.18 crores (Table. 8.14.2).

In the case of commercial buildings, limitations such as non-availability of space and fiscal constraints for construction of huge storage tanks are very significant. The potential was computed for 50 commercial buildings that come to a tune of 0.07 MCM. As the minimum per-capita requirement exists under flushing category (15-20 lpcd), this potential may be utilized for flushing throughout the year by constructing a storage tank of $100m^3$. In the case of commercial buildings, the cost involved for construction and installation of rain water harvesting system (Rs. 30/- per litre) will be Rs. 30.0 lakhs. To validate the feasibility and potential benefits, a pilot project, with 10 government buildings can be selected to implement and the total cost is Rs. 3.0 crore. The water requirement for about 500 government buildings and schools at the rate of 1000 to 2000 liters per day is around is 274 m^3. Presently, majority of these buildings harness rain water under various schemes and average unit cost for conservation structure is 0.5 lakh for a building with roof area 100 sq.m.with recharge pit capacity ranging from $10m^3$ to $20m^3$ (GWD, Govt. of Kerala).

Thus, the total cost for the roof top rain water harvesting in the state has been estimated to be Rs. 724.18Crores in the first phase. If the pilot project of implementation of RWH in commercial buildings is successful, the remaining buildings can be considered in the second phase. Buildings in topographic highs in midland and highland regions and houses located in brackish water zone in coastal tracts can be given priority.

8.12.7 Total Cost

The total cost estimate for artificial recharge in Kerala is Rs 3259.82Cr with a break up of Rs 2535.64 Cr for rural areas & Rs 724.18 Cr for urban areas.

8.13 MADHYA PRADESH

Madhya Pradesh is a land locked State located in the central part of India. It has a geographical area of 3,08,339.84 Sq. km. There are 52 districts and 313 Community Development blocks in Madhya Pradesh. The population of State as per census 2011 is 7,25,97,565 with a population density of 236 persons per sq.km area. Out of total population, 74.7% is rural. Madhya Pradesh is drained by five major river basins namely Ganga, Narmada, Godavari, Tapi and Mahi.The state is underlain by various geological formations ranging in age from the Archaean to the Recent. Hard rock areas cover more than 80% of total land area of the State.

8.13.1 Identification of Area

In addition to the area with post monsoon water level (2018) and long term post monsoon water level trend(2009-2018) showinga declining trend (>0.10m/year), the following additional criteria have been considered for identification of area for artificial recharge in the state.

- OCS (Over Exploited, Critical & Semi Critical) Blocks having depth to water level >3m bgl
- Water scarce area inBundelkhand Region having water level >3m bgl (Chhatarpur, Damoh, Datia, Panna, Sagar and Tikamgarh Districts).
- Safe Blocks, where water level is greater than 9m bgl without considering the trend

The area identified for artificial recharge has been provided in Fig 8.13.1 & is found in the order of 1,46,053 sq. km.

8.13.2 Available Sub-Surface Storage & Surface Water Requirement

The thickness of available unsaturated zone (below 3 m bgl) is estimated by considering the different ranges of water level. The volume unsaturated sub surface zone is estimated by multiplying the thickness and the area and is of the order of 758453 MCM. The volume available for artificial recharge is given by the product of unsaturated zone and specific yield and is of the order of 24957 MCM. Considering an efficiency of 75% of these artificial recharge structures, water required for artificial recharge works out to be 33193 MCM (Table .8.13.1).

8.13.3 Source Water Availability for Artificial Recharge

The rainfall received during southwest monsoon between June and September is the principal source of water in the state of Madhya Pradesh. The surface water resources have been calculated block wise by considering Strange's Table. Out of 81500 MCM, 56000 MCM is allocated for Madhya Pradesh and remaining 27000 MCM is allocated to neighboring states by virtue of different interstate agreements (www.mpwrd.gov.in). 44064 MCM available surface water, is committed to Major, Medium and Minor projects, leaving a balance of non-committed runoff is 11936 MCM. In some of the blocks the non-committed runoff is more than the water requirement, whereas, in other blocks it is less than requirement. Considering the water requirement and availability, 9188 MCM water is proposed to be utilised for artificial recharge.

Table 8.13.1. Scope for Artificial Recharge in Madhya Pradesh

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Agar	2722	2516	12936	259	344	196
2	Alirajpur	3318	516	4784	144	191	38
3	Ashoknagar	4674	1071	4623	92	123	60
4	Barwani	5422	2529	22533	467	621	231
5	Betul	10043	3945	22090	442	588	353
6	Bhind	4459	3431	41557	4156	5527	121
7	Bhopal	2772	1284	3195	64	85	80
8	Burhanpur	3233	2571	18031	499	664	157

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
9	Chhatarpur	8687	7904	33164	497	662	521
10	Chhindwara	11815	4980	33465	669	890	526
11	Damoh	7306	4746	13876	208	277	264
12	Datia	2691	2662	16250	1351	1797	121
13	Dewas	7021	5708	40849	817	1087	477
14	Dhar	8153	2957	13938	279	371	145
15	Guna	6390	2364	13774	275	366	197
16	Gwalior	4564	2531	23870	1131	1504	128
17	Hoshangabad	6704	1966	16542	2055	2733	368
18	Indore	3898	3819	24041	481	639	234
19	Jabalpur	5221	464	3112	93	124	54
20	Katni	4894	1256	8612	215	286	132
21	Khandwa	7525	861	1120	22	30	30
22	Khargone	8030	1321	6830	137	182	55
23	Mandsaur	5535	4990	20419	408	543	202
24	Morena	4989	3874	45150	3298	4386	159
25	Narsinghpur	5133	2182	11311	1448	1926	159
26	Neemuch	4200	3757	10022	200	267	163
27	Panna	7135	6625	17323	281	373	373
28	Raisen	8466	4225	14010	280	373	207
29	Rajgarh	6155	6155	27948	559	743	401
30	Ratlam	4861	4616	22152	443	589	256
31	Rewa	6314	1539	11263	169	225	148
32	Sagar	10252	9254	27585	414	550	447
33	Satna	7502	2620	10056	151	201	151
34	Sehore	6578	3517	22100	442	588	301
35	Shahdol	5841	750	4976	100	132	66
36	Shajapur	3473	3396	15670	313	417	250
37	Sheopur	6606	3698	29848	448	595	149
38	Shivpuri	10278	9770	30843	493	656	475
39	Sidhi	4854	660	4986	75	99	64
40	Singrauli	5672	1399	5978	179	239	86
41	Tikamgarh	5048	4881	9908	149	198	198
42	Ujjain	6130	5930	32469	649	864	355
43	Umaria	4539	813	5242	105	139	91
Total		**259105**	**146053**	**758453**	**24957**	**33193**	**9188**

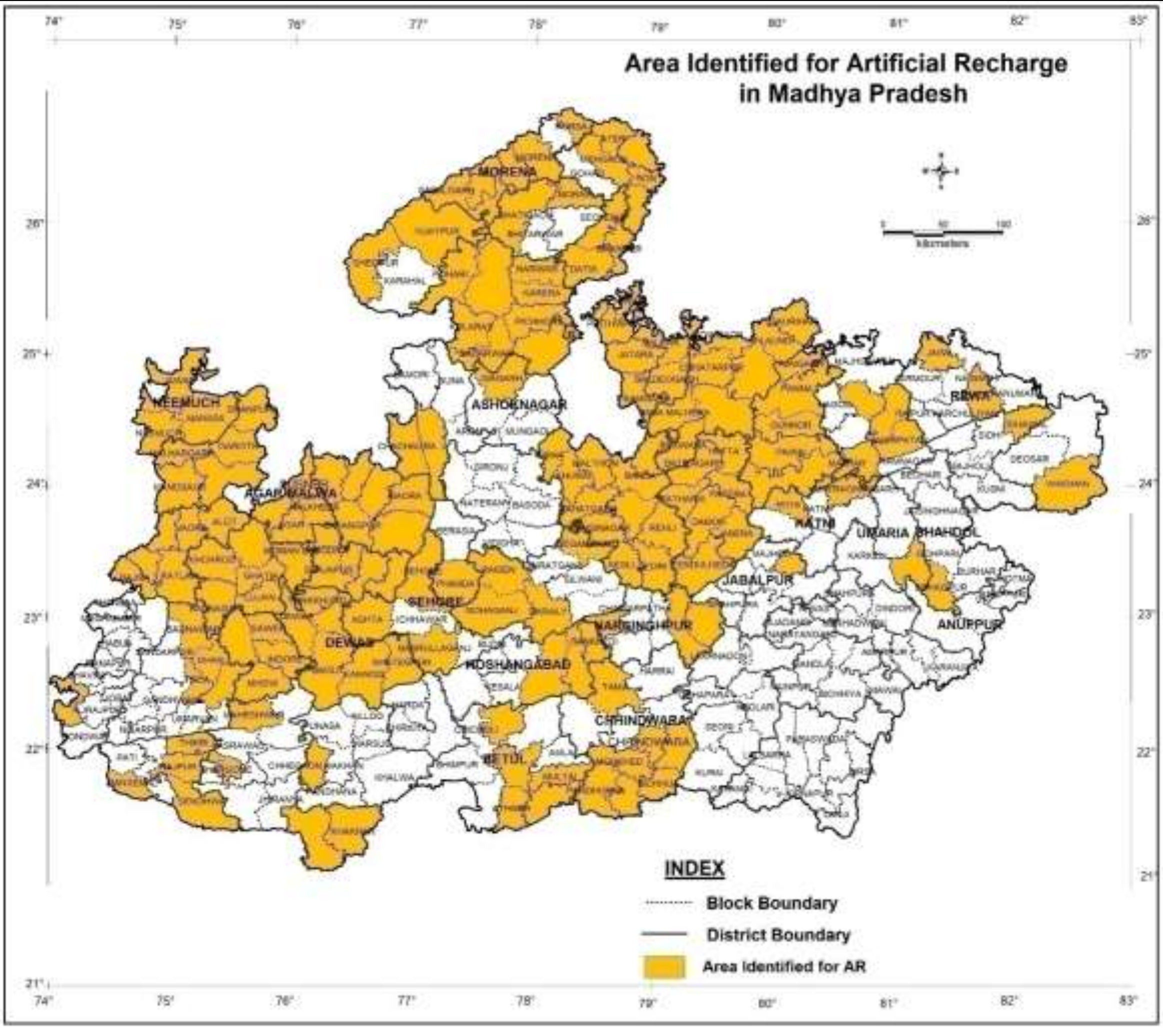


Fig. 8.13.1Area identified for Artificial Recharge in Madhya Pradesh

8.13.4 Artificial Recharge & Cost Estimates

The areas have been broadly grouped into hard rock and alluvial areas. In hard rock areas the surface spreading techniques consisting of percolation tanks and Check dams/cement plugs/nala bunds along with recharge shafts are most appropriate. In alluvial areas the percolation tanks in mountain fronts are most suitable. Recharge shaft in check dam will facilitate direct recharge to the ground water. Accordingly, these structures have been recommended for artificial recharge.Other structures like contour trenches and gabion structure etc. may also be taken up side-by-side, which would be more appropriate for soil and moisture conservation. The underground Bhandaras or sub surface dykes are ground water conservation structures and hence may be taken up at site specific location to conserve the ground water at technically suitable locations.The storage capacity of recharge structure was worked out based on the findings of various artificial recharge studies under taken in Madhya Pradesh. Depending upon the rainfall pattern during the monsoon season, 3 to 4 fillings of the structures are considered to arrive at the storage capacity of the structure.Based on the field situation it has been considered that 35% storage would be through percolation tank, 45% by check dams, 15% by nala bunds and cement plug, and remaining 5% by Renovation of village ponds/form pond. The structures constructed and have been deducted from the proposed number of structures. The cost of artificial recharge through these interventions works out to be Rs 9708.66**Cr** (Table 8.13.2).

Rainwater Harvesting

Rainwater Harvesting In Urban Area

Rooftop Rainwater Harvesting has been considered in four Cities having population of more than one Million, Namely Bhopal, Indore, Gwalior and Jabalpur. 30 % of the total household (as per 2011 Census) have been considered for Roof Top Rainwater Harvesting. Total 408938 households are considered for RTRWH. Considering average 50 Sq m area for each household, total roof area is estimated as 20446830Sq m (20.45 sq. km). It is estimated that 17.41 MCM/yr will recharge from these measures.

The average expenditure on providing the necessary arrangements through pipe fittings, filters etc. to divert the roof water to existing structure Tubewell/Borewell/Dugwell) has been considered as Rs. 20000/- per house. The total cost of Roof Top Rainwater Harvesting in the urban areas of the State works out Rs. 817.88Crore.(Table 8.13.2)

8.13.5 Total Cost Estimates

The total cost of artificial recharge for the State of Madhya Pradesh is of the order of Rs 10526.54 Cr, out of which, cost estimate for Rural area is of the order of Rs 9708.66 Cr and Urban area is 817.88 Cr.

Table 8.13.2 Artificial Recharge in Madhya Pradesh

S.No	District	Number of Structure						Unit Cost structure (Lakh)						Cost of Structure (Lakh)						Total Cost (Lakh)
		CD	RS	VP	PT	NB/CP	RTRWH	CD	RS	VP	PT	NB/CP	RTRWH	CD	RS	VP	PT	NB/CP	RTRWH	
1	Agar	2667	2667	480	310	2855		6	1	2.5	20	1		16002	2667	1200	6200	2855		28924
2	Alirajpur	112	112	120	0	369		6	1	2.5	20	1		672	112	300	0	369		1453
3	Ashoknagar	480	480	176	24	782		6	1	2.5	20	1		2880	480	440	480	782		5062
4	Barwani	501	501	421	227	3327		6	1	2.5	20	1		3006	501	1053	4540	3327		12426.5
5	Betul	0	0	645	497	5103		6	1	2.5	20	1		0	0	1613	9940	5103		16655.5
6	Bhind	1735	1735	675	198	1378		6	1	2.5	20	1		10410	1735	1688	3960	1378		19170.5
7	Bhopal	1144	1144	189	139	1179	119000	6	1	2.5	20	1	0.2	6864	1144	472.5	2780	1179	23800.00	36239.50
8	Burhanpur	138	138	256	25	0		6	1	2.5	20	1		828	138	640	500	0		2106
9	Chhatarpur	274	274	1036	698	6823		6	1	2.5	20	1		1644	274	2590	13960	6823		25291
10	Chhindwara	3316	3316	1036	567	7758		6	1	2.5	20	1		19896	3316	2590	11340	7758		44900
11	Damoh	2986	2986	1143	325	3445		6	1	2.5	20	1		17916	2986	2858	6500	3445		33704.5
12	Datia	1201	1201	588	192	1035		6	1	2.5	20	1		7206	1201	1470	3840	1035		14752
13	Dewas	5912	5912	1008	630	6763		6	1	2.5	20	1		35472	5912	2520	12600	6763		63267
14	Dhar	194	194	573	71	1868		6	1	2.5	20	1		1164	194	1433	1420	1868		6078.5
15	Guna	233	233	606	321	2942		6	1	2.5	20	1		1398	233	1515	6420	2942		12508
16	Gwalior	1520	1520	226	201	1782	67613	6	1	2.5	20	1	0.2	9120	1520	565	4020	1782	13522.60	30529.60
17	Hoshangabad	5338	5338	385	627	5488		6	1	2.5	20	1		32028	5338	962.5	12540	5488		56356.50
18	Indore	3285	3285	602	387	3367	138623	6	1	2.5	20	1	0.2	19710	3285	1505	7740	3367	27724.60	63331.60
19	Jabalpur	745	745	149	94	794	83702	6	1	2.5	20	1	0.2	4470	745	372.5	1880	794	16740.40	25001.90
20	Katni	984	984	237	200	1868		6	1	2.5	20	1		5904	984	592.5	4000	1868		13348.5
21	Khandwa	0	0	85	19	308		6	1	2.5	20	1		0	0	212.5	380	308		900.5
22	Khargone	0	0	225	0	666		6	1	2.5	20	1		0	0	562.5	0	666		1228.5
23	Mandsaur	1073	1073	878	113	2878		6	1	2.5	20	1		6438	1073	2195	2260	2878		14844
24	Morena	1101	1101	687	161	2209		6	1	2.5	20	1		6606	1101	1718	3220	2209		14853.5
25	Narsinghpur	2074	2074	535	230	2225		6	1	2.5	20	1		12444	2074	1338	4600	2225		22680.5
26	Neemuch	2240	2240	670	210	2435		6	1	2.5	20	1		13440	2240	1675	4200	2435		23990
27	Panna	4622	4622	909	521	4890		6	1	2.5	20	1		27732	4622	2273	10420	4890		49936.5

S.No	District	Number of Structure						Unit Cost structure (Lakh)						Cost of Structure (Lakh)						Total Cost (Lakh)
		CD	RS	VP	PT	NB/CP	RTRWH	CD	RS	VP	PT	NB/CP	RTRWH	CD	RS	VP	PT	NB/CP	RTRWH	
28	Raisen	2917	2917	843	304	3003		6	1	2.5	20	1		17502	2917	2108	6080	3003		31609.5
29	Rajgarh	1142	1142	1647	592	5867		6	1	2.5	20	1		6852	1142	4118	11840	5867		29818.5
30	Ratlam	3207	3207	1048	148	3750		6	1	2.5	20	1		19242	3207	2620	2960	3750		31779
31	Rewa	1526	1526	784	255	2187		6	1	2.5	20	1		9156	1526	1960	5100	2187		19929
32	Sagar	4664	4664	1849	758	5822		6	1	2.5	20	1		27984	4664	4623	15160	5822		58252.5
33	Satna	874	874	724	240	1369		6	1	2.5	20	1		5244	874	1810	4800	1369		14097
34	Sehore	3513	3513	759	469	4452		6	1	2.5	20	1		21078	3513	1898	9380	4452		40320.5
35	Shahdol	0	0	158	100	947		6	1	2.5	20	1		0	0	395	2000	947		3342
36	Shajapur	2772	2772	576	429	3478		6	1	2.5	20	1		16632	2772	1440	8580	3478		32902
37	Sheopur	1633	1633	377	220	2076		6	1	2.5	20	1		9798	1633	942.5	4400	2076		18849.5
38	Shivpuri	2397	2397	1216	732	6380		6	1	2.5	20	1		14382	2397	3040	14640	6380		40839
39	Sidhi	568	568	292	111	837		6	1	2.5	20	1		3408	568	730	2220	837		7763
40	Singrauli	1058	1058	203	0	1241		6	1	2.5	20	1		6348	1058	507.5	0	1241		9154.5
41	Tikamgarh	61	61	851	217	2545		6	1	2.5	20	1		366	61	2128	4340	2545		9439.5
42	Ujjain	5015	5015	1086	593	5212		6	1	2.5	20	1		30090	5015	2715	11860	5212		54892
43	Umaria	780	780	105	154	1324		6	1	2.5	20	1		4680	780	262.5	3080	1324		10126.5
Total		**76002**	**76002**	**27058**	**12309**	**125027**	**408938**	6	1	2.5	20	1	0.2	**456012**	**76002**	**67645**	**246180**	**125027**	**81787.60**	**1052653.60**

Note: PT: Percolation Tank, CD: Check Dam, RS: Recharge Shaft, NB/CP: Nala Bund/Cement Plug, VP: Village Pond, **RTRWH: Roof Top Rain water Harvesting**

8.14 MAHARASHTRA

Maharashtra State covers an area of 3,07,713 sq.km. and comprises of 36 districts and 355 talukas. There are 40959 inhabited villages and 2706 un-inhabited villages. As per 2011 census, the population of Maharashtra state is 112.37 million and is ranked 2nd by population and 3rd in terms of area. The State is highly urbanised with 45.2 per cent population living in towns. The State experiences south west monsoon with rainfall ranging from 6000 mm in Western Ghats to less than 500 mm in Madhya Maharashtra. The eastern part of Maharashtra, known as Vidharba Region, receives rainfall up to 1500 mm. Maharashtra falls in four major basins, viz., Godavari (49%), Krishna (22.6%), Tapi-Purna (16.7%) and west flowing small rivers known as Coastal river basin. These basins represent varied hydrogeological, meteorological and agroclimatic features.

The geology of Maharashtra is famous for the Deccan Traps, which occur in all the districts of the State, except Bhandara, Gondia and Gadchiroli. The other geological formations, older and younger than Deccan Traps, occur in the northeast and as isolated patches in the Sindhudurg and Ratnagiri districts. The Deccan Trap occupies nearly 82 % area of the State, whereas other hard rocks area occupy around 10% and remaining 8% of the area is occupied by soft rock and alluvium in the state. The plan for artificial recharge is prepared considering the hydrogeological parameters and hydrological data base.

8.14.1 Identification of Area

The area for artificial recharge was identified based on long term decadal (2009-18) post monsoon (November) depth to water levels, long term post monsoon decadal water level trend (2009-18), OCS areas (2017), aquifer type, sub-regional issues etc. An area of 1,23,884 Sq.Km. had been identified for artificial recharge in parts of 267 blocks of 32 districts of Maharashtra State out of the total 36 districts and 355 talukas in the State. In 2 districts i.e., Raigarh and Thane, there is no scope for artificial recharge as per above criterions, whereas 2 districts i.e., Mumbai and Mumbai sub-urban being completely urban districts artificial recharge structures are not feasible. However, in urban areas of all these 4 districts, RTRWH and Runoff Rainwater Harvesting has been proposed. The areas feasible for artificial recharge are shown in Fig.8.14.1.

8.14.2 Sub-Surface Storage and Water Requirement

The thickness of available unsaturated zone (below 3 m bgl) is estimated by considering the mean water levels in the taluka/block below 3 mbgl.

The total volume of unsaturated strata is calculated as 330024.51 MCM in hard rock areas and 103629.54 MCM in soft rock areas. This volume was then multiplied by aquifer wise specific yields to arrive at water required for artificial recharge. Thus, the sub-surface storage potential / water required for artificial recharge in hard rock areas was estimated at 6563.08 MCM of and 7058.15 MCM in soft rock areas, totaling 13621.23 MCM of water requirement.

However, based on the experiences gained in the field experiments, an average recharge efficiency of 75% can be achieved by the individual structure. Thus 18081.09 MCM is required as source water to bring water level up to 3m bgl (Table. 8.14.1).

Table 8.14.1 Scope of Artificial Recharge in Maharashtra

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Ahmadnagar	17048	11349	43134	863	1150	262
2	Akola	5421	3004	19909	1241	1655	31
3	Amravati	12210	5661	19954	943	1258	81
4	Aurangabad	10107	5269	20296	406	541	110
5	Beed	10693	8261	26135	523	697	187
6	Bhandara	4087	1170	3558	172	229	26
7	Buldana	9661	6881	25228	1145	1527	104
8	Chandrapur	11443	2614	4032	112	150	58
9	Dhule	7195	4715	12226	502	670	49
10	Gadchiroli	14412	190	168	3	3	4
11	Gondia	5234	356	357	5	7	903
12	Hingoli	4827	3254	11310	226	302	73
13	Jalgaon	11765	6757	45560	2744	3659	70
14	Jalna	7718	3727	13650	273	364	83
15	Kolhapur	7685	380	456	9	12	9
16	Latur	7157	3286	12570	251	335	73
17	Mumbai	69	Not Feasible	-	-	-	-
18	Mumbai (Suburban)	534	Not Feasible	-	-	-	-
19	Nagpur	9892	4900	16245	334	445	110
20	Nanded	10528	3149	9657	193	258	70
21	Nandurbar	5955	2280	13143	896	1195	32
22	Nasik	15530	6334	25441	509	678	266
23	Osmanabad	7569	3576	10887	218	290	84
24	Parbhani	6214	2809	10649	213	284	63
25	Pune	15643	5375	16871	337	450	132
26	Raigarh	7152	0	-	-	-	-
27	Ratnagiri	8208	1361	7749	155	207	285
28	Sangli	8572	3124	11815	236	315	77
29	Satara	10480	4007	9657	193	258	98
30	Sindhudurg	5207	533	1165	23	31	112
31	Solapur	14895	8355	19496	390	520	205
32	Thane	4497	0	-	-	-	-
33	Palghar	5061	489	1017	70	93	11
34	Wardha	6311	2247	4722	94	126	50
35	Washim	5153	3664	7664	153	124	45
36	Yavatmal	13582	4804	8935	187	249	107
Total		**307715**	**123884**	**433654**	**13621**	**18081**	**3872**

8.14.3 Source Water Availability

The surface water resources available in various basins & sub basins were calculated based on information provided by the state government. The data available for each sub basin included committed runoff, reserved for future planning and surplus water available.
In order to account for the requirement of identified area, taluka wise apportioning of surface water availability was done from Sub basin. A total of 12308 MCM run off/surface water is available in the State and can be utilized for artificial recharge, however after proportioning it for the target area of 123884 sq. km, the surface water availability comes out to be 3871.98 MCM. Invariably the proportionate surface water availability is less (3871.98 MCM) and the storage volume or requirement of surface water for AR is more (13621.23 MCM). However, in coastal districts of Maharashtra and Gadchiroli, Dhule, Nandurbar districts, the availability of source water is more and the requirement for artificial recharge is less due to shallow ground water level conditions. Further, only 75% of the surface water available was considered as available for artificial recharge since the entire surface runoff availability cannot be considered as many un-planned recharge activities through NGO's and other private organisations are also taken-up. Thus the proportionate surface water availability for artificial recharge is 2060.52 MCM for the State (Hard rock areas -1921.43 MCM and Soft rock/Alluvial areas-139.09 MCM).

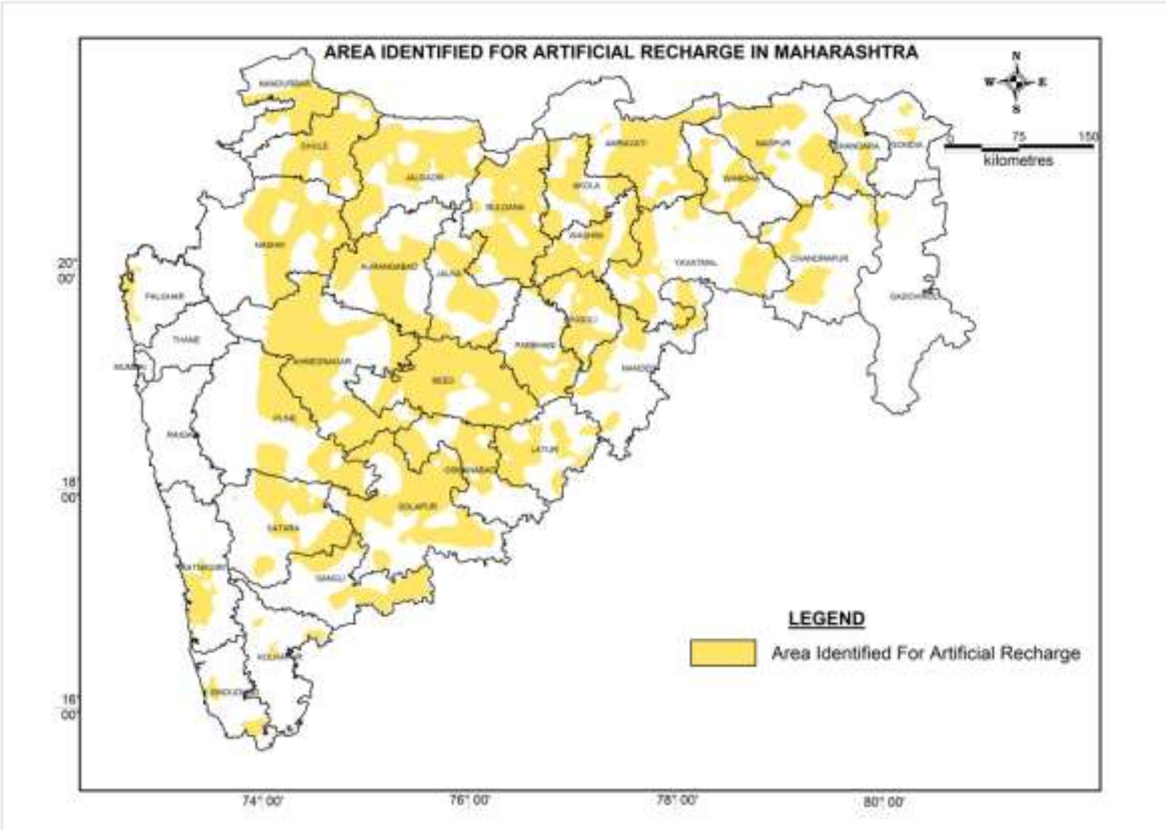


Fig 8.14.2. Areas Identified for Artificial Recharge

8.14.4 Recharge Structures and Cost Estimates

The areas have been broadly grouped into hard rock and alluvial areas. In hard rock areas i.e. Godavari, Krishna, Coastal basins and part of Tapi-Purna, the surface spreading techniques consisting of percolation tanks and cement plugs/bunds are most appropriate. In alluvial areas i.e. part of Tapi and Purna basins, the percolation tanks in mountain fronts and recharge shaft in alluvial/bazada zone are the most feasible structures. Accordingly, these structures have been recommended for artificial recharge. The storage capacity for different structures considering multiple fillings is worked out as 200 TCM (100 TCM for single filling) for percolation tanks, 30TCM (10 TCM for single filling) for check dams and 60 TCM (1 TCM/day*60 days) for recharge shafts. Other structures like contour trenches, gabion structure, nala bunds, village ponds etc. may also be taken up side by side which would be more appropriate for soil and moisture conservation. Besides these, many site specific popular practices are being adopted by state govt. which can also be taken depending upon local hydrogeological settings in lieu of proposed percolation tanks and check dams. The under-ground bandharas or sub surface dykes & KT Weirs are ground/surface water conservation structures and hence can be taken up at site specific location to conserve the ground water.

The amount of surface water considered for planning the artificial recharge is 2060.52 MCM. Based on the field situation it has been considered that 70% storage would be through percolation tanks and remaining by check dams (Hard rock areas) or recharge shafts (Alluvial areas). Accordingly 1436.38 MCM (70%) will be stored in percolation tanks, 577.12 MCM will be stored in Cement plugs/check dams and 46.93 MCM through recharge shafts. Therefore, 7188 percolation tanks, 19243 check dams/cement plugs and 838 recharge shafts are proposed in the identified areas of Maharashtra. The percolation tanks should be constructed on second and third order drainage, on favorable hydrogeological and physiographical locations. The cement plugs can be constructed on 1st and 2nd order of drainage.

The cost estimate for artificial recharge structures viz., percolation tank and check dams/cement plugs for different regions are worked out based on the "Common Schedule of Rates -2018" (CSR-2018) of Water Resources Department, Govt. of Maharashtra. In respect of recharge shaft, the rates of Rural Water Supply Division, ZillaParishad were considered.

Table 8.14.2 Cost estimates as per CSR – 2018

S. No.	Region	Cost of 100 TCM Percolation Tank (Rs. in Cr)	Cost of 10 TCM Check Dam / Cement Plug (Rs. in Cr)	Cost of 60 TCM Recharge Shaft (Rs. in Cr)
1	Vidarbha	1.75145	0.194230	0.075
2	Marathwada	1.32332	0.146750	0.075
3	Kokan	1.36226	0.120855	0.075
4	Rest of Maharashtra	1.32332	0.146750	0.075

Therefore, an expenditure of total Rs.13219.12 crores is estimated to undertake the construction of proposed recharge structures. The district wise plan of artificial recharge is given in Table 8.14.3.

Table 8.14.3 Artificial Recharge & Cost Estimate in Maharashtra

S.No	District	Number of Structures					Unit Cost structure (Lakhs)					Cost of Structures (Lakhs)					Total Cost (Lakhs)
		CD	RS	RTRWH	PT	Urban Runoff Harvesting	CD	RS	RTRWH	PT	Urban Runoff Harvesting	CD	RS	RTRWH	PT	Urban Runoff Harvesting	
1	Ahmadnagar	1967	0	95471	688	320	14.7	7.5	0.3	132.3	7.5	28865.73	0.00	28641.15	91043.04	2400.00	150949.92
2	Akola	105	71	72765	82	215	19.4	7.5	0.3	175.1	7.5	2039.42	515.28	21829.50	14361.48	1612.50	40358.18
3	Amravati	354	132	108585	211	215	19.4	7.5	0.3	175.1	7.5	6875.74	957.99	32575.35	36954.54	1612.50	78976.12
4	Aurangabad	769	0	165483	269	275	14.7	7.5	0.3	132.3	7.5	11285.08	0.00	49644.75	35596.77	2062.50	98589.10
5	Beed	1405	0	50124	490	135	14.7	7.5	0.3	132.3	7.5	20618.38	0.00	15037.05	64841.70	1012.50	101509.63
6	Bhandara	132	33	26572	67	180	19.4	7.5	0.3	175.1	7.5	2563.84	239.50	7971.45	11734.38	1350.00	23859.16
7	Buldana	588	92	59241	267	195	19.4	7.5	0.3	175.1	7.5	11420.72	667.69	17772.15	46762.38	1462.50	78085.44
8	Chandrapur	84	126	90229	111	345	19.4	7.5	0.3	175.1	7.5	1631.53	914.45	27068.70	19440.54	2587.50	51642.72
9	Dhule	309	33	56079	129	155	14.7	7.5	0.3	132.3	7.5	4534.58	239.50	16823.55	17070.57	1162.50	39830.69
10	Gadchiroli	27	0	14011	9	90	19.4	7.5	0.3	175.1	7.5	524.42	0.00	4203.30	1576.26	675.00	6978.98
11	Gondia	60	0	24265	18	150	19.4	7.5	0.3	175.1	7.5	1165.38	0.00	7279.35	3152.52	1125.00	12722.25
12	Hingoli	545	0	16307	192	45	14.7	7.5	0.3	132.3	7.5	7997.88	0.00	4891.95	25407.36	337.50	38634.69
13	Jalgaon	336	107	139537	184	335	14.7	7.5	0.3	132.3	7.5	4930.80	776.55	41860.95	24348.72	2512.50	74429.52
14	Jalna	625	0	35397	219	60	14.7	7.5	0.3	132.3	7.5	9171.88	0.00	10618.95	28980.27	450.00	49221.10
15	Kolhapur	58	0	135861	19	380	14.7	7.5	0.3	132.3	7.5	851.15	0.00	40758.15	2514.27	2850.00	46973.57
16	Latur	551	0	59082	193	105	14.7	7.5	0.3	132.3	7.5	8085.93	0.00	17724.45	25539.69	787.50	52137.57
17	Mumbai			337170		100			0.3		7.5	0.00		101150.85		750.00	101900.85
18	Mumbai (Suburban)			1052802		100			0.3		7.5	0.00		315840.60		750.00	316590.60
19	Nagpur	755	27	350774	280	650	19.4	7.5	0.3	175.1	7.5	14664.37	195.95	105232.05	49039.20	4875.00	174006.57
20	Nanded	514	0	85547	179	290	14.7	7.5	0.3	132.3	7.5	7542.95	0.00	25663.95	23687.07	2175.00	59068.97
21	Nandurbar	95	74	25369	82	135	14.7	7.5	0.3	132.3	7.5	1394.13	537.06	7610.70	10851.06	1012.50	21405.44
22	Nasik	1859	0	312039	650	460	14.7	7.5	0.3	132.3	7.5	27280.83	0.00	93611.70	86014.50	3450.00	210357.03
23	Osmanabad	585	0	27394	205	120	14.7	7.5	0.3	132.3	7.5	8584.88	0.00	8218.05	27127.65	900.00	44830.58
24	Palghar	4	126	185860	0	335	12.1	7.5	0.3	0.0	7.5	48.34	914.45	55757.85	0.00	2512.50	59233.14
25	Parbhani	471	0	52366	167	120	14.7	7.5	0.3	132.3	7.5	6911.93	0.00	15709.65	22099.11	900.00	45620.69
26	Pune	982	0	685766	345	595	14.7	7.5	0.3	132.3	7.5	14410.85	0.00	205729.65	45653.85	4462.50	270256.85
27	Raigarh			115293		630			0.3		7.5	0.00		34587.90		4725.00	39312.90
28	Ratnagiri	1550	0	30899	543	240	12.1	7.5	0.3	136.2	7.5	18731.75	0.00	9269.55	73967.46	1800.00	103768.76

S.No	District	Number of Structures					Unit Cost structure (Lakhs)					Cost of Structures (Lakhs)					Total Cost (Lakhs)
		CD	RS	RTRWH	PT	Urban Runoff Harvesting	CD	RS	RTRWH	PT	Urban Runoff Harvesting	CD	RS	RTRWH	PT	Urban Runoff Harvesting	
29	Sangli	546	0	77975	191	140	14.7	7.5	0.3	132.3	7.5	8012.55	0.00	23392.50	25275.03	1050.00	57730.08
30	Satara	717	0	62574	250	330	14.7	7.5	0.3	132.3	7.5	10521.98	0.00	18772.20	33082.50	2475.00	64851.68
31	Sindhudurg	233	0	13319	81	120	12.1	7.5	0.3	136.2	7.5	2815.81	0.00	3995.70	11033.82	900.00	18745.33
32	Solapur	1536	0	139804	537	230	14.7	7.5	0.3	132.3	7.5	22540.80	0.00	41941.05	71061.21	1725.00	137268.06
33	Thane			807924		675			0.3		7.5	0.00		242377.05		5062.50	247439.55
34	Wardha	377	0	48677	132	195	19.4	7.5	0.3	175.1	7.5	7322.47	0.00	14602.95	23118.48	1462.50	46506.40
35	Washim	349	0	20531	123	60	19.4	7.5	0.3	175.1	7.5	6778.63	0.00	6159.15	21542.22	450.00	34930.00
36	Yavatmal	755	17	65692	275	270	19.4	7.5	0.3	175.1	7.5	14664.37	123.38	19707.60	48163.50	2025.00	84683.84
Total		**19243**	**838**	**5646772**	**7188**	**8995**						**294789**	**6082**	**1694031**	**1021041**	**67463**	**3083406**

8.14.5 Roof Top Rain Water and Runoff Harvesting In Urban Areas

Considering the over-all demographic, climatic, hydrogeological, physiographic and socio-economic set up and quality of the source water available in the urban areas, following recharge techniques are proposed- Roof Top Rainwater Harvesting (RTRWH) & Runoff Rainwater Harvesting

Roof Top Rainwater Harvesting

These techniques are feasible in densely populated urban pockets where land availability for construction of tanks/reservoirs etc. is almost non-existent and quality of surface water is very poor due to domestic pollution. As per 2011 census there are 537 urban towns with 1,12,93,543 households in 36 districts of the State. In the absence of data on the exact size of each individual house, an average roof size of 50 sq.m has been considered and further, due to various losses, 80% of the volume of rainwater from the roof is considered for harvesting. Considering a roof area of area of 564.68 sq.m and an average annual rainfall for the period 2009-18, total harnessable rainwater from roof area works out to be 917.87 MCM. In the areas of shallow water table, the harnessed water can be used to augment the water supply instead of using for recharge. In the proposed plan the households having dugwell or borewell etc, which is about 50% (56,46,772) are targeted for recharging the harnessed water from roof top. An average cost for providing the necessary arrangements, for recharge into existing wells shall be around Rs. 30,000/- per house. The estimated total cost comes out to be Rs. 16940.31 crores for covering all the 537 urban towns (Table 8.14.4). Since only 50% of the households are considered for RTRWH, the rainwater available on roof tops will be 458.935 MCM. The above quantity of rainwater is received at rooftop but same is not available down the roof due to various losses in the form of moisture absorption, evaporation losses and leakage etc. Therefore 80% of the above figure i.e., 367.148 MCM is considered available for harvesting the rainwater which will be taken as source for artificial recharge to ground water. The recharge efficiency of the structures is considered 75%, thus ultimate recharge potential available by RTRWH is about 275.361MCM. It is estimated that about 226 lakh additional urban population would get adequate water supply round the year by implementing this scheme.

Runoff Water Harvesting

The rainfall runoff flowing from the roads and open grounds is substantial during rains, which ultimately flows out of the city unutilized. This water if conserved and utilized properly for recharging the ground water reservoir may bring much needed relief to the water scarcity areas of the city. A scheme suitable for artificial recharge in urban area was prepared by C.G.W.B and was successfully implemented and operated at Nagpur Municipal Corporation ground. In this scheme about 15000 sq.m of residential catchment was intercepted and runoff generated was diverted into the specially constructed recharge well in the public garden. The runoff water was filtered silt free by providing a filter pit. Number of such locations can be identified within city areas where such structure may be constructed to provide a sustainable ground water based water supply in the city.

It is estimated that in 537 urban areas of Maharashtra around 8995 schemes would be needed with an average of 15 schemes per town/city, except Mumbai and Mumbai Sub-urban where 100 schemes each are proposed considering its dense urban set-up and vast areas, whereas in other 24 major cities/town coming under Municipal Corporations like Navi Mumbai, Thane, Kalyan-Dombivali, Vasai-Virar, Pune, PCMC, Nashik, Aurangabad, Nagpur etc 50 schemes each are proposed. The cost estimate of these schemes would work out to be Rs 674.63 cr at unit cost of Rs 7.5 lakh. It is estimated that about 9 lakh additional urban population would get adequate water supply round the year by implementing this scheme.

8.14.6 Total Cost

The total cost estimate for artificial recharge in Maharashtra is Rs 30834.06Cr with a break up of Rs 13893.74 Cr for rural areas & Rs 16940.31 Cr for urban areas.

8.15 ODISHA

The State of Odisha is the eighth largest State in India bounded between North latitudes 17°49' to 22°34' and East longitude 81°24' to 87°29'. It spreads over a geographical area of 1,55,707 sq. km.The state comprises of 3 revenue divisions having 30 districts.The total population of Orissa is 4,19,74,218 as per census report of 2011 and largely depends on agriculture.

There are eleven principal rivers traversing the entire state that can be grouped under eight major river basins within the state. Most of the major rivers flow in easterly and south-easterly directions with gentle gradient. The normal annual rainfall of the state is 1451mm with average annual rainy days of 74.The rainfall is highest in the northern part of the coastal tract and reduces westward. The low rainfall area stretches from Keonjhar on the north to Gopalpur in the south through Angul and Phulbani district.

Geological setting, climate and topography plays important role in the occurrence and movement of groundwater. The state can be broadly divided into three distinct units,based on hydrogeology.

Area with Precambrian consolidated formations: The consolidated formations include the hard crystalline and metamorphosed compact sedimentary formations belonging to Precambrian era and occupies nearly 80% of the total geographical area of the state. The groundwater occurs in secondary porosity resulting from weathering, fracturing and jointing. The weathered mantle is composed of loose regolith with intergranular porosity, which facilitates free circulation of groundwater through deeper fractures and forms potential repository of groundwater. In general the average thickness of weathered residuum varies from 15 to 20m. The groundwater occurs under water table conditions. The water bearing fracture zones generally occur within 100 meters of depth.

Area with semi-consolidated Gondwana & Tertiary formation: The semi-consolidated formations include Gondwana Sedimentaries ranging in age from Upper Carboniferous to Cretaceous and the Baripada beds of Middle-Pliocene age. The coarse to medium grained, weathered, fractured and friable Gondwana sandstones and the semi-consolidated sand beds of Baripada Formation form the aquifers. The groundwater occurs under water table conditions in the near surface aquifers and under confined conditions in the deeper aquifers. The depth of weathering in Gondwanas generally extends to a depth of 15m.

Area with unconsolidated Quaternary formations: The unconsolidated sediments include Pleistocene and Recent alluvium. The older alluvium is generally overlain by laterites, which forms a conspicuous and significant horizon. The laterites are vesicular essentially ferruginous and form good repository of groundwater. Maximum development of alluvial formations occurs along the coastal tract, exceeding 600m of thickness. Alluvium also occurs as discontinuous patches adjoining the river courses, where the thickness is limited to 45m. The sand and gravel layers act as repository of groundwater. The coastal tract holds potential for large scale groundwater development as the sand zones form prolific aquifers. But, the coastal tract is beset with salinity problems both in shallow as well as deeper aquifers at different locales.

The electrical conductivity (EC) of ground water is generally below 1000 μS/cm at 25°C in around 90% of the area of the State. EC value more than 2000 μS/cm is observed mostly in coastal districts of the State. High EC value, which is an indicator of salinity of water has been observed in Bhadrak, Jagatsinghpur, Kendrapara, Balasore and Ganjam districts. Apart from the coastal districts, small pockets in Bargarh, Balangir and Kalahandi districts also show higher value of EC in groundwater.

The groundwater quality in shallow wells has got a marked difference in hard rock area and in coastal area. The chloride value is generally below 50 mg/L in the State. The low values of chloride have been observed in the hard rock area, as compared to the coastal area. The high values of chloride in coastal Odisha may be due to upconing of saline water existing underneath fresh water or due to sea water ingression.

8.15.1 Identification of Areas

The areas suitable for artificial recharge is identified based on the following information:

Areas showing post monsoon depth to water level (2018) more than 5m

Areas showing declining decadal water level trend (2009-2018) more than 10 cm/year
Areas showing EC more than 2000 µS/cm at 25°C

All these three maps are superimposed and the area common in these three maps has been identified as the area identified for artificial recharge. It has been observed that the areas with EC> 2000 µS/cm neither have depth to water level more than 5 mbgl during post-monsoon season nor have falling trend of water level more than10cm/yr during post-monsoon season. As a result, the area having DTW more than 5 mbgl and falling trend of water level more than 10cm/yr during post-monsoon season have been identified as the areas suitable for artificial recharge. The area identified for artificial recharge has been given in Fig8.15.1. and presented as Table 8.15.1

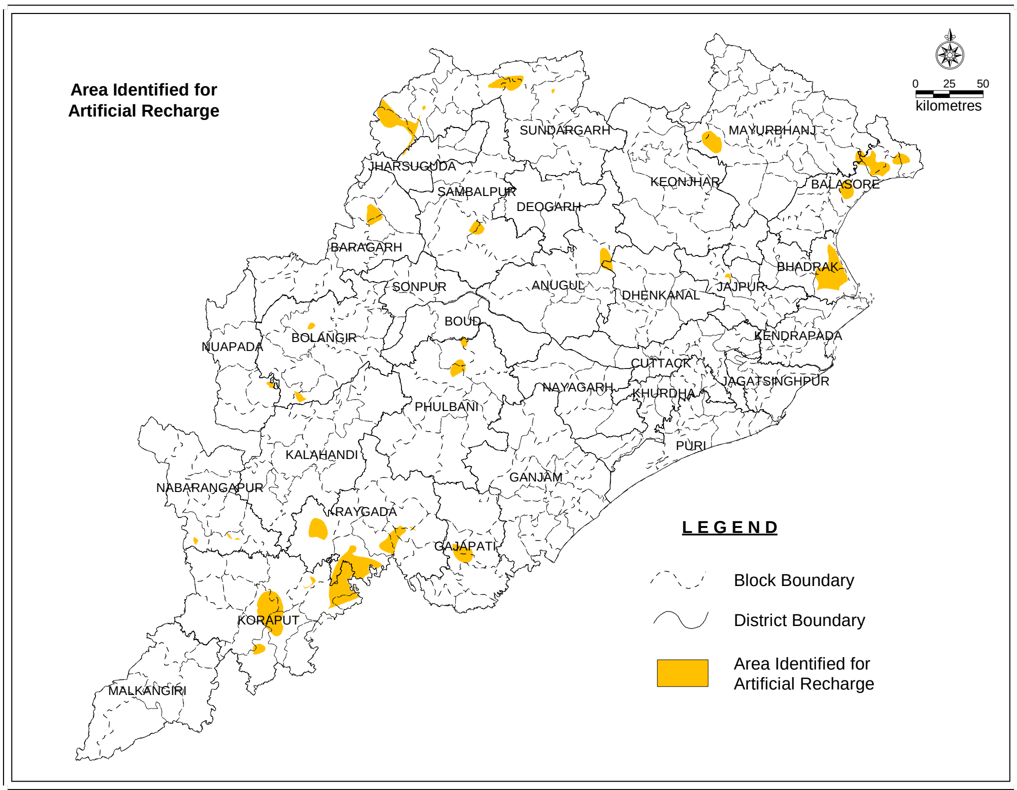


Fig. 8.15.1 Areas identified for artificial recharge

Table 8.16.1. Scope of Artificial Recharge

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Anugul	6375.00	79.34	357.03	7.32	9.74	31.44
2	Balangir	6575.00	55.18	248.30	5.11	6.79	20.92
3	Baleshwar	3806.00	409.42	1842.38	109.78	146.00	201.52
4	Bargarh	5837.00	127.37	573.15	17.19	22.87	43.86
5	Baudh	3098.00	0.00				
6	Bhadrak	2505.00	448.36	2017.63	161.41	214.68	281.22

7	Cuttack	3932.00	0.00				
8	Debagarh	2940.00	0.00				
9	Dhenkanal	4452.00	39.59	178.15	5.34	7.11	14.90
10	Gajapati	4325.00	150.36	676.63	20.30	27.00	73.26
11	Ganjam	8206.00	0.00				
12	Jagatsinghpur	1668.00	0.00				
13	Jajapur	2899.00	13.16	59.21	1.48	1.97	5.93
14	Jharsuguda	2081.00	7.60	34.20	0.68	0.91	3.16
15	Kalahandi	7920.00	0.00				
16	Kandhamal	8021.00	127.51	573.80	11.48	15.26	62.67
17	Kendrapara	2644.00	0.00				
18	Kendujhar	8303.00	0.00				
19	Khordha	2813.00	0.00				
20	Koraput	8807.00	974.00	4382.99	120.48	160.24	397.15
21	Malkangiri	5791.00	0.00				
22	Mayurbhanj	10418.00	204.91	922.08	21.80	29.00	86.05
23	Nabarangapur	5291.00	22.73	102.31	3.07	4.08	11.94
24	Nayagarh	3890.00	0.00				
25	Nuapada	3852.00	17.91	80.60	2.42	3.22	6.61
26	Puri	3479.00	0.00				
27	Rayagada	7073.00	751.81	3383.15	101.49	134.99	306.98
28	Sambalpur	6657.00	77.95	350.77	8.85	11.77	38.00
29	Subarnapur	2337.00	0.00				
30	Sundargarh	9712.00	536.41	2413.87	71.26	94.78	200.88
	Total	**155707.00**	**4043.61**	**18196.24**	**669.46**	**890.41**	**1786.49**

8.15.2 Subsurface Storage Space and Water Requirement

In the identified areas for artificial recharge, the water table is planned to be raised up to 3m bgl from its existing level. The thickness of available unsaturated zone (below 3 mbgl) is estimated by considering the different ranges of water level. The different ranges of DTW (depth to water level) are averaged to arrive at thickness of unsaturated zone. The volume of desaturated sub surface space up to 3m bgl is given by the product of area and the thickness. The volume of space available for artificial recharge is estimated by the product of volume of desaturated sub surface and respective specific yield of the formation. The estimated volume of sub surface space available for recharge is 669 MCM. Based on the experience gained in the pilot/demonstrative recharge projects implemented in different hydrogeological situations, an average recharge efficiency of 75% of the individual structure is considered. Thus the volume of water required for recharge is 890 MCM. The scope of artificial recharge for each district has been provided in Table 8.15.1.

8.15.3 Source Water Availability

The yield from the catchment has been calculated following the Strange's table, after deducting the volume of surface water already committed for the existing structures, available surplus runoff for artificial recharge has been worked out and found to be of the order of 1786 MCM(Table 8.15.1). In all the districts, the available surplus run off is found to be more than the water required for artificial recharge.

8.15.4 Recharge Structures and Cost Estimates

The physiography, hydrogeology and hydrology of an area play important role in deciding the type of recharge structures feasible in an area. Accordingly, allocation of various structures has been made for various district and furnished as Table 8.15.2. The numbers of structures have been worked out based on the gross capacity with multiple fillings, viz., 200 TCM for percolation tank, 150 TCM for Nala bund/contour bunding/check dam.

In urban areas of the state due to higher concentration of population and allied activities the extraction of ground water is observed to be higher as compared to rural areas. Further due to construction activities in these urban areas open areas available has also reduced resulting in decrease in natural recharge. Hence, apart from above recharge structures, it is proposed tohave roof top rainwater harvesting in 15700 school and college buildings in urban areas of allthe districts in the State. The district wise proposed number of roof top rainwater harvesting structures is given in table 8.15.2.

8.15.5 Total Cost

The total cost estimate for artificial recharge in Odisha is Rs 801.65 Cr with a break up of Rs 597.55 Cr for rural areas & Rs 204.10 Cr for urban areas through Rooftop rainwater harvesting .

8.15.2 Artificial Recharge Structures & Cost Estimates

S.No	District	Number of Structures							Unit Cost of Structures (Lakh)							Cost of Structures (Lakh)							
		CD	RS	PT	NB/CB	ST conversion to PT	SSD	RTRWH	CD	RS	PT	NB/CB	ST conversion to PT	SSD	RTRWH	CD	RS	PT	NB/CB	ST conversion to PT	SSD	RTRWH	Total Cost (Lakh)
1	Anugul	19	0	10	20	10	20	287	5	2	20	5	10	10	1.3	95.00	0.00	200.00	100.00	100.00	200.00	373.10	1068.10
2	Balangir	14	0	7	14	7	14	310	5	2	20	5	10	10	1.3	70.00	0.00	140.00	70.00	70.00	140.00	403.00	893.00
3	Baleshwar	389	219	219	0	219	0	759	5	2	20	5	10	10	1.3	1945.00	438.00	4380.00	0.00	2190.00	0.00	986.70	9939.70
4	Bargarh	45	0	23	46	23	46	243	5	2	20	5	10	10	1.3	225.00	0.00	460.00	230.00	230.00	460.00	315.90	1920.90
5	Baudh	0	0	0	0	0	0	29	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	37.70	37.70
6	Bhadrak	573	322	322	0	322	0	510	5	2	20	5	10	10	1.3	2865.00	644.00	6440.00	0.00	3220.00	0.00	663.00	13832.00
7	Cuttack	0	0	0	0	0	0	1754	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	2280.20	2280.20
8	Debagarh	0	0	0	0	0	0	68	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	88.40	88.40
9	Dhenkanal	11	0	8	15	8	15	251	5	2	20	5	10	10	1.3	55.00	0.00	160.00	75.00	80.00	150.00	326.30	846.30
10	Gajapati	0	0	35	85	35	64	171	5	2	20	5	10	10	1.3	0.00	0.00	700.00	425.00	350.00	640.00	222.30	2337.30
11	Ganjam	0	0	0	0	0	0	1591	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	2068.30	2068.30
12	Jagatsinghpur	0	0	0	0	0	0	146	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	189.80	189.80
13	Jajapur	5	3	3	0	3	0	264	5	2	20	5	10	10	1.3	25.00	6.00	60.00	0.00	30.00	0.00	343.20	464.20
14	Jharsuguda	2	0	1	2	1	2	313	5	2	20	5	10	10	1.3	10.00	0.00	20.00	10.00	10.00	20.00	406.90	476.90
15	Kalahandi	0	0	0	0	0	0	211	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	274.30	274.30
16	Kandhamal	1	0	19	48	19	35	196	5	2	20	5	10	10	1.3	5.00	0.00	380.00	240.00	190.00	350.00	254.80	1419.80
17	Kendrapara	0	0	0	0	0	0	169	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	219.70	219.70
18	Kendujhar	0	0	0	0	0	0	464	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	603.20	603.20
19	Khordha	0	0	0	0	0	0	2838	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	3689.40	3689.40
20	Koraput	4	0	143	681	143	265	435	5	2	20	5	10	10	1.3	20.00	0.00	2860.00	3405.00	1430.00	2650.00	565.50	10930.50
21	Malkangiri	0	0	0	0	0	0	106	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	137.80	137.80
22	Mayurbhanj	10	6	44	67	44	67	758	5	2	20	5	10	10	1.3	50.00	12.00	880.00	335.00	440.00	670.00	985.40	3372.40

S.No	District	Number of Structures							Unit Cost of Structures (Lakh)							Cost of Structures (Lakh)							
		CD	RS	PT	NB/CB	ST conversion to PT	SSD	RTRWH	CD	RS	PT	NB/CB	ST conversion to PT	SSD	RTRWH	CD	RS	PT	NB/CB	ST conversion to PT	SSD	RTRWH	Total Cost (Lakh)
23	Nabarangapur	0	0	6	11	6	11	201	5	2	20	5	10	10	1.3	0.00	0.00	120.00	55.00	60.00	110.00	261.30	606.30
24	Nayagarh	0	0	0	0	0	0	146	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	189.80	189.80
25	Nuapada	6	0	3	6	3	6	78	5	2	20	5	10	10	1.3	30.00	0.00	60.00	30.00	30.00	60.00	101.40	311.40
26	Puri	0	0	0	0	0	0	561	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	729.30	729.30
27	Rayagada	79	0	142	438	142	268	370	5	2	20	5	10	10	1.3	395.00	0.00	2840.00	2190.00	1420.00	2680.00	481.00	10006.00
28	Sambalpur	21	0	13	25	13	25	736	5	2	20	5	10	10	1.3	105.00	0.00	260.00	125.00	130.00	250.00	956.80	1826.80
29	Subarnapur	0	0	0	0	0	0	108	5	2	20	5	10	10	1.3	0.00	0.00	0.00	0.00	0.00	0.00	140.40	140.40
30	Sundargarh	113	0	113	213	113	213	1627	5	2	20	5	10	10	1.3	565.00	0.00	2260.00	1065.00	1130.00	2130.00	2115.10	9265.10
	Total	1292	550	1111	1671	1111	1051	15700								6460.00	1100.00	22220.00	8355.00	11110.00	10510.00	20410.00	80165.00

Note:PT: Percolation Tank, ST conversion to PT: Storage Tank Conversion to Percolation Tank, SSD: Sub- surface dyke, NB/CB: Nala bund/ Contour bunding, CD: Check dams/ weir, RS: Recharge shaft, RTRWH: Roof Top rainwater Harvesting

8.16 PUNJAB

Punjab State, one of the smallest states of India having geographical area of 50,362 sq km is pre-dominantly an agrarian state contributing around two third of the food grains procured annually in the country and is devoid of any other mineral or natural resource except water. Agriculture in the State is highly intensive which needs heavy requirement of water.

The studies carried out by Central Ground Water Board through ground water exploration has revealed existence of thick fresh water aquifers throughout the State. Upper Bari- Doab area reveals the presence of 4 to 5 thick permeable granular zones to a depth of 300 m having three-aquifer groups in depth range of 9 to 138mbgl, 106 to 264m bgl and 197 to 300mbgl. In Bist Doab Area, the aquifers comprise sand and silt with intercalation of little clay and kankarhaving in depth range of 15to 130mbgl, 128to 225m bgl and 234 to 300mbgl. Sand content decreases towards South and aquifers become thinner and quality of ground water also deteriorates. In South western districts of the state, aquifers are interbedded with clay layers below 30 m depth, clay invariably forms the major portion of alluvium. Aquifers in these districts, particularly in the saline areas, are mostly thin and pinch out at short distances, thus restricting the movement of ground water. In rest of the districts of the state, the aquifers are extensive in nature and are separated by 8-10 m thick clay beds. Aquifer -I extends maximum down to 111 m of depth followed by persistent clay layer separating Aquifer II at the depth of 128-195 m and another clay layer separates Aquifer-III down to 300m depth.

8.16.1 Identification of Area

Based on the post monsoon depth to water level of the year 2018 and long term (2009-18) ground water level trends, it has been estimated that approximately 45,592 sq. kms area is feasible for artificial recharge(Fig 8.16.1). The area feasible for artificial recharge to ground water is demarcated based on criteria of depth to water level of more than 3 m bgl during post-monsoon season and continuous annual decline rate of more than 10 cm per annum.

8.16.2 Sub-Surface Storage Space and Water Requirement

The total volume of unsaturated strata is calculated by considering unsaturated thickness of aquifers on block-wise basis. The sub-surface storage potential is estimated by multiplying the volume of unsaturated aquifer by average specific yield (12%). Sub surface storage potential of the state is estimated as 86,789MCM during post-monsoon season of 2018. The quantity of water required to saturate the storage is estimated by multiplying the sub-surface storage potential with 1.33 factors. The quantity of water required for filling the sub-surface storage potential (unsaturated zone) is approximately 115430 MCM (Table 8.16.1).

8.16.3 Source Water Availability

The quantity of non-committed surface water in the Punjab state has been estimated to be only 1200.99 MCM (as per the data available from the state government). The surplus canal water available for recharge for each district has also been provided by State Government. In addition, it is proposed to harvest run off from agricultural land, which may be retained in the agricultural land in local depressions etc. This has been computed as run off only from 10% of the agricultural landwith a run off coefficient of 15%. The total source water available will be a sum of all three sources mentioned above is of the order of 1201 MCM and is provided in the table 8.16.1.

8.16.4 Recharge Structure and Cost Estimates

Recharge is envisaged to be carried out through four sources, viz., uncommitted surplus run off, surplus canal water, surface run off from agricultural land in large agricultural Farms and Roof Top Rainwater harvesting (RTRWH). The uncommitted surplus run off is to be used by proposed Check dam and recharge shaft, while surplus canal water is envisaged to be recharged through injection wells and run off from the large agricultural Land through the farm ponds in respective farms and provision of RTRWH in urban area for rainwater from roof top. Considering the intake capacity of injection wells, the number injections wells have been finalized, while 1 farm pond per Ha has been proposed to harvest the run off from agricultural land.

The source water availability and the plan for artificial recharge were proposed by the State Agency but subsequently, State Agency expressed the man power constraints regarding the construction and maintainance of structures, however, in bview of the availability of source water fo recharge, the plan may be included and the the State agency may consider about the implementation, after these issues are resolved.

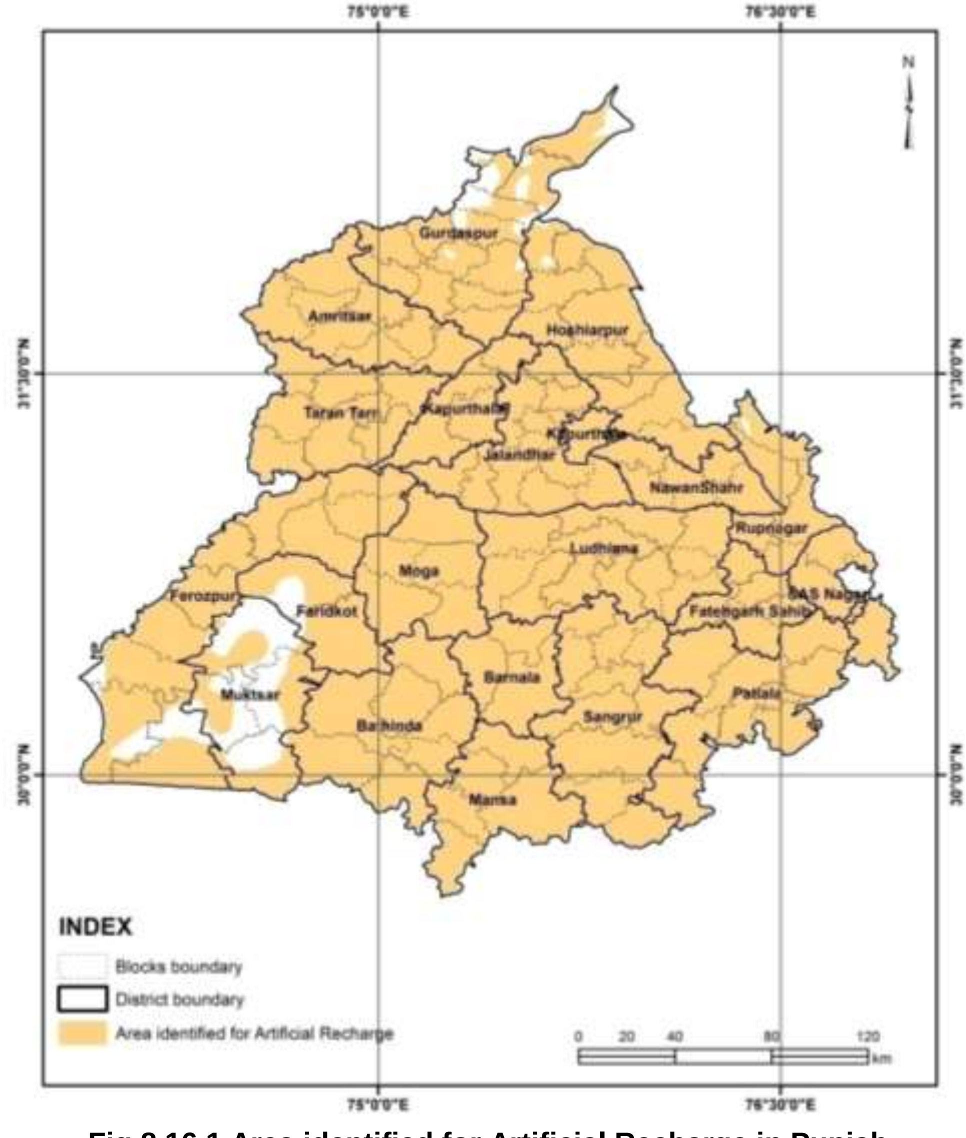


Fig 8.16.1 Area identified for Artificial Recharge in Punjab

Table 8.16.1 Scope of Artificial Recharge in Punjab

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Amritsar	2403.00	2271.00	27138.45	3256.61	4331.30	117.88
2	Barnala	1352.00	1343.00	43392.33	5207.08	6925.42	18.49
3	Bathinda	3547.00	3311.00	50327.20	6039.26	8032.22	32.08
4	Faridkot	1419.00	1249.00	6782.07	813.85	1082.42	18.88

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
5	Fatehgarg Sahib	1117.00	1117.00	22138.94	2656.67	3533.37	21.68
6	Ferozpur	5442.00	4658.00	36285.82	4354.30	5791.22	65.18
7	Gurdaspur	3513.00	2901.00	13170.54	1580.46	2102.02	202.56
8	Hoshiarpur	3331.00	3320.00	42197.20	5063.66	6734.67	125.05
9	Jalandhar	2634.00	2158.00	48921.86	5870.62	7807.93	60.77
10	Kapurthala	1618.00	1603.00	23868.67	2864.24	3809.44	64.72
11	Ludhiana	3587.00	3383.00	56935.89	6832.31	9086.97	40.47
12	Mansa	2071.00	2071.00	22760.29	2731.23	3632.54	46.56
13	Moga	2172.00	2172.00	47436.48	5692.38	7570.86	20.76
14	Muktsar	2656.00	1186.00	308.36	37.00	49.21	0.00
15	Nawanshahr	1325.00	1271.00	19306.49	2316.78	3081.32	10.92
16	Patiala	3303.00	3241.00	81284.28	9754.11	12972.97	129.54
17	Ropar	1370.00	1312.00	13631.68	1635.80	2175.62	18.98
18	Mohali	1182.00	1105.00	17050.15	2046.02	2721.20	28.64
19	Sangrur	3737.00	3517.00	111594.41	13391.33	17810.47	51.12
20	Tarn Taran	2583.00	2403.00	38712.33	4645.48	6178.49	126.71
Total		50362.00	45592.00	723243.44	86789.21	115429.65	1200.99

Table 8.16.2 Artificial Recharge Structures and Cost Estimates in Punjab

S.No	District	Number of Structure					Unit Cost structure (Lakhs)					Cost of Structure (Lakhs)					Total Cost (Lakhs)
		CD	RS	FP	RTRWH	IW	CD	RS	FP	RTRWH	IW	CD	RS	FP	RTRWH	IW	
1	Amritsar		7859	22710	48890	294	40	3	0.5	0.3	3		23577	11355	14667	882	50481
2	Barnala		1233	13430	11580	1020	40	3	0.5	0.3	3		3699	6715	3474	3060	16948
3	Bathinda		2139	33110	27390		40	3	0.5	0.3			6417	16555	8217	0	31189
4	Faridkot		1259	12490	12089		40	3	0.5	0.3			3777	6245	3626.7	0	13648.7
5	Fatehgarh Sahib		1445	11170	11810	666	40	3	0.5	0.3	3		4335	5585	3543	1998	15461
6	Ferozpur		4345	46580	38599		40	3	0.5	0.3			13035	23290	11579.7	0	47904.7
7	Gurdaspur	15	13464	29010	44367		40	3	0.5	0.3		600	40392	14505	13310.1	0	68807.1
8	Hshiarpur	25	8270	33200	33699		40	3	0.5	0.3		1000	24810	16600	10109.7	0	52519.7
9	Jalandhar		4051	21580	46164	1896	40	3	0.5	0.3	3		12153	10790	13849.2	5688	42480.2
10	Kapurthala		4315	16030	16799	442	40	3	0.5	0.3	3		12945	8015	5039.7	1326	27325.7
11	Ludhiana		2698	33830	71683	856	40	3	0.5	0.3	4		8094	16915	21504.9	3424	49937.9
12	Mansa		3104	20710	14963	1838	40	3	0.5	0.3	3		9312	10355	4488.9	5514	29669.9
13	Moga		1384	21720	19326	1362	40	3	0.5	0.3	3		4152	10860	5797.8	4086	24895.8
14	Muktsar		0	11860	17436		40	3	0.5	0.3			0	5930	5230.8	0	11160.8
15	Nawanshahr	25	661	12710	12950	506	40	3	0.5	0.3	3	1000	1983	6355	3885	1518	14742
16	Patiala		8636	32410	37229	862	40	3	0.5	0.3	3		25908	16205	11168.7	2586	55867.7
17	Ropar	15	1225	13120	13564	26	40	3	0.5	0.3	3	600	3675	6560	4069.2	78	14982.2
18	Mohali	5	1896	11050	20541		40	3	0.5	0.3		200	5688	5525	6162.3	0	17575.3
19	Sangrur		3408	35170	31887	2674	40	3	0.5	0.3	3		10224	17585	9566.1	8022	45397.1
20	Tarn Taran		8447	24030	20342	968	40	3	0.5	0.3	3		25341	12015	6102.6	2904	46362.6
Total		**85**	**79839**	**455920**	**551308**	**13410**						**3400**	**239517**	**227960**	**165392.4**	**41086**	**677355.40**

Roof Top Rainwater Harvesting

It has been assessed that roof top rainwater harvesting can be adopted in government buildings, institutes and 55 lakh houses with 200 Sq.mt roof area, of the state for artificial recharge in the first phase. It will harness 52.49 MCM rain water to augment groundwater resources considering normal rainfall for the state and 70% efficiency of the system. The cost of roof top rain water harvesting of a buildingshaving roof and paved areas of ~ 200 sq.m in a cluster of 4-6 houses has been assessed to be Rs. 30,000/-.

8.16.5 Total Cost

The total cost of artificial recharge in Punjab is of the order of Rs 6773.55 Cr, out of which artificial recharge in rural area is of the order of Rs 5119.63 Cr and RTRWH in urban areas is Rs1653.92 Cr.

8.17 RAJASTHAN

Rajasthan is the driest and most water deficient State of India. It is situated in the North-western part of India and shares its border with Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, and Gujarat States. The western border is shared with Pakistan. It has a total geographic area of 3,42,239 sq km. and situated between 23° 03'to 30° 12' North latitudes and 69° 30' to 78° 17' East longitudes. The State is divided into 33 districts and 295 blocks. As per Census 2011, Rajasthan State has population of 6,85,48,437with population density of 200 persons per sq kmspread over 9892 Gram Panchayats and 45884 villages.

There are 14 river basins in the State, viz., Shekhawati, Banganga, Sabi (Sahibi), Banas, West Banas, Chambal, Luni, Sukli, Mahi, Ruparail, Gambhir, Parbati, Sabarmati& other nallahs of Jalore, which cover eastern, northern and southern river catchments. Aravallis form major drainage divide with majority of rivers originating from it flowing towards east and very few flowing towards west. Luni is the only river, in West of Aravalli whereas remaining Western Rajasthan has internal drainage which dies out in the desert sand after flowing for limited distance.

Rainfall is the major source of ground water recharge in the state. The state receives 90% rainfall from southwest monsoon from June to September. The winter rainfall is meagre. The decadal average annual rainfall of the state (2009-18) is 542.7 mm. The state can be divided into four units, viz., (a) Aravalli hill ranges (b) Eastern plains (c) Western Sandy Plain and Sand Dunes and (d) VindhyanScarpland and Deccan Lava Plateau.

The Aravalli ranges trending NE-SW are the oldest mountain chain in India. They are composed of Bhilwara, Aravalli and Delhi Super group of rocks ranging in age from Archaean to Proterozoic. The south-eastern plains are locally characterized by plateau, scarp land and ravines. The sandy plains in western Rajasthan, forming a part of Thar Desert, are mainly occupied by alluvium and blown sands. The VindhyanScarpland is seen all along the Great Boundary Fault from Chittorgarh to the trijunction of Bharatpur, Dholpur and SawaiMadhopur districts. The Deccan Lava Plateau is mainly confined to parts of Kota, Jhalawar, Banswara and Chittorgarh districts. The ravines, locally impassable, are confined to the alluvium overlying the Vindhyans in Dholpur, SawaìMadhopur, Jhalawar and Kota districts along the Chambal River and its tributaries.

The structures are proposed keeping in view the traditional practices, successful case studies of previous works, social adaptability, forest cover, favourable land use etc. The master plan has been prepared using data of Central Ground Water Board (CGWB), Ground Water Department (GWD), Watershed Development & Soil Conservation (WD&SC) and input of JAL Shakti Abhiyan (JSA) etc.

8.17.1 Identification of Area

Rajasthan State has been divided by Aravalli ranges. Western part is characterized by arid to semi-arid climatic conditions with normal rainfall of less than 500 mm whereas eastern part has sub-humid to humid climate with normal rainfall ranging from more than 500 to 1070mm. in addition to the ground water exploitation, the criteria of the areas with post monsoon water level between 3 & 9m bgl, 9 & 20mbgl and more than 20mbgl, with post monsoon long term water level showing declining trend between 0.2m/yr& 0.5 m/yr and more than 0.5m/yr and with EC less than2500 µS/cm at 25^{0}C have been considered for the identification of areas for artificial recharge (Fig 8.17.1).

8.17.2 Subsurface Storage Space and Water Requirement

The subsurface storage space available for artificial recharge has been worked out below 3 m bgl as per methodology. The unsaturated zone available is of the order of 2469104 MCM and the volume available for artificial recharge considering the specific yield of the formation is 159115 MCM. Considering the efficiency of 75% of the proposed structures, water required for artificial recharge is 211626 MCM (Table 8.17.1).

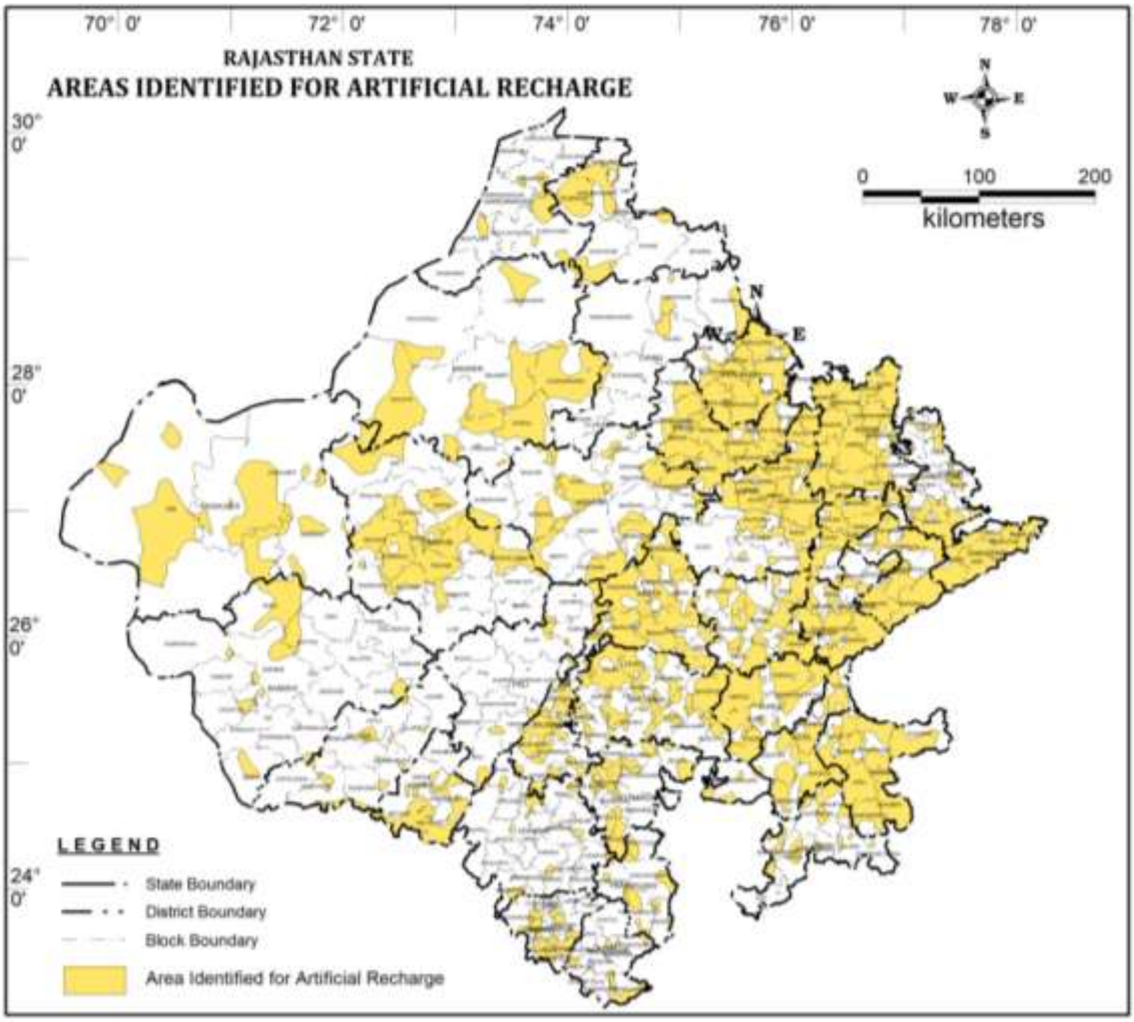


Fig 8.17.1 Area identified for Artificial Recharge in Rajasthan

Table 8.17.1 Scope of Artificial Recharge in Rajasthan

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Ajmer	8481.00	6067.00	47023.00	1558.00	2072.00	22.00
2	Alwar	8380.00	7095.00	208670.00	15769.00	20973.00	68.00
3	Banswara	4536.00	558.00	1359.00	31.00	41.00	217.00
4	Baran	6955.00	5313.00	22831.00	465.00	619.00	895.00
5	Barmer	28387.00	2566.00	70271.00	4174.00	5552.00	5.00
6	Bharatpur	5100.00	1821.00	20104.00	1637.00	2178.00	40.00
7	Bhilwara	10455.00	4540.00	25578.00	472.00	628.00	159.00
8	Bikaner	27244.00	8961.00	490137.00	31386.00	41743.00	0.00
9	Bundi	5550.00	4005.00	30815.00	922.00	1226.00	719.00
10	Chittaurgarh	7880.00	2198.00	12855.00	201.00	267.00	308.00
11	Churu	16830.00	978.00	18292.00	1194.00	1588.00	0.00
12	Dausa	3470.00	2559.00	76624.00	4917.00	6539.00	7.00

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
13	Dholpur	3000.00	2745.00	30107.00	1863.00	2478.00	166.00
14	Dungarpur	3770.00	1104.00	4214.00	102.00	136.00	164.00
15	Ganganagar	10978.00	2252.00	16298.00	1766.00	2348.00	0.00
16	Hanumangarh	9656.00	6119.00	87725.00	10594.00	14091.00	0.00
17	Jaipur	11066.00	8059.00	317846.00	25246.00	33577.00	33.00
18	Jaisalmer	38401.00	705.00	27349.00	1208.00	1607.00	0.00
19	Jalore	10640.00	1297.00	33321.00	1934.00	2572.00	8.00
20	Jhalawar	6219.00	4542.00	11940.00	365.00	485.00	808.00
21	Jhunjhunu	5928.00	8097.00	428290.00	29980.00	39874.00	4.00
22	Jodhpur	22850.00	3721.00	165913.00	7990.00	10627.00	2.00
23	Karauli	5016.00	3032.00	48513.00	3021.00	4018.00	145.00
24	Kota	5481.00	5087.00	22439.00	612.00	814.00	656.00
25	Nagaur	17718.00	895.00	45323.00	2605.00	3465.00	6.00
26	Pali	12387.00	872.00	10513.00	378.00	503.00	12.00
27	Pratapgarh	4360.00	2036.00	8027.00	102.00	136.00	280.00
28	Rajsamand	4768.00	3396.00	21977.00	435.00	578.00	14.00
29	Sawai Madhopur	5043.00	5624.00	54699.00	2075.00	2760.00	137.00
30	Sikar	7732.00	1896.00	79795.00	5160.00	6863.00	6.00
31	Sirohi	5136.00	886.00	12046.00	456.00	607.00	21.00
32	Tonk	7194.00	3653.00	16371.00	464.00	617.00	79.00
33	Udaipur	11628.00	819.00	1839.00	33.00	44.00	324.00
Total		342239.00	113498.00	2469104.00	159115.00	211626.00	5305.00

8.17.3 Source Water Availability

In consultation with State Groundwater Department, Rajasthan, surplus surface water has been taken from report on “Study on Planning of Water Resources of Rajasthan- Integrated State Water Resources Plan,2014” after apportioning from basin to block. Accordingly, amount of surplus surface water considered for planning the artificial recharge is 5304.75 MCMat 75% dependability. The surplus water utilized for proposed interventions of water conservation and artificial recharge to ground water has been computed as 1158.08 MCM. District wise detail of surplus surface water availability in the State is given in Table-8.17.1

Table-8.17.2 Artificial Recharge in Rajasthan

S.No	District	Number of Structure									Unit Cost structure (Lakhs)								
		CD	RS	FP	PT	CAT(ha)	Tanka	Anicut	MST	MPT	CD	RS	FP	PT	CAT	Tanka	Anicut	MST	MPT
1	Ajmer	831	0	4547	1629	13741	0	422	24	3615	6	2	1.5	3	1	2	15	50	1
2	Alwar	1582	21	594	3375	5116	0	713	36	7001	6	2	1.5	3	1	2	15	50	1
3	Banswara	2633	0	0	5006	4625	0	1376	73	10646	6	2	1.5	3	1	2	15	50	1
4	Baran	2062	0	33492	3599	9583	0	927	48	7855	6	2	1.5	3	1	2	15	50	1
5	Barmer	0	0	0	0		42117	0	0		6	2	1.5	3	1	2	15	50	1
6	Bharatpur	365	4	365	772	1142	0	120	0	1743	6	2	1.5	3	1	2	15	50	1
7	Bhilwara	1526	0	297	2876	609	0	722	26	5735	6	2	1.5	3	1	2	15	50	1
8	Bikaner	0	0	0	0		24889	0	0		6	2	1.5	3	1	2	15	50	1
9	Bundi	1526	0	2306	2962	5990	0	897	50	6482	6	2	1.5	3	1	2	15	50	1
10	Chittaurgarh	1567	0	11525	3074	12947	0	752	41	7844	6	2	1.5	3	1	2	15	50	1
11	Churu	0	0	0	0		25592	0	0		6	2	1.5	3	1	2	15	50	1
12	Dausa	246	51	0	506	1496	0	109	2	1569	6	2	1.5	3	1	2	15	50	1
13	Dholpur	830	3	0	1504	4627	0	367	14	3210	6	2	1.5	3	1	2	15	50	1
14	Dungarpur	2232	0	11197	4108	4109	0	1035	40	8690	6	2	1.5	3	1	2	15	50	1
15	Ganganagar	0	0	0	0		29378	0	0		6	2	1.5	3	1	2	15	50	1
16	Hanumangarh	0	0	0	0		26836	0	0		6	2	1.5	3	1	2	15	50	1
17	Jaipur	1004	57	2311	2034	10910	0	598	19	4946	6	2	1.5	3	1	2	15	50	1
18	Jaisalmer	0	0	0	0		10043	0	0		6	2	1.5	3	1	2	15	50	1
19	Jalore	303	0	0	622	14328	0	134	1	3320	6	2	1.5	3	1	2	15	50	1
20	Jhalawar	2499	0	20635	4492	9998	0	1148	61	9820	6	2	1.5	3	1	2	15	50	1
21	Jhunjhunu	0	0	0	0		31302	0	0		6	2	1.5	3	1	2	15	50	1
22	Jodhpur	50	0	200	200		42509	0	0	600	6	2	1.5	3	1	2	15	50	1

S.No	District	Number of Structure									Unit Cost structure (Lakhs)							
		CD	RS	FP	PT	CAT(ha)	Tanka	Anicut	MST	MPT	CD	RS	FP	PT	CAT	Tanka	Anicut	MST	MPT
23	Karauli	1494	45	15582	3060	5662	0	930	52	6771	6	2	1.5	3	1	2	15	50	1
24	Kota	678	0	27616	1418	16206	0	344	15	2987	6	2	1.5	3	1	2	15	50	1
25	Nagaur	0	0	0	0		49941	0	0		6	2	1.5	3	1	2	15	50	1
26	Pali	175	50	2465	669	15167	0	78	12	2063	6	2	1.5	3	1	2	15	50	1
27	Pratapgarh	2753	0	15149	5280	3501	0	1465	81	11354	6	2	1.5	3	1	2	15	50	1
28	Rajsamand	496	0	465	1052	7656	0	256	12	5337	6	2	1.5	3	1	2	15	50	1
29	SawaiMadhopur	715	0	0	1388	7176	0	288	13	2816	6	2	1.5	3	1	2	15	50	1
30	Sikar	0	0	0	0		35740	0	0		6	2	1.5	3	1	2	15	50	1
31	Sirohi	790	0	0	1585	6327	0	530	13	5164	6	2	1.5	3	1	2	15	50	1
32	Tonk	617	0	20175	1210	12041	0	285	12	2600	6	2	1.5	3	1	2	15	50	1
33	Udaipur	5770	0	23688	10737	13534	0	2836	203	23763	6	2	1.5	3	1	2	15	50	1
Total		32744	231	192609	63158	186491	318347	16332	848	145931									

CAT	Catchment Area Treatment (Plantation, Staggered Trench &Continuous Contour Trench)
RS	Recharge Shaft in existing village pond
MPT	Mini Percolation Tank
P T	Percolation Tank
PCD	Pacca Check dam
MST	Macro Storage Tank
F P	Farm Pond

S.No	District	Cost of Structure (Lakhs)									Total Cost (Lakh)
		CD	RS	FP	PT	CAT	Tanka	Anicut	MST	MPT	
1	Ajmer	4986	0	6820.5	4887	13741	0	6330	1200	3615	41580
2	Alwar	9492	42	891	10125	5116	0	10695	1800	7001	45162
3	Banswara	15798	0	0	15018	4625	0	20640	3650	10646	70377
4	Baran	12372	0	50238	10797	9583	0	13905	2400	7855	107150
5	Barmer	0	0	0	0	0	84234	0	0	0	84234
6	Bharatpur	2190	8	547.5	2316	1142	0	1800	0	1743	9747
7	Bhilwara	9156	0	445.5	8628	609	0	10830	1300	5735	36704
8	Bikaner	0	0	0	0	0	49778	0	0	0	49778
9	Bundi	9156	0	3459	8886	5990	0	13455	2500	6482	49928
10	Chittaurgarh	9402	0	17287.5	9222	12947	0	11280	2050	7844	70033
11	Churu	0	0	0	0	0	51184	0	0	0	51184
12	Dausa	1476	102	0	1518	1496	0	1635	100	1569	7896
13	Dholpur	4980	6	0	4512	4627	0	5505	700	3210	23540
14	Dungarpur	13392	0	16795.5	12324	4109	0	15525	2000	8690	72836
15	Ganganagar	0	0	0	0	0	58756	0	0	0	58756
16	Hanumangarh	0	0	0	0	0	53672	0	0	0	53672
17	Jaipur	6024	114	3466.5	6102	10910	0	8970	950	4946	41483
18	Jaisalmer	0	0	0	0	0	20086	0	0	0	20086
19	Jalore	1818	0	0	1866	14328	0	2010	50	3320	23392
20	Jhalawar	14994	0	30952.5	13476	9998	0	17220	3050	9820	99511
21	Jhunjhunu	0	0	0	0	0	62604	0	0	0	62604
22	Jodhpur	300	0	300	600	0	85018	0	0	600	86818
23	Karauli	8964	90	23373	9180	5662	0	13950	2600	6771	70590
24	Kota	4068	0	41424	4254	16206	0	5160	750	2987	74849
25	Nagaur	0	0	0	0	0	99882	0	0	0	99882
26	Pali	1050	100	3697.5	2007	15167	0	1170	600	2063	25855
27	Pratapgarh	16518	0	22723.5	15840	3501	0	21975	4050	11354	95962
28	Rajsamand	2976	0	697.5	3156	7656	0	3840	600	5337	24263
29	SawaiMadhopur	4290	0	0	4164	7176	0	4320	650	2816	23416
30	Sikar	0	0	0	0	0	71480	0	0	0	71480
31	Sirohi	4740	0	0	4755	6327	0	7950	650	5164	29586
32	Tonk	3702	0	30262.5	3630	12041	0	4275	600	2600	57111
33	Udaipur	34620	0	35532	32211	13534	0	42540	10150	23763	192350
Total		**196464**	**462**	**288913.5**	**189474**	**186491**	**636694**	**244980**	**42400**	**145931**	**1931810**

8.17.4 Recharge Structures and Cost Estimates

The artificial recharge is accorded priority in such blocks where the stage of groundwater extraction is more than 100%, while considering all the blocks having stage of ground water extraction more than 70%. In the other bocks (< 70% of groundwater extraction), the proposal

is limited to Catchment area works only which is adequate at this junctureas it will serve natural process of ground water recharge.
Keeping in view the hydro-geological conditions in various parts of the State and discussions held with the State Government Agencies, artificial recharge structures are proposed for Eastern and Western Districts of the State separately. The details are given below:
Eastern Rajasthan covers 23 districts, viz., Ajmer, Alwar, Banswara, Baran, Bharatpur, Bhilwara, Bundi, Chittaurgarh, Dausa, Dholpur, Dungarpur, Jaipur, Jalore, Jhalawar, Karauli, Kota, Pali, Pratapgarh, Rajsamand, Sawai Madhopur, Sirohi, Tonk& Udaipur. In these areas, water conservation/augmentation measures include Catchment Area Treatment (Plantation, Staggered Trenches& CCT, etc.), Recharge Shaft in existing village ponds, Mini Percolation Tanks, Percolation Tanks, Pacca Check Dam, Anicut, MST and Recharge/Farm Pond etc are recommended.
Western desertic part of Rajasthan covers 10 districts, viz., Barmer, Bikaner, Churu, Ganganagar, Hanumangarh, Jaisalmer, Jhunjhunu, Jodhpur, Nagaur& Sikar. In these desert part of the State, it has been found that artificial recharge practically not feasible under the prevailing circumstances. Hence, it is proposed to promote rain water harvesting through storage structures like Tankas.
There is localized drainage available in the area where sandstone, limestone and other rocks are exposed creating runoff during monsoon. The pond (talab) with recharge borewell are proposed to conserve rain water and for recharging the aquifers for sustainable ground water utilization. The quantification of such ponds will depend on availability of site specific data and case to case basis. The district-wise detailof number of various interventions of conservation/recharge structures proposed in the State along with cost estimate is given in Table-8.17.2.
The cost estimates of the rain water harvesting and aquifer recharge structures are taken from the Watershed Development and Soil Conservation Department of the State, which is based on the implementation of Mukhyamantri Jal Swablamban Abhiyan (MJSA)in Rajasthan under various phases of MGNAREGA activities. Accordingly, total cost of rain water harvesting and aquifer recharge schemes in Eastern (Non-desert) and Western (Desert) districts of the State would be Rs. 19,318.10 Crores.

Roof Top Rain Water Harvesting In Urban Areas

Watershed and Soil Conservation Department of Govt. of Rajasthan has prepared a plan for creation of roof top rain water harvesting in urban areas under National Water Conservation Scheme (Jal Jeevan Mission-Varsha Jal DharaKe Tal) of Ministry of Jal Shakti, Govt of India. The scheme shall be Central Sponsored Scheme (CSS) with sharing pattern of funds between Centre and State in the ratio of 60:40. Around 20% of households shall be identified for disbursing the benefits of this scheme for construction of roof top rain water system.
The capacity of rain water harvesting system shall depend on roof top of individual household, considering roof and paved area of 200 sqm of each household, normal rainfall of the State and 80 % efficiency of the system, it is presumed to be harnessed 83.25 MCM rain water to augment ground water resources. The Govt. buildings, institutes etc. in urban and municipal areas of the state may be taken up for artificial recharge in priority/phase wise manner.
The total cost of the harvesting works proposed under the National Water Conservation Scheme by the WD&SC Department would be Rs, 1,440 Cr., considering an average unit cost of structure Rs, 15000/- as fixed in the scheme. The recharge plan under National Water Conservation Scheme has already been submitted to the Govt. of India by the WD&SC department of Govt. of Rajasthan. The details are given below:

Total nos. of households in urban areas: 48,00,000 Nos.
Total nos. of harvesting works proposed for 20% of households: 9,60,000 Nos.
Total cost of harvesting works proposed under the scheme: Rs. 1,440 Crores

Hence, rooftop rainwater harvesting has not been included for the State of Rajasthan and thus the total cost estimate for artificial recharge in Rajasthan for rural areas works out to be 19,318.10 Crores.

8.18 SIKKIM

Sikkim State occupies a total geographical area of 7,096 sq km with four districts, viz. North, East, South & West Districts. The state is drained by perennial Tista and Rangit rivers and their tributaries. The major river Tista, originates from Tista-Khangse glacier drains the major part of the state. Inspite of copious rainfall received to the tune of 2500 mm per annum, extreme water scarcity is felt in the lean periods (January to April) especially in the rain shadow areas falling in parts of South, West and East districts.

Although so far there is negligible ground water development in the State of Sikkim, still there is scope for: (a) water conservation in the Spring sheds, where the terrain slope is within 50°, so that ground water is recharged through construction of contour trenches/staggered trenches, slope terracing, cement plug/subsurface dykes to obtain sustainable yield from the springs. (b) Augmenting artificial recharge in the hillslopes to rejuvenate springs in downslopes through renovation of old lakes/ponds or excavation of new ponds in suitable geomorphic locales (c) Augmenting artificial recharge in the hillslopes through irrigation in the terraced paddy field diverting perennial flow along slope through check dam cum diversion weir and conveyance drain/pipes (d) Further to augment the water availability in such sloping terrain receive high rainfall, there is vast scope for roof top rainwater harvesting as also harvesting of rainwater in landscapes through wrapping permeable membrane (Polythene sheets) in the dig out ponds and through harvesting perennial surface flow along slopes and surplus monsoon rainfall through streams by means of check dam where the terrain slope is within 30-40°. The State is dotted with good number of springs which are mainly controlled by geological structures and topography. From the study by CGWB it is observed that all the spring under use for rural drinking water supply are located within 50% terrain slope. These springs can be developed and rejuvenated for providing sustainable water supply to the rural population. The spring water can be transported under gravity for drinking purposes as also for irrigation.

8.18.1 Identification of Area

The area identified for artificial recharge and water conservation in Sikkim has been made with twin objectives of providing assured water supply during non-rainy seasons and for providing sustainability to the springs whose discharge reduces considerably during non-rainy season. In order to provide sustainability to water supply, based on the slope, area have been categorized as highly feasible and less feasible areas and provided in Fig 8.18.1 & Table 8.18.1

Table 8.18.1 Scope for Artificial Recharge & Water Conservation in Sikkim

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)	Harnessable water for Artificial Reharghe
1	East	954.00	485.00	485.00	58.20	77.41	77571.68	77.41
2	South	750.00	500.00	750.00	90.00	119.70	82602.93	119.70
3	North	4226.00	380.00	285.00	34.20	45.49	48597.48	45.49
4	West	1166.00	469.00	562.80	67.54	89.82	72674.29	89.82
	Total	7096.00	1834.00	2082.80	249.94	332.41	281446.38	332.41

Note: Surplus Available for artificial recharge is taken as equal to water required, in view of the rugged Himalayan terrain, which is 0.1 % of surplus available. Hence source water availability is considered as Harnessable water for artificial recharge

8.18.2 Artificial Recharge and Cost Estimates

In order to provide sustainability to water supply, various structures are proposed to recharge and to conservation water as given below

Check Dam and Check Dam cum Diversion Weir with Conveyance Drain/Pipe

Spring Shed Development
Rejuvenation of Lakes/Ponds
Subsurface Dyke and Cement Plug
Roof Top Rainwater Harvesting (RTRWH) and Rainwater Harvesting In The Landscape

A plan for development and augmentation of fresh water resources including ground water in the State is envisaged and it is contemplated that 540 Spring Shed development, 1,500 roof top rain water harvesting structures, 300 Rainwater harvesting structure made of impermeable membrane in slopes, 450 nos. cement plugs,125 subsurface dykes, and 380 Check dams including Check dam cum diversion weir and 40 Lake/pond rejuvenation or excavation work may be undertaken in the state of Sikkim. In case of Check dam cum diversion weir, there should be provision for conveyance of water through cemented drains/pipes to the terraced agricultural field for irrigation and augmentation of recharge.

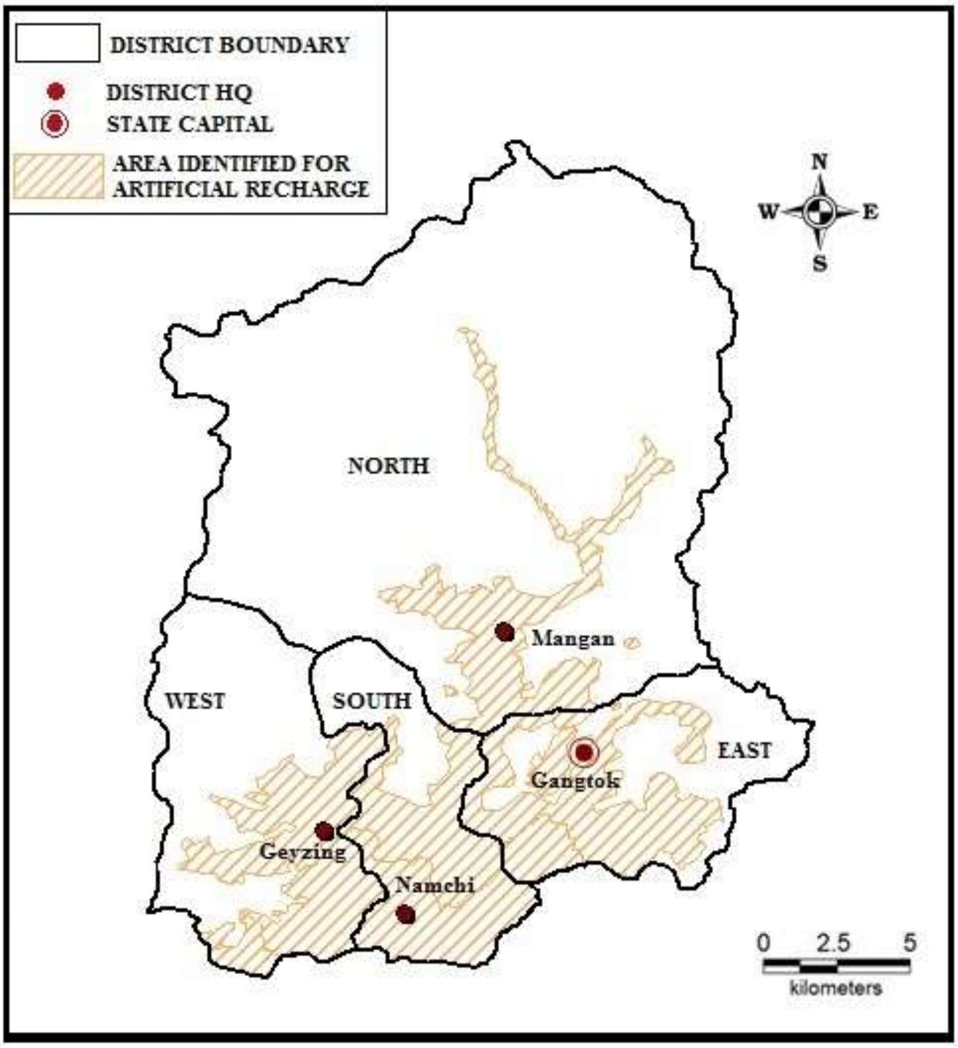


Fig 8.18.1 Area identified for Artificial Recharge in Sikkim

On implementation, a volume of 32.35MCM of rainwater, perennial surplus flow water can be harnessed and a fund of Rs.19887.5 lakh rupees would be required for the construction purposes (Table- 8.18.2).

Table 8.18.2 Artificial Recharge & Water Conservation in Sikkim

State	Number Of Structures							Unit Cost of Structures (Lakh)						
	CD/CD cum DW with conveyance drain/pipe	RTRWH	Gabion /CB	Rej. of Lake/pond excavation of new pond	Rainwater harvesting in slope	SSD and Cement Plug	Spring Shed Development	CD/CD cum DW with conveyance drain/pipe	RTRWH	Gabion /Contour bund	Rejuvenation of Lake/pond rejuvenation/ excavation of new pond	Rainwater harvesting in slope	Subsurface Dyke and Cement Plug	Spring Shed Development
Sikkim	380	1500	450	40	300	125	540	8.947	5	1.166	80	7.5	2.5	5

S.No	State	Cost of Structures (Lakh)							Total Cost (Lakh)
		CD/CD cum DW with conveyance drain/pipe	RTRWH	Gabion /Contour bund	Rej of Lake/pond/ excavation of new pond	Rainwater harvesting in slope	Subsurface Dyke and Cement Plug	Spring Shed Development	
1	Sikkim	3399.86	7500	524.7	3200	2250	312.5	2700	19887.06

8.19 TAMIL NADU

Tamil Nadu spreads over an area of 130058 Sq.km and has been divided into 32 districts, which are further sub-divided into 386 blocks. The State of Tamil Nadu, along with the enclaves constituting the Union Territory of Pondicherry is characterized by diverse climatic, physiographic, and hydrogeological conditions. The state receives rainfall during south west monsoon (June – October) & northeast monsoon (November – December) and the normal annual rainfall is of the order of 1008.1 mm (1951 - 2018). The contribution from south west monsoon is of the order of 525.1 mm (52%), while the contribution from north east monsoon is of the order of 28% and non monsoon rainfall (January – May) is of the order of 200.5 mm (20%). The ground water development scenario of the state is also very complex. Increasing demand and vagaries of rainfall, coupled with the near-total utilization of available surface water resources have resulted in increasing dependence on ground water which has become the major source for domestic, agricultural and industrial sectors. Development of ground water has already reached a critical stage in many parts of the state. Over exploitation of ground water in more than 50% of the geographical area has resulted in declining ground water levels, shortage in water supply, deepening of pumping levels and consequent increase in power consumption.

The increased ground water development in pockets for the industrial use has resulted in ground water mining in such pockets warranting a long term remediation. The regional ground water development in the sedimentary aquifers of larger areal extent for industrial and agricultural activity is in the rise in recent years and the vulnerability of coastal aquifers for sea water ingress is noticed.

Various State Agencies, viz., Agricultural Engineering Department, Public Works Department, Tamil Nadu Water Supply & Drainage Board and Forest Department have already constructed artificial recharge structures under various schemes. Forest Department has constructed Check Dams in the high reaches of Reserved Forest area. In the recent 5 years period, DRDA has constructed large number of artificial recharge structures as well as renovated water bodies, which are locally called 'Ooranis' or 'Kudis' and this process of rejuvenation is locally called as 'Kudimarammathu'. So far DRDA desilted and renovated about 40,000 such Ooranis under this scheme of Kudimarammathu in the state which improved not only the storage capacity of water bodies but also groundwater sustainability in the vicinity of those water bodies. In this decade i.e., since 2010 more than a lakh artificial recharge structures have been constructed in the state by different State Government Departments under different schemes like MGNREGA.

In spite of these all-out efforts the water levels in many parts of the state are deep and not rise to the expected levels. However, the decadal post monsoon water level trends for the period of 2010-2019 are not showing any significant fall more than 0.1m/year, which may be attributed to the augmentation of groundwater from the artificial recharge structures constructed during the preceding decade. Therefore, it is imperative to increase the density of suitable artificial recharge structures across the identified areas of the state in order to further rise the status of groundwater storage without compromising the current developmental level.

8.19.1 Identification of the Area

The area characterized by depth to water level more than 4 m during the post monsoon period (Jan 2019) coupled with declining decadal long term water level trend (Jan 2010 – Jan 2019) of more than 0.1m/yr, is considered as area requiring intervention through artificial recharge. In addition, the localized pockets of intensive agriculture and industrial activity identified by state agencies and select locations of sedimentary aquifers of multi layered aquifer system requiring special intervention have also been considered. Thus the area identified for recharge is 91,224 Sq.km and given in Table 8.19.1 & Fig 8.19.1.

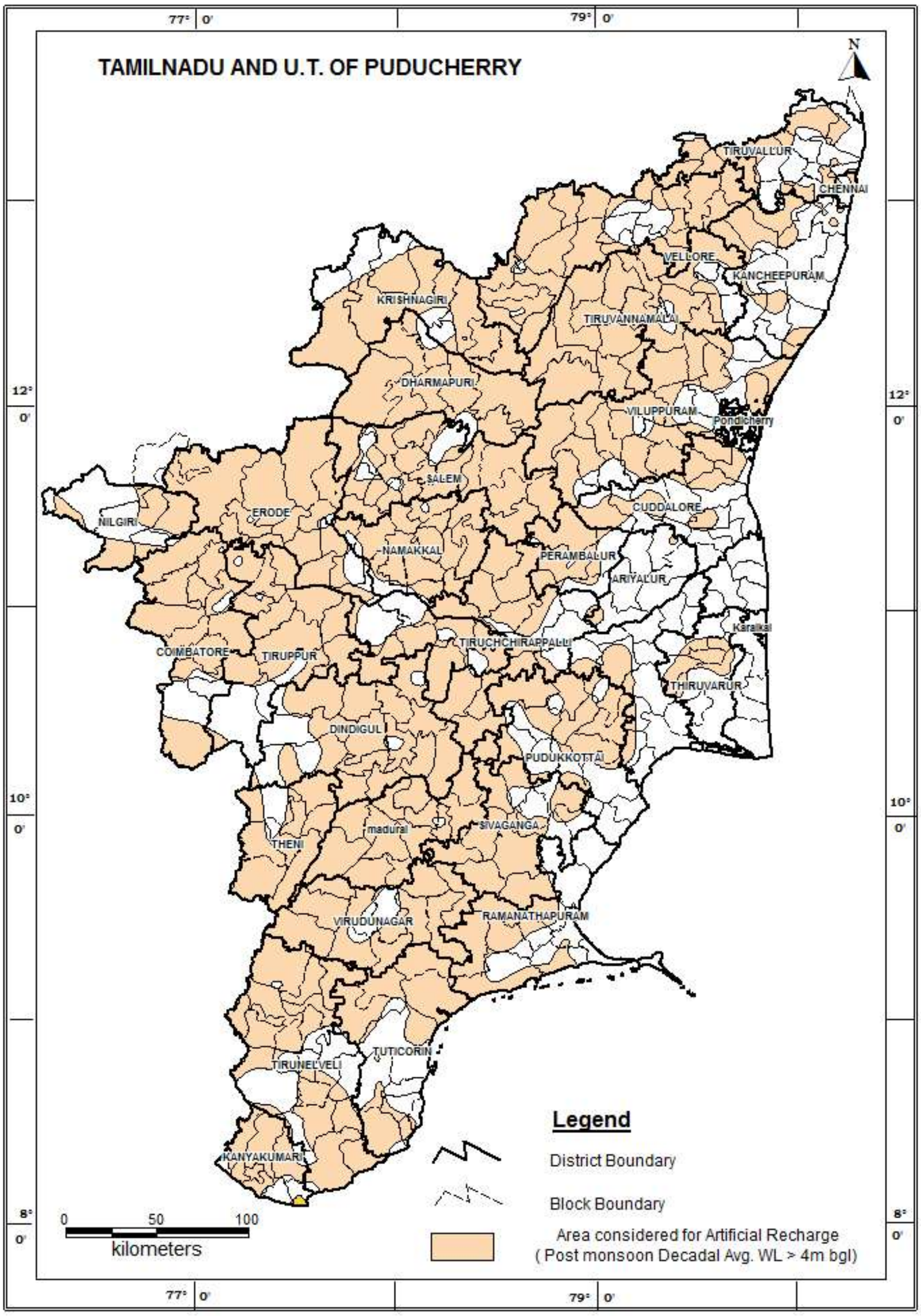


Fig 8.19.1 Area identified for Artificial Recharge in Tamil Nadu

Table 8.19.1 Scope of Artificial Recharge in Tamil Nadu

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Ariyalur	1940	229.64	478.68	9.57	12.73	3.77
2	Chennai	175	28.00	76.68	1.53	2.04	0.76
3	Coimbatore	4732	4017.83	35377.94	707.56	941.05	59.60
4	Cuddalore	3703	1438.43	4643.82	92.88	123.53	23.30
5	Dharmapuri	4497	4131.80	18754.19	375.08	498.86	37.39
6	Dindigul	6036	5003.31	20622.45	412.45	548.56	51.89
7	Erode	5760	5366.97	36387.09	727.74	967.90	42.33
8	Kancheepuram	4483	1076.84	3768.88	75.38	100.25	35.30
9	Kanyakumari	1684	1336.52	4094.06	81.88	108.90	21.80
10	Karur	2904	1991.68	8755.26	175.11	232.89	18.06
11	Krishnagiri	5129	4953.30	22744.90	454.90	605.01	43.33
12	Madurai	3710	3682.66	14678.06	293.56	390.44	33.25
13	Nagapattinam	2569	191.00	145.36	2.91	3.87	2.65
14	Namakkal	3420	3152.80	26297.56	525.95	699.52	26.50
15	Nilgiris	2563	903.18	5198.21	103.96	138.27	23.90
16	Peramballur	1756	1276.49	4174.92	83.50	111.05	13.32
17	Pudukkottai	4644	2782.43	8257.45	165.15	219.65	34.31
18	Ramanathapuram	4104	1452.86	6702.38	134.05	178.28	13.23
19	Salem	5237	4290.10	25160.58	503.21	669.27	42.54
20	Sivaganga	4233	3210.20	11230.98	224.62	298.74	33.83
21	Thanjavur	3411	1055.43	3158.86	63.18	84.03	19.11
22	Theni	2868	2377.59	13505.43	270.11	359.24	24.39
23	Thiruppur	5187	3921.55	23302.35	466.05	619.84	27.36
24	Thiruvallur	3394	1721.19	3938.64	78.77	104.77	28.10
25	Thiruvarur	2274	230.09	1070.34	21.41	28.47	12.10
26	Tirunelveli	6693	4996.17	21632.31	432.65	575.42	53.24
27	Tiruvannamalai	6188	5670.73	23470.13	469.40	624.31	6.44
28	Trichy	4509	3319.80	21339.66	426.79	567.64	32.97
29	Tuticorin	4745	2925.80	9105.15	182.10	242.20	29.05
30	Vellore	6075	5239.91	22034.14	440.68	586.11	51.08
31	Villupuram	7194	5382.96	18073.80	361.48	480.76	81.85
32	Virudhunagar	4241	3866.84	16859.53	337.19	448.46	32.55
	Total	**130058**	**91224.1**	**435039.79**	**8700.8**	**11572.06**	**959.3**

8.19.2 Subsurface Storage Space and Water Requirement

The thickness of unsaturated zone up to 4m bgl is assessed as the difference between the post monsoon water level and 04m and multiplied by the area would yield the volume of unsaturated zone up to 04m bgl. It works out to be 434050 MCM. The product of volume of unsaturated zone and specific yield would provide the volume of space available for recharge and is found to be of the order of 8701 MCM. An average specific yield of 1.5% and 10% has been assumed for crystalline and sedimentary formations respectively. The experience in this field has indicated that all the recharge structures have an efficiency of 75% in conveying the water to groundwater system and hence the water required for artificial recharge is accordingly estimated as 11572 MCM. (Table 8.19.1)

8.19.3 Source Water Availability

The surface water availability has been computed using improved strange curve for each watershed in a project entitled "Identification of Recharge areas Using Remote Sensing and GIS in Tamil Nadu, taken up by the Institute of Remote Sensing, Anna University, Chennai and sponsored by the Dept. of Rural Development, Govt. of Tamil Nadu and Tamil Nadu Water Supply and Drainage Board. The same has been utilized in this report for determining the surface water availability for each district. The map of area identified for artificial recharge has been superimposed over the block map and the blocks covering the critical area either full or in part has been identified and the harnessable surface water for each of the blocks have been summed up to get the surface water availability for each district. However in the present proposals 10 percent of the normal rainfall of the development blocks has been taken as uncommitted surplus runoff available for artificial recharge, instead of 15 percent of normal rainfall. The reduced 5 percent is presumed to feed the artificial recharge structures already constructed by different state government departments and agencies (Table 8.19.1)

8.19.4 Artificial Recharge and Cost Estimate

The number of artificial recharge structures has been worked out on the basis of existing artificial recharge structures in the State as in march 2019, constructed through any schemes and available surplus water for recharge and the type of structure depends on hydrogeology of the area. The details of proposed artificial recharge along with cost estimate has been provided as Table 8.19.2.

In respect of rainwater harvesting, the State of Tamil Nadu was the first State to make it mandatory for all the buildings in the State and hence it is considered as an activity already completed. The proposed artificial recharge in the State of Tamil Nadu would have an estimated cost of Rs 2463.14.

Table 8.19.2 Artificial Recharge in Tamil Nadu

		No of artificial recharge structures feasible						Unit Cost (Lakh)						Cost of Structures (Lakh)						
S.No	District	CD/NB	RS/ BW	Others FP/ RP	RTW	PP	RT (km)	CD/ NB	RS/ BW	Others FP/RP	RTW	PP	RT (km)	CD/NB	RS/ BW	Others FP/ RP	RTW	PP	RT (km)	Total Cost (Lakh)
1	Ariyalur	28	150	28	1	9	0	15	1	1	3	25	1	420.00	150.00	28.00	3.00	225.00	0.00	826.00
2	Chennai	6	30	6	1	2	0	15	1	1	3	25	1	90.00	30.00	6.00	3.00	50.00	0.00	179.00
3	Coimbatore	447	4768	447	14	149	13	15	1	1	3	25	1	6705.00	4768.00	447.00	42.00	3725.00	13.00	15700.00
4	Cuddalore	175	1863	175	0	59	7	15	1	1	3	25	1	2625.00	1863.00	175.00	0.00	1475.00	7.00	6145.00
5	Dharmapuri	281	2990	281	0	93	10	15	1	1	3	25	1	4215.00	2990.00	281.00	0.00	2325.00	10.00	9821.00
6	Dindigul	389	4152	389	0	131	12	15	1	1	3	25	1	5835.00	4152.00	389.00	0.00	3275.00	12.00	13663.00
7	Erode	316	3386	316	0	106	9	15	1	1	3	25	1	4740.00	3386.00	316.00	0.00	2650.00	9.00	11101.00
8	Kancheepuram	266	2825	266	0	90	10	15	1	1	3	25	1	3990.00	2825.00	266.00	0.00	2250.00	10.00	9341.00
9	Kanyakumari	164	1722	164	1	55	4	15	1	1	3	25	1	2460.00	1722.00	164.00	3.00	1375.00	4.00	5728.00
10	Karur	136	1446	136	0	45	5	15	1	1	3	25	1	2040.00	1446.00	136.00	0.00	1125.00	5.00	4752.00
11	Krishnagiri	326	3467	326	0	109	12	15	1	1	3	25	1	4890.00	3467.00	326.00	0.00	2725.00	12.00	11420.00
12	Madurai	250	2660	250	0	85	8	15	1	1	3	25	1	3750.00	2660.00	250.00	0.00	2125.00	8.00	8793.00
13	Nagapattinam	19	102	19	5	7	0	15	1	1	3	25	1	285.00	102.00	19.00	15.00	175.00	0.00	596.00
14	Namakkal	197	2119	197	0	66	5	15	1	1	3	25	1	2955.00	2119.00	197.00	0.00	1650.00	5.00	6926.00
15	Nilgiris	166	1777	166	0	55	6	15	1	1	3	25	1	2490.00	1777.00	166.00	0.00	1375.00	6.00	5814.00
16	Peramballur	99	1066	99	0	33	4	15	1	1	3	25	1	1485.00	1066.00	99.00	0.00	825.00	4.00	3479.00
17	Pudukkottai	258	2258	258	20	87	10	15	1	1	3	25	1	3870.00	2258.00	258.00	60.00	2175.00	10.00	8631.00
18	Ramanathapuram	99	529	99	24	32	3	15	1	1	3	25	1	1485.00	529.00	99.00	72.00	800.00	3.00	2988.00
19	Salem	316	3402	316	0	104	9	15	1	1	3	25	1	4740.00	3402.00	316.00	0.00	2600.00	9.00	11067.00
20	Sivaganga	253	2470	253	10	83	10	15	1	1	3	25	1	3795.00	2470.00	253.00	30.00	2075.00	10.00	8633.00
21	Thanjavur	144	765	144	34	49	5	15	1	1	3	25	1	2160.00	765.00	144.00	102.00	1225.00	5.00	4401.00
22	Theni	183	1952	183	0	61	5	15	1	1	3	25	1	2745.00	1952.00	183.00	0.00	1525.00	5.00	6410.00
23	Thiruppur	204	2189	204	0	68	7	15	1	1	3	25	1	3060.00	2189.00	204.00	0.00	1700.00	7.00	7160.00
24	Thiruvallur	210	2247	210	0	70	5	15	1	1	3	25	1	3150.00	2247.00	210.00	0.00	1750.00	5.00	7362.00
25	Thiruvarur	92	483	92	21	31	2	15	1	1	3	25	1	1380.00	483.00	92.00	63.00	775.00	2.00	2795.00

		No of artificial recharge structures feasible						Unit Cost (Lakh)						Cost of Structures (Lakh)						
S.No	District	CD/NB	RS/ BW	Others FP/ RP	RTW	PP	RT (km)	CD/ NB	RS/ BW	Others FP/RP	RTW	PP	RT (km)	CD/NB	RS/ BW	Others FP/ RP	RTW	PP	RT (km)	Total Cost (Lakh)
26	Tirunelveli	400	4260	400	0	134	13	15	1	1	3	25	1	6000.00	4260.00	400.00	0.00	3350.00	13.00	14023.00
27	Tiruvannamalai	49	514	49	0	18	0	15	1	1	3	25	1	735.00	514.00	49.00	0.00	450.00	0.00	1748.00
28	Trichy	248	2640	248	0	83	8	15	1	1	3	25	1	3720.00	2640.00	248.00	0.00	2075.00	8.00	8691.00
29	Tuticorin	218	1204	218	46	74	7	15	1	1	3	25	1	3270.00	1204.00	218.00	138.00	1850.00	7.00	6687.00
30	Vellore	382	4085	382	0	126	13	15	1	1	3	25	1	5730.00	4085.00	382.00	0.00	3150.00	13.00	13360.00
31	Villupuram	615	4335	615	95	202	21	15	1	1	3	25	1	9225.00	4335.00	615.00	285.00	5050.00	21.00	19531.00
32	Virudhunagar	244	2604	244	0	81	10	15	1	1	3	25	1	3660.00	2604.00	244.00	0.00	2025.00	10.00	8543.00
	Total	7180	70460	7180	272	2397	233							107700.00	70460.00	7180.00	816.00	59925.00	233.00	246314.00

8.20 TELANGANA

Telangana State is the 29thState of India covering geographical area of 1,12,077 Km^2 lies between NL 15° 48' and 19° 54'and EL 77° 12'and 81° 50'. The state is bordered by the states of Maharashtra, Chhattisgarh to the north, Karnataka to the west and Andhra Pradesh to the south, east and north-east. The State comprises 33 districts, 584 mandals with 10,434 revenue villages. The total population of the state is ~3.5 Crores (2011 census), of which 61 % lives in rural area and 39% in urban area. The density of population is 312 per Sq. Km. The decadal growth in population is ~13.6 % (2001 to 2011 census). The state is mainly drained by Godavari and Krishna and their tributaries. There are 2 major basins and 13 sub basins in the state. The normal annual rainfall of the state is 909 mm. The annual rainfall in 2018 ranges from 478 mm in Mahbubnagar district to 1215 mm in Adilabad district. Major part of the State is underlain by gneissic complex with a structural fill of sedimentary formations and basin-fill of meta-sedimentary formations.

8.20.1 Identification of Area:

The area suitable for ground water augmentation through artificial recharge has been demarcated based on the analysis of average post-monsoon depth to water level data of the observation wells for the period of 2009-2018 and the existing data on artificial recharge structures constructed under various schemes of Mahatma Gandhi National Rural Employment Guarantee Scheme (MNREGS) and Integrated Watershed Management Programs (IWMP) by Rural Development department, Govt. of Telangana. Accordingly, an area of 42,155.89 sq.kms area spread over in 279 mandals falling in 29 districts is identified for recommendation of artificial recharge structures. The remaining area of 52,820 sq.kms comprises of 295 mandals have water level less than 5 m bgl and an area of 1,587 sq.kms comprises in 10 mandals have sufficient number of existing artificial recharge structures hence, no scope for taking up artificial recharge.

8.20.2 Sub Surface Storage Space

The availability of sub-surface storage volume of aquifers in each district is computed as the product of area, thickness of aquifer zone between 5 m. bgl and the average post-monsoon water level. The sub surface storage volume is estimated as **1,67,141 MCM**. The recharge potential/sub surface space of the aquifers is calculated by multiplying the sub surface storage volume with specific yield of the aquifers, which is in the range of 2-3% (hard rock aquifer system). The Sub surface space/recharge potential of the aquifers is **3342.82 MCM** in the State (Table 8.20.2). The water required to recharge the subsurface storage capacity is **4445.97 MCM**, considering 77% efficiency of the recharge structures.

8.20.3 Source Water Availability

The source water availability is estimated from the rain fall and run off correlations. The runoff was calculated by taking into account of normal monsoon rainfall of the mandal and corresponding runoff yield from Strangers Table for average catchment type. Out of the total run off available in the mandal, only 20% is considered for recommendation of artificial recharge structures considering the riparian rights and other practical considerations for recommending the artificial recharge structures. Though the sub surface space/recharge potential of the aquifers is **3342.82 MCM,** only **1186.48 MCM of** surplus run off is available for recharge the aquifers (Table 8.20.2). The storage required for existing 20,610 no. of artificial recharge structures (7,980 check dams and 12,630 percolation tanks) constructed by State Govt. departments under different IWMP and MNREGS schemes is deducted to arrive the balance surplus run off availability for recommending the additional feasible artificial recharge structures.

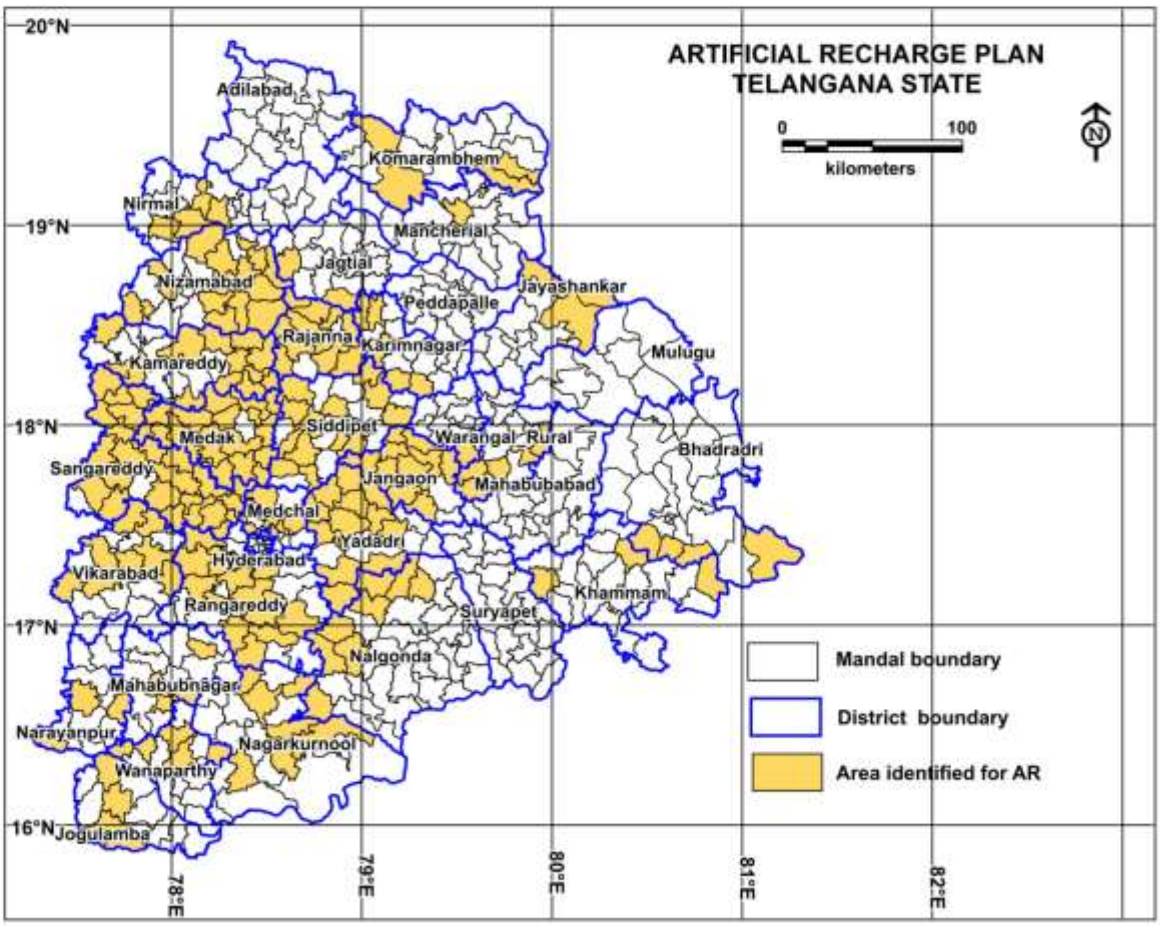


Fig 8.20.1: Area Identified for Artificial Recharge in Telangana

Table 8.20.2 Scope of Artificial Recharge in Telangana

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Adilabad	4153.00	0.00	0.00	0.00	0.00	0.00
2	Bhadradri Kothagudem	7483.00	1045.74	1811.13	36.22	48.18	40.33
3	Hyderabad	217.00	217.00	0.00	0.00	0.00	0.00
4	Jagtial	2419.00	507.09	757.00	15.14	20.14	16.02
5	Jangaon	2188.00	1652.26	4863.02	97.26	129.36	28.28
6	Jayashankar Bhupalapalli	7194.00	534.48	1295.15	25.90	34.45	79.69
7	Jogulamba Gadwal	2928.00	880.70	3319.34	66.39	88.29	4.30
8	Kamareddy	3652.00	1911.94	6854.44	137.09	182.33	76.07
9	Karimnagar	2128.00	699.12	1073.75	21.48	28.56	16.34
10	Khammam	4361.00	678.49	278.02	5.56	7.40	29.42
11	Kumaram Bheem Asifabad	4878.00	1219.13	874.03	17.48	23.25	71.65
12	Mahabubabad	2877.00	0.00		0.00	0.00	0.00
13	Mahabubnagar	5286.00	1529.32	11310.47	226.21	300.86	18.05
14	Mancherial	4016.00	325.86	844.35	16.89	22.46	23.80

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
15	Medak	2786.00	2418.66	12558.91	251.18	334.07	98.85
16	Medchal Malkajgiri	1084.00	767.46	3829.69	76.59	101.87	11.82
17	Mulugu	4208	307.87	2548.12	50.96	67.78	32.60
18	Nagarkurnool	6545.00	3077.63	21550.69	431.01	573.25	30.69
19	Nalgonda	7122.00	1575.05	5030.17	100.60	133.80	32.81
20	Narayanpet	2388	1825.77	3809.56	76.19	101.33	15.05
21	Nirmal	3845.00	570.48	1822.20	36.44	48.47	35.04
22	Nizamabad	4288.00	2450.70	5220.17	104.40	138.86	104.24
23	Peddapalli	2236.00	0.00	0.00	0.00	0.00	0.00
24	Rajanna	2019.00	1591.05	6431.18	128.62	171.07	46.42
25	Rangareddy	5031.00	3737.59	25553.51	511.07	679.72	46.67
26	Sangareddy	4403.00	3612.54	17056.37	341.13	453.70	132.57
27	Siddipet	3632.00	2563.70	14521.67	290.43	386.28	63.51
28	Suryapet	3607.00	0.00	0.00	0.00	0.00	0.00
29	Vikarabad	3386.00	2280.98	4437.08	88.74	118.03	55.40
30	Wanaparthy	2152.00	1071.00	2338.07	46.76	62.19	9.78
31	Warangal rural	2175.00	730.89	817.61	16.35	21.75	24.03
32	Warangal urban	1309.00	123.48	449.02	8.98	11.94	3.31
33	Yadadri	3092.00	2249.91	5886.34	117.73	156.58	39.73
		112492.00	42155.89	167141.06	3342.80	4445.97	1186.47

The number of artificial structures is recommended based on the surplus run off availability which is limited in the state in comparison to the available subsurface space and water required for recharge. The sub surface space considered for artificial recharge is 3342.80 MCM after deducting the storage of 261.76 MCM created by existing structures constructed by State Govt. departments under various schemes. The volume of surface water required for artificial recharge is 4445.97 MCM. The total Surplus runoff available for recharge is 1186.47 MCM.

8.20.4 Artificial Recharge & Cost Estimates

The State is underlain mainly by hard rock aquifer system and surface water spread techniques like percolation tanks and check dams are most appropriate for the terrain. The number of Artificial Recharge Structures feasible has been recommended in areas, by considering the available surplus yield and number of existing structures. The total number of Check dams and Percolation Tanks are recommended by taking 5 fillings for Check dams and 1.5 fillings for Percolation Tanks. Accordingly, a total of **22188** number of artificial recharge structures (**11552** number of check dams and **10636** percolation tanks with Recharge Shafts) are recommended in **42155** sq.kms area spread over 263 mandals of 29 districts of the State, which are approximately 1 recharge structures per 1.90 sq.kms. In addition, **22188** number of recharge shafts/recharge bore wells are recommended in the CDS and PTS proposed for effective recharge. The unit cost of construction for check dam, Percolation Tanks and Recharge shaft is Rs. 8 Lakhs, 13 Lakhs and 2 Lakhs respectively. The total outlay is estimated to be Rs. **2750** Cr for the artificial recharge structures in the state@ Rs. **1155.20 Cr** for check dams and @ Rs **1595.40** Cr for percolation Tanks (Table-8.20.3).

Table 8.20.3 Artificial Recharge Structures and Cost Estimates in Telangana

		Number of Structures				Unit Cost of Structures				Cost of Structures				
State	District	CD	RTRWH	PT	Recharge Shafts	CD	RTRWH	PT	RS	CD	RTRWH	PT	Recharge Shafts	Total Cost
Telangana	Adilabad	0	5520	0	0	8.0	0.20	13.0	2.0	0.00	1104.00	0.00	0.00	1104
Telangana	Bhadradri Kothagudem	516	13168	455	971	8.0	0.20	13.0	2.0	4128.00	2634.00	5915.00	1942.00	14619
Telangana	Hyderabad	0	212263	0	0	8.0	0.20	13.0	2.0	0.00	42453.00	0.00	0.00	42453
Telangana	Jagtial	177	7910	174	351	8.0	0.20	13.0	2.0	1416.00	1582.00	2262.00	702.00	5962
Telangana	Jangaon	322	2496	232	554	8.0	0.20	13.0	2.0	2576.00	499.00	3016.00	1108.00	7199
Telangana	Jayashankar Bhupalpalli	439	2018	437	876	8.0	0.20	13.0	2.0	3512.00	404.00	5681.00	1752.00	11349
Telangana	Jogulamba_Gadwal	16	1977	12	28	8.0	0.20	13.0	2.0	128.00	395.00	156.00	56.00	735
Telangana	Kamareddy	757	4066	739	1496	8.0	0.20	13.0	2.0	6056.00	813.00	9607.00	2992.00	19468
Telangana	Karimnagar	250	11183	243	493	8.0	0.20	13.0	2.0	2000.00	2237.00	3159.00	986.00	8382
Telangana	Khammam	89	12492	54	143	8.0	0.20	13.0	2.0	712.00	2498.00	702.00	286.00	4198
Telangana	Komaram Bheem	296	2976	228	524	8.0	0.20	13.0	2.0	2368.00	595.00	2964.00	1048.00	6975
Telangana	Mahabubabad	0	2750	0	0	8.0	0.20	13.0	2.0	0.00	550.00	0.00	0.00	550
Telangana	Mahabubnagar	82	9260	82	164	8.0	0.20	13.0	2.0	656.00	1852.00	1066.00	328.00	3902
Telangana	Mancherial	197	13085	74	271	8.0	0.20	13.0	2.0	1576.00	2617.00	962.00	542.00	5697
Telangana	Medak	1312	1831	1303	2615	8.0	0.20	13.0	2.0	10496.00	366.00	16939.00	5230.00	33031
Telangana	Medchal-Malkajgiri	136	82488	129	265	8.0	0.20	13.0	2.0	1088.00	16498.00	1677.00	530.00	19793
Telangana	Mulugu	552	0	523	1075	8.0	0.20	13.0	2.0	4416.00	0.00	6799.00	2150.00	13365
Telangana	Nagarkurnool	129	2855	113	242	8.0	0.20	13.0	2.0	1032.00	571.00	1469.00	484.00	3556
Telangana	Nalgonda	370	13431	368	738	8.0	0.20	13.0	2.0	2960.00	2686.00	4784.00	1476.00	11906
Telangana	Narayanapet	35	0	35	70	8.0	0.20	13.0	2.0	280.00	0.00	455.00	140.00	875
Telangana	Nirmal	455	4945	436	891	8.0	0.20	13.0	2.0	3640.00	989.00	5668.00	1782.00	12079
Telangana	Nizamabad	902	15089	861	1763	8.0	0.20	13.0	2.0	7216.00	3018.00	11193.00	3526.00	24953
Telangana	Peddapalli	0	11449	0	0	8.0	0.20	13.0	2.0	0.00	2290.00	0.00	0.00	2290
Telangana	Rajanna_Sircilla	599	4348	586	1185	8.0	0.20	13.0	2.0	4792.00	870.00	7618.00	2370.00	15650
Telangana	Rangareddy	445	48526	379	824	8.0	0.20	13.0	2.0	3560.00	9705.00	4927.00	1648.00	19840

		Number of Structures				Unit Cost of Structures				Cost of Structures				
State	District	CD	RTRWH	PT	Recharge Shafts	CD	RTRWH	PT	RS	CD	RTRWH	PT	Recharge Shafts	Total Cost
Telangana	Sangareddy	1779	18036	1730	3509	8.0	0.20	13.0	2.0	14232.00	3607.00	22490.00	7018.00	47347
Telangana	Siddipet	496	4742	428	924	8.0	0.20	13.0	2.0	3968.00	948.00	5564.00	1848.00	12328
Telangana	Suryapet	0	6199	0	0	8.0	0.20	13.0	2.0	0.00	1240.00	0.00	0.00	1240
Telangana	Vikarabad	361	3844	217	578	8.0	0.20	13.0	2.0	2888.00	769.00	2821.00	1156.00	7634
Telangana	Wanaparthy	77	2933	77	154	8.0	0.20	13.0	2.0	616.00	587.00	1001.00	308.00	2512
Telangana	Warangal_Rural	215	1823	175	390	8.0	0.20	13.0	2.0	1720.00	365.00	2275.00	780.00	5140
Telangana	Warangal_Urban	56	27074	56	112	8.0	0.20	13.0	2.0	448.00	5415.00	728.00	224.00	6815
Telangana	Yadadri_Bhongiri	492	4316	490	982	8.0	0.20	13.0	2.0	3936.00	863.00	6370.00	1964.00	13133
	Total	11552	555093	22188	10636					92416.00	111020.00	138268.00	44376.00	386080.00

8.20.5 Roof Top Rain Water Harvesting in Urban Areas

As per the statistical data (2016-17) of Govt. of Telangana, the total number of urban households is 31.53 Lakhs in 31 districts of the State. Out of total population, about 38% resides in the urban areas. As per WALTA act, Govt. of Telangana is mandated to construct roof top rain water harvesting structures for the buildings with roof area is 200 sq. m and above. The approximate cost for construction of roof top rain water harvesting has been assessed to be Rs. ~20,000/- for a 200 sq.m building. Out of 31.53 Lakhs households in the urban areas, it is assumed that 15% of households with roof area of ~200 sq.m and the total cost for the roof top rain water harvesting estimated to be Rs1110.19 crores (Table-8.20.3). It will conserve ~72 MCM of rain water considering the normal rainfall and 80% efficiency of the system, which either can be stored and recharged depending upon the hydro geological feasibility.

In addition to this, there are 40821 no. of School buildings, ~2000 hostel buildings, 5622 college buildings, ~2000 hospital buildings, 14,427 no. of industries, 5835 post office buildings and 1291 telephone exchange buildings in the State, where roof top rain water harvesting can be taken up. It is estimated that ~10.5 MCM of rainfall/run off can be harvested through the institutional interventions.

8.20.6 Total Cost

The total cost for proposed artificial recharge is Rs 3860.80 Cr, out of which Rs 2750.60 Cr is in rural areas for artificial recharge structure and Rs 1110.20 Cr is for rooftop rainwater harvesting in urban areas.

8.21 UTTAR PRADESH

State of Uttar Pradesh forms a part of vast Gangetic Alluvial Plain covering an area of 2,40,928 sq.km. The state is a part Ganga basin comprising of Yamuna, Ram Ganga, Gomti, Ghaghra and son sub basins. The alluvial plains and southern rocky terrain are main water bearing formations from point of view of ground water availability.
The state of Uttar Pradesh is categorized with five distinct hydrogeological units – Bhabar, Terai, Central Ganga Plains, Marginal Alluvial Plain, Southern Peninsular area. Bhabar is mainly the recharge zone having deeper water levels. Ground water development in phreatic aquifer is through hand pumps, dug wells, dug cum bore wells and shallow tube wells. Terai zone lies between Bhabar in the North and Central Ganga Plain in the South. It is characterized by fine grained sediments with occasional pebbles and boulders. Central Ganga Plain constitutes the most promising ground water repository characterized by multi-layered aquifer systems. Marginal alluvial plain consists of kankar mixed clay-silt beds intercalated with sand and gravel lenses. Southern Peninsular Region is characterized by sedimentary formations (sandstone, quartzite, limestone, shale). The artificial recharge in these aquifers depend on the geomorphology & groundwater regime.

8.21.1 Identification of Area

The area for artificial recharge in the state has been identified with block as the unit for identification aggregated to districts, for technical and administrative convenience. The criteria used for identification of area for artificial recharge are given below.

- All the Over-exploited and Critical blocks with post monsoon water level > 5m bgl (Average post-monsoon WL, 2018 of individual block).
- Entire Bundelkhand Region, UP, as well as Mirzapur and Sonbhadra districts, where sustainability is an issue, necessitating water conservation.
- ‘Semi-critical’ and ‘Safe’ blocks showing water level decline of more than 20 cm/yr (as per consultation with State Government criterion of significant decline considered in the State has been applied) and with water levels deeper than 5 mbgl.

Total 276 blocks, falling in 54 districts and covering 97,335 sq.km. area, have been identified for artificial recharge and shown as selected blocks in the Fig 8.21.1.

8.21.2 Sub-Surface Storage Space and Water Requirement

The difference between average depth to water level (2018) in the block and 5m was calculated to arrive at thickness of effective unsaturated zone. The product of area and the thickness of unsaturated zone gives the volume of unsaturated zone in the State, which on multiplying with specific yield provides the volume of unsaturated zone available for artificial recharge. Considering an efficiency of 75% of the artificial recharge structures, volume of required water for saturating the available unsaturated zone was worked out. The details of the computations are provided as Table 8.21.1. A perusal of the table shows that for an area of 97335 sq.km, volume of space available for recharge works out to be 66971 MCM and the water required for recharge is of the order of 89071 MCM.

8.21.3 Source Water Availability

In the absence of precise data on surface water utilization for the State, surface water availability has been calculated by considering average monsoon run off of 30% of which 30% has been taken as non-committed water availability (i.e overall 9% of Monsoon Rainfall). The 30% of monsoon rainfall has been taken considering the erratic and localized rainfall pattern. Ensuring sufficient allocation for existing and ongoing surface water conservation projects 40% of the present non-committed surface water has been considered for preparing the recharge plan (i.e net available quantum is 3.6% of Monsoon Rainfall). Total utilizable run-off has been worked out as 2743 MCM against the required 89071 MCM (Table 8.21.1).

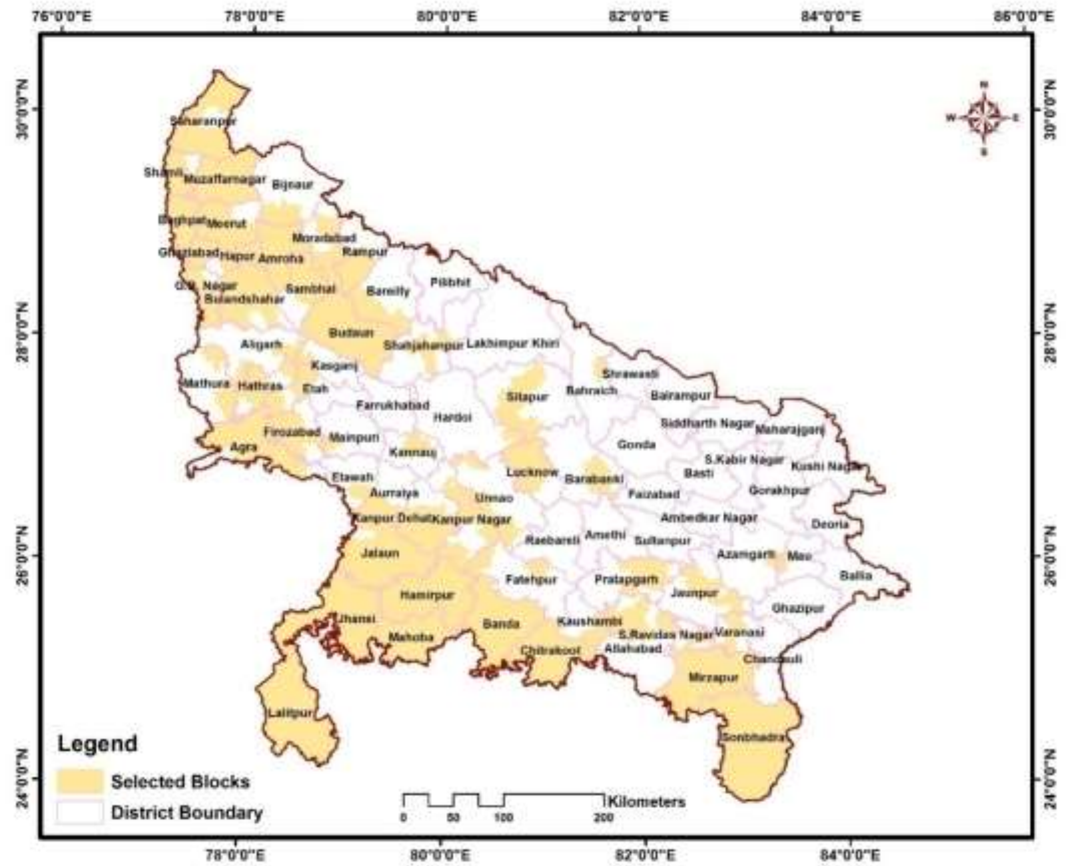


Fig 8.21.1 Area identified for Recharge in Uttar Pradesh

Table-8.21.1 Scope of Artificial Recharge in Uttar Pradesh

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Availabe Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Agra	4027.00	3183.00	72811.00	11650.00	15494.00	81.00
2	Aligarh	3650.00	598.00	4427.00	708.00	942.00	17.00
3	Allahabad	5486.00	1687.00	6270.00	779.00	1037.00	42.00
4	Aurraiya	2177.00	795.00	2657.00	425.00	565.00	18.00
5	Azamgarh	4222.00	159.00	73.00	12.00	16.00	4.00
6	Baghpat	1321.00	1327.00	21090.00	3374.00	4488.00	32.00
7	Bahraich	4855.00	222.00	151.00	24.00	32.00	5.00
8	Banda	4460.00	4389.00	17399.00	1722.00	2290.00	130.00
9	Barabanki	4405.00	759.00	1885.00	226.00	301.00	21.00
10	Bareilly	4115.00	1235.00	3560.00	570.00	758.00	35.00
11	Bijnore	4561.00	767.00	3295.00	527.00	701.00	19.00
12	Budaun	4234.00	4377.00	20446.00	3020.00	4017.00	130.00
13	Bulandshahar	4352.00	3004.00	9328.00	1492.00	1985.00	89.00
14	Chitrakoot	3164.00	3250.00	8287.00	642.00	854.00	114.00
15	Etah	2688.00	973.00	4909.00	786.00	1045.00	30.00
16	Etawah	2148.00	311.00	315.00	50.00	67.00	9.00
17	Fatehpur	4145.00	839.00	4778.00	501.00	666.00	25.00
18	Firozabad	2353.00	1481.00	24568.00	3931.00	5228.00	38.00
19	G.B. Nagar	1442.00	1219.00	1706.00	273.00	363.00	26.00

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Availabe Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
20	Ghaziabad	867.00	867.00	4659.00	745.00	991.00	20.00
21	Hamirpur	4282.00	4257.00	38949.00	2989.00	3976.00	129.00
22	Hapur	1116.00	875.00	5639.00	902.00	1200.00	22.00
23	Hardoi	5988.00	248.00	498.00	80.00	106.00	7.00
24	Hathras	1840.00	1182.00	11723.00	1876.00	2495.00	36.00
25	Jalaun	4544.00	4291.00	12229.00	1223.00	1626.00	124.00
26	Jaunpur	4038.00	1195.00	6399.00	768.00	1021.00	38.00
27	Jhansi	5024.00	5030.00	12927.00	233.00	310.00	118.00
28	JP Nagar (Amroha)	2249.00	2170.00	12751.00	2040.00	2713.00	73.00
29	Kannauj	2091.00	417.00	5330.00	853.00	1134.00	17.00
30	Kanpur Dehat	2995.00	2054.00	17033.00	2725.00	3625.00	60.00
31	Kanpur Nagar	3180.00	1720.00	11427.00	1426.00	1897.00	62.00
32	Kasganj	1793.00	221.00	812.00	130.00	173.00	8.00
33	Kaushambi	1780.00	659.00	5759.00	921.00	1225.00	21.00
34	Lalitpur	5039.00	5041.00	13753.00	138.00	183.00	120.00
35	Lucknow	2526.00	1802.00	6252.00	1000.00	1330.00	50.00
36	Mahoba	2884.00	2832.00	693.00	7.00	9.00	82.00
37	Mainpuri	2758.00	198.00	4243.00	679.00	903.00	7.00
38	Mathura	3339.00	985.00	6492.00	1039.00	1382.00	30.00
39	Mau	1712.00	188.00	241.00	39.00	51.00	5.00
40	Meerut	2590.00	2027.00	14252.00	2422.00	3222.00	58.00
41	Mirzapur	4518.00	4518.00	7393.00	607.00	807.00	137.00
42	Moradabad	2271.00	1388.00	4473.00	716.00	952.00	40.00
43	Muzaffarnagar	2991.00	2865.00	13510.00	2162.00	2875.00	81.00
44	Pratapgarh	3716.00	1355.00	6265.00	752.00	1000.00	34.00
45	Rampur	2367.00	1059.00	1270.00	203.00	270.00	33.00
46	St R Nagar (Bhadohi)	1015.00	348.00	597.00	72.00	95.00	9.00
47	Saharanpur	3689.00	3168.00	17937.00	2870.00	3817.00	80.00
48	Shahjahanpur	4569.00	875.00	3110.00	382.00	507.00	29.00
49	Sambhal	2453.00	1503.00	13696.00	2191.00	2914.00	43.00
50	Shamli	1168.00	1087.00	17808.00	2849.00	3789.00	27.00
51	Sitapur	5736.00	1792.00	3920.00	445.00	592.00	59.00
52	Sonbhadra	6816.00	6816.00	5418.00	81.00	108.00	172.00
53	Unnao	4556.00	1184.00	2461.00	394.00	524.00	34.00
54	Varanasi	1535.00	546.00	2496.00	299.00	398.00	13.00
	Total	**177840.00**	**97338.00**	**500370.00**	**66970.00**	**89069.00**	**2743.00**

*Although non-committed availability is 2744 MCM, utilizable quantum is 2742 due to lesser available storage space in one block.

8.21.4 Recharge Structures and Cost Estimates

Based on the hydrogeology and terrain conditions, different structure, viz., Check Dam (CD)/ Nala Bund (NB)/ Cement Plug (CP), Ponds, Dug Well (DW) Recharge/ Tube Well (TW) Recharge/ Recharge Shafts & Percolation Tanks have been considered for artificial recharge. Number of recharge structures have been calculated by allocating available surface water to different type of structures according to their relative potential in terms of recharge/ conservation and apportioning the quantum to the standard unit storage volume/ capacity with number of fillings. The allocation of source water for different type of structure has been made accordingly and given below.

Structures	Area (Alluvium/ Hard Rock)	Allocated Surface Water (%)
Percolation Tank (Cumulative capacity 1 Lakh Cum x 2 fillings)	Hard Rock	20%
Recharge Shaft (3m)/ DW/ TW Recharge (20000 Cum x 3 fillings)	Hard Rock	20%
	Alluvium	
Check Dam/ Nala Bund/ Cement Plug etc. (10000 Cum x 3 fillings)	Hard Rock	10%
	Alluvium	
Average 1 Ha Ponds (30000 Cum x 3 fillings)	Hard Rock	50%
	Alluvium	70%

Details of artificial recharge in the State is given in Table 8.21.2.

Roof Top Rainwater Harvesting

Total urban area in Uttar Pradesh is around 6095 Sq Km (District Statistical Data, 2018; www.updes.up.nic.in). This comprises 15 Nagar Nigams, 196 Nagar Palika Parishads, 422 Nagar Panchayats, 13 Cantonment Boards and 175 Census Towns. Since, information about Roof Top Area is not readily available, certain assumptions have been made. Out of the total area, 3% has been taken as Roof Top Area, which comes to ≈183 Sq Km, 15% of which, i.e ≈27 Sq Km (≈27 million Sqm) has been considered as Roof Top area of Government buildings. It is presumed that 25% Government Buildings already have RTRWH system in place, leaving ≈20.57 sqm where RTRWH is to be implemented. Cost of RTRWH for 100 Sqm is approximately Rupees 1 Lakh. The total cost thus will be Rs 205722 Lakhs (Rupees 2057 Crore). Roof Top Rain Water Harvesting proposal is summarized in following table.

8.21.5 Total Cost

The total cost of artificial recharge for the State of Uttar Pradesh is of the order of Rs 7156.45 Cr, out of which, cost estimate for Rural area is of the order of Rs 5099.23 Cr and Urban area is 2057.22 Cr.

Table-8.21.2 Artificial Recharge in Uttar Pradesh

		Number of Structures					Unit Cost of Structures (Lakh)					Cost of Structures (Lakh)					
S.No	District	CD/NB/ CP	DW/T W/' RS	Pond	RTRWH (Area in sq.km)	PT	CD/N B/ CP	DW/T W/ RS	Pond	RTRW H (per 100sq m)	PT	CD/NB/ CP	DW/TW / RS	Pond	RTRWH	PT	Total Cost (Lakh)
1	Agra	190	190	446	0.6473		20.0	1.5	30.0	1.0	60.0	3800.00	285.00	13380.00	6473.25	0.00	23938.25
2	Aligarh	39	39	92	0.4905		20.0	1.5	30.0	1.0	60.0	780.00	58.50	2760.00	4905.23	0.00	8503.73
3	Allahabad	97	97	230	0.5468		20.0	1.5	30.0	1.0	60.0	1940.00	145.50	6900.00	5467.50	0.00	14453.00
4	Aurraiya	43	43	101	0.1245		20.0	1.5	30.0	1.0	60.0	860.00	64.50	3030.00	1245.38	0.00	5199.88
5	Azamgarh	8	8	20	0.2010		20.0	1.5	30.0	1.0	60.0	160.00	12.00	600.00	2010.15	0.00	2782.15
6	Baghpat	76	76	179	0.2006		20.0	1.5	30.0	1.0	60.0	1520.00	114.00	5370.00	2006.10	0.00	9010.10
7	Bahraich	12	12	28	0.1011		20.0	1.5	30.0	1.0	60.0	240.00	18.00	840.00	1010.81	0.00	2108.81
8	Banda	172	172	288	0.1177	52	20.0	1.5	30.0	1.0	60.0	3440.00	258.00	8640.00	1176.86	3120.00	16634.86
9	Barabanki	50	50	118	0.1768		20.0	1.5	30.0	1.0	60.0	1000.00	75.00	3540.00	1768.16	0.00	6383.16
10	Bareilly	81	81	191	0.7138		20.0	1.5	30.0	1.0	60.0	1620.00	121.50	5730.00	7137.79	0.00	14609.29
11	Bijnore	44	44	106	0.5271		20.0	1.5	30.0	1.0	60.0	880.00	66.00	3180.00	5270.74	0.00	9396.74
12	Budaun	302	302	712	0.3622		20.0	1.5	30.0	1.0	60.0	6040.00	453.00	21360.00	3622.05	0.00	31475.05
13	Bulandshahar	209	209	491	0.2424		20.0	1.5	30.0	1.0	60.0	4180.00	313.50	14730.00	2424.26	0.00	21647.76
14	Chitrakoot	153	153	254	0.0364	46	20.0	1.5	30.0	1.0	60.0	3060.00	229.50	7620.00	363.83	2760.00	14033.33
15	Etah	70	70	165	0.0866		20.0	1.5	30.0	1.0	60.0	1400.00	105.00	4950.00	866.03	0.00	7321.03
16	Etawah	22	22	50	0.0818		20.0	1.5	30.0	1.0	60.0	440.00	33.00	1500.00	818.10	0.00	2791.10
17	Fatehpur	59	59	137	0.2669		20.0	1.5	30.0	1.0	60.0	1180.00	88.50	4110.00	2668.95	0.00	8047.45
18	Firozabad	88	88	209	1.1662		20.0	1.5	30.0	1.0	60.0	1760.00	132.00	6270.00	11661.98	0.00	19823.98
19	G.B. Nagar	60	60	140	0.5087		20.0	1.5	30.0	1.0	60.0	1200.00	90.00	4200.00	5087.48	0.00	10577.48
20	Ghaziabad	47	47	111	0.5360		20.0	1.5	30.0	1.0	60.0	940.00	70.50	3330.00	5359.50	0.00	9700.00
21	Hamirpur	172	172	288	0.0666	52	20.0	1.5	30.0	1.0	60.0	3440.00	258.00	8640.00	665.55	3120.00	16123.55
22	Hapur	51	51	120	0.1808		20.0	1.5	30.0	1.0	60.0	1020.00	76.50	3600.00	1808.33	0.00	6504.83
23	Hardoi	18	18	41	0.1947		20.0	1.5	30.0	1.0	60.0	360.00	27.00	1230.00	1947.38	0.00	3564.38

		Number of Structures					Unit Cost of Structures (Lakh)					Cost of Structures (Lakh)					
S.No	District	CD/NB/ CP	DW/T W/' RS	Pond	RTRWH (Area in sq.km)	PT	CD/N B/ CP	DW/T W/ RS	Pond	RTRW H (per 100sq m)	PT	CD/NB/ CP	DW/TW / RS	Pond	RTRWH	PT	Total Cost (Lakh)
24	Hathras	83	83	196	0.1473		20.0	1.5	30.0	1.0	60.0	1660.00	124.50	5880.00	1472.51	0.00	9137.01
25	Jalaun	163	163	381	0.2036		20.0	1.5	30.0	1.0	60.0	3260.00	244.50	11430.00	2035.80	0.00	16970.30
26	Jaunpur	88	88	210	0.1588		20.0	1.5	30.0	1.0	60.0	1760.00	132.00	6300.00	1588.28	0.00	9780.28
27	Jhansi	158	158	263	0.2268	47	20.0	1.5	30.0	1.0	60.0	3160.00	237.00	7890.00	2267.66	2820.00	16374.66
28	JP Nagar (Amroha)	171	171	402	0.1705		20.0	1.5	30.0	1.0	60.0	3420.00	256.50	12060.00	1704.71	0.00	17441.21
29	Kannauj	40	40	95	0.2386		20.0	1.5	30.0	1.0	60.0	800.00	60.00	2850.00	2386.13	0.00	6096.13
30	Kanpur Dehat	142	142	332	0.0923		20.0	1.5	30.0	1.0	60.0	2840.00	213.00	9960.00	923.06	0.00	13936.06
31	Kanpur Nagar	146	146	342	1.0194		20.0	1.5	30.0	1.0	60.0	2920.00	219.00	10260.00	10193.85	0.00	23592.85
32	Kasganj	18	18	43	0.0810		20.0	1.5	30.0	1.0	60.0	360.00	27.00	1290.00	809.66	0.00	2486.66
33	Kaushambi	48	48	113	0.1035		20.0	1.5	30.0	1.0	60.0	960.00	72.00	3390.00	1035.11	0.00	5457.11
34	Lalitpur	160	160	266	0.0693	48	20.0	1.5	30.0	1.0	60.0	3200.00	240.00	7980.00	693.23	2880.00	14993.23
35	Lucknow	116	116	274	1.4069		20.0	1.5	30.0	1.0	60.0	2320.00	174.00	8220.00	14069.03	0.00	24783.03
36	Mahoba	110	110	183	0.1011	33	20.0	1.5	30.0	1.0	60.0	2200.00	165.00	5490.00	1010.81	1980.00	10845.81
37	Mainpuri	16	16	39	0.4284		20.0	1.5	30.0	1.0	60.0	320.00	24.00	1170.00	4284.23	0.00	5798.23
38	Mathura	70	70	164	0.4879		20.0	1.5	30.0	1.0	60.0	1400.00	105.00	4920.00	4879.24	0.00	11304.24
39	Mau	12	12	29	0.2772		20.0	1.5	30.0	1.0	60.0	240.00	18.00	870.00	2771.89	0.00	3899.89
40	Meerut	135	135	317	0.8265		20.0	1.5	30.0	1.0	60.0	2700.00	202.50	9510.00	8265.04	0.00	20677.54
41	Mirzapur	320	320	535	0.1901	95	20.0	1.5	30.0	1.0	60.0	6400.00	480.00	16050.00	1901.14	5700.00	30531.14
42	Moradabad	92	92	218	0.4818		20.0	1.5	30.0	1.0	60.0	1840.00	138.00	6540.00	4817.81	0.00	13335.81
43	Muzaffarnagar	189	189	445	0.1529		20.0	1.5	30.0	1.0	60.0	3780.00	283.50	13350.00	1529.21	0.00	18942.71
44	Pratapgarh	80	80	188	0.1712		20.0	1.5	30.0	1.0	60.0	1600.00	120.00	5640.00	1712.48	0.00	9072.48
45	Rampur	78	78	182	0.2127		20.0	1.5	30.0	1.0	60.0	1560.00	117.00	5460.00	2127.26	0.00	9264.26
46	Sant Ravidas Nagar (Bhadohi)	186	186	438	0.1140		20.0	1.5	30.0	1.0	60.0	3720.00	279.00	13140.00	1140.41	0.00	18279.41
47	Saharanpur	101	101	237	0.1842		20.0	1.5	30.0	1.0	60.0	2020.00	151.50	7110.00	1842.08	0.00	11123.58

		Number of Structures					Unit Cost of Structures (Lakh)					Cost of Structures (Lakh)					
S.No	District	CD/NB/ CP	DW/T W/' RS	Pond	RTRWH (Area in sq.km)	PT	CD/N B/ CP	DW/T W/ RS	Pond	RTRW H (per 100sq m)	PT	CD/NB/ CP	DW/TW / RS	Pond	RTRWH	PT	Total Cost (Lakh)
48	Shahjahanpur	68	68	159	0.1211		20.0	1.5	30.0	1.0	60.0	1360.00	102.00	4770.00	1211.29	0.00	7443.29
49	Sambhal	63	63	148	0.1550		20.0	1.5	30.0	1.0	60.0	1260.00	94.50	4440.00	1549.80	0.00	7344.30
50	Shamli	137	137	323	0.0947		20.0	1.5	30.0	1.0	60.0	2740.00	205.50	9690.00	946.69	0.00	13582.19
51	Sitapur	401	401	668	0.2720	120	20.0	1.5	30.0	1.0	60.0	8020.00	601.50	20040.00	2720.25	7200.00	38581.75
52	Sonbhadra	20	20	48	0.2054		20.0	1.5	30.0	1.0	60.0	400.00	30.00	1440.00	2054.36	0.00	3924.36
53	Unnao	79	79	187	0.1863		20.0	1.5	30.0	1.0	60.0	1580.00	118.50	5610.00	1863.00	0.00	9171.50
54	Varanasi	29	29	69	0.5385		20.0	1.5	30.0	1.0	60.0	580.00	43.50	2070.00	5385.49	0.00	8078.99
55	Ambedkarnag ar				0.3121										3120.86		3120.86
56	Amethi				0.0557										556.88		556.88
57	Ayodhya				0.2102										2101.95		2101.95
58	Basti				0.2819										2819.14		2819.14
59	Chandauli				0.1410										1409.74		1409.74
60	Ballia				0.1823										1822.50		1822.50
61	Balrampur				0.0688										687.83		687.83
62	Deoriya				0.2000										2000.03		2000.03
63	Ghazipur				0.1553										1552.50		1552.50
64	Gonda				0.1809										1809.00		1809.00
65	Gorakhpur				0.6808										6808.39		6808.39
66	Farrukhabad				0.1446										1445.85		1445.85
67	Kushinagar				0.1554										1553.85		1553.85
68	Lakhimpur Khiri				0.2690										2690.21		2690.21
69	Maharajganj				0.1657										1656.79		1656.79
70	Pilibhit				0.1117										1117.13		1117.13
71	Raebareilly				0.2537										2536.99		2536.99

		Number of Structures					Unit Cost of Structures (Lakh)					Cost of Structures (Lakh)					
S.No	District	CD/NB/ CP	DW/T W/' RS	Pond	RTRWH (Area in sq.km)	PT	CD/N B/ CP	DW/T W/ RS	Pond	RTRW H (per 100sq m)	PT	CD/NB/ CP	DW/TW / RS	Pond	RTRWH	PT	Total Cost (Lakh)
72	Shravasti				0.0084										84.04		84.04
73	Siddharth Nagar				0.1705										1705.39		1705.39
74	Sant Kabirnagar				0.0642										641.59		641.59
75	Sultanpur				0.0644										643.95		643.95
	Total	5582	5582	12011	20.5721	493						111640.00	8373.00	360330.00	205721.53	29580.00	715644.53

Note:

CD/NB/CP- Check Dam/ NalaBunding/ Cement Plug

RS/ DW/ TW Rech. - Recharge Shaft/ Dug Well/ Tube Well Recharge

PT = Percolation tank

Numbers of structures given have been arrived at after calculating the number of feasible structures and deducting the numbers considered as already constructed (60% in Bundelkhand Region and 30% in other areas).

As per selection criteria, districts at Serial No. 55 to 75 (21 Nos) do not have any block/ areafor rural interventions. Only RTRWH has been proposed in urban areas of these districts

8.22 UTTARAKHAND

The state of Uttarakhand, which comprises 13 districts, lies between 28°43'20" – 31°28'00" - latitude and 77°34'06"–81°01'31" - longitude with geographical area of 53,483 km2. About 85% of the area of Uttarakhand state is occupied by the Himalayan Mountain. The Himalayan Mountain is represented by NW-SE trending hill ranges, which exhibit highly rugged youthful topography. Uttarakhand State has a very prominent drainage system varying from first to fourth or fifth order. The main drainage patterns are dendritic, trellis and rectangular. The Yamuna, Ganga, Ramganga and Sarda rivers drain the area. Each river has numerous tributaries in Uttarakhand Himalayas.

The Higher Himalayan range is perennially covered by snow. The area is divided into units like High relief glaciated area, Structural hills, Denudational hills, dissected fans, river terraces and flood plains. The southern boundary of Foot Hills of Himalayas is covered by Bhabar, Tarai, Doon Gravels and alluvium. Major part of the hilly area has a slope more than 20%. A slope of the magnitude of this order makes the area unsuitable for groundwater development due to low groundwater potential. In Himalayan Region groundwater mainly manifests in the form of springs. Groundwater mainly occurs under unconfined conditions and the water table follows the topography. Springs occurring in the entire state are generally confined toCentral Crystallines andare of both types, viz., hot and cold. The hot water springs are structurally controlled with a temperature range of 32^0C to 90^0C and about 25 hot springs are reported from this region with discharge ranging from 1 to 10 lps. Out of 600 cold springs, with discharge ranging from <1 to 30 lps, 330 are located in (granites, gneiss, schists etc.), 180 in quartzites, 50 in shales / slates and 40 in carbonate rocks.

The river terraces are most significant repository of groundwater comprising assorted material such as boulder, cobble, gravel, sand and clays. The terrace material has been tapped, at few places, through open wells and bore wells.In Bhabar zone groundwater occurs under unconfined conditions and Water level is generally deep and observed as deep as 173.71 m bgl at Haldwani. Tarai zone is characterized by moist, waterlogged area, which is gently sloping southwards (2.5 m/km). This zone is traversed by numerous perennial sluggish channels rendering the area swampy.

8.22.1 Area Identified for Artificial Recharge/Rainwater Harvesting

Area suitable for ground water augmentation through artificial recharge has been demarcated based on the analysis of available data on depth to water level (2018) and long-term post monsoon water level trends (2009 to 2018) in the plain areas and foot hill areas. The entire area falling in foot hills of the Himalayas, i.e. Bhabar areas and Intermontane Doon Gravel areas have been considered and identified (Fig 8.22). Rest of the area (nine districts) has been selected for implementing the rainwater harvesting. Hilly areas experience acute water shortage during summers and hence considered for implementing rainwater harvesting to meet the domestic water requirements and rainfall is the only source. Further, in urban areas, it has been proposed to practice artificial recharge measures to groundwater through available rooftop rainwater harvesting.

8.22.2 Sub-Surface Storage Space and Water Requirement

In Uttarakhand state, except Haridwar and Udham Singh Nagar all other districts possess highly undulating topography where generally aquifer systems are very much localized. In the Outer Himalaya wherever alluvium or valley deposits occur they are relatively covered by bigger surface area than that of the Middle Himalayas. The depth to water level in this alluvium terrainis very much variable than the plain area of Tarai and further beyond in the Gangetic Plain. Thus, subsurface storage space is hereby generalized for 2m as unsaturated zone. For the seven districts of Garwhal Division and six districts of Kumaon Division the subsurface storage space has been calculated as 4011 MCM (Table 8.22.1) whereas for their saturation, the volume of water required is 5335 MCM.

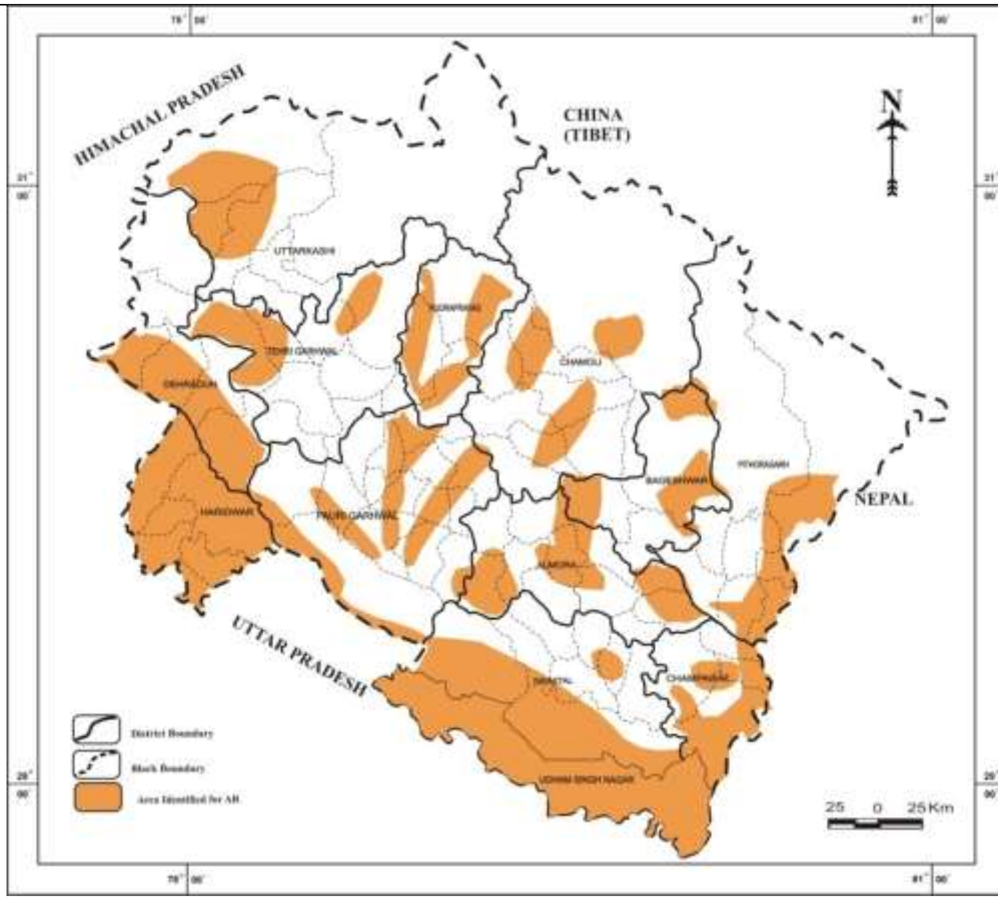


Fig 8.22.1 Area identified for Artificial Recharge in Uttarakhand

Table 8.22.1 Scope of Artificial Recharge in Uttarakhand

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Dehradun	3088.00	772.00	1544.00	232.00	308.00	1931.00
2	Haridwar	2360.00	590.00	1180.00	177.00	235.00	1476.00
3	Tehri Garhwal	3796.00	949.00	1898.00	285.00	379.00	2374.00
4	Chamoli	7520.00	1880.00	3760.00	564.00	750.00	4703.00
5	Pauri Garhwal	5230.00	1308.00	2615.00	392.00	522.00	3271.00
6	Uttarkashi	8016.00	2004.00	4008.00	601.00	800.00	5013.00
7	Rudraprayag	2439.00	610.00	1220.00	183.00	243.00	1525.00
8	Almora	3689.00	922.00	1845.00	277.00	368.00	2307.00

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
9	Nainital	3422.00	856.00	1711.00	257.00	341.00	2140.00
10	Bageshwar	1696.00	424.00	848.00	127.00	169.00	1061.00
11	Ptihroragarh	7169.00	1792.00	3585.00	538.00	715.00	4484.00
12	Champawat	2004.00	501.00	1002.00	150.00	200.00	1253.00
13	Udham Singh Nagar	3055.00	764.00	1528.00	229.00	305.00	1911.00
	Total	53484.00	13372.00	26744.00	4012.00	5335.00	33449.00

8.22.3 Source Water Availability

The four major riverbasins, viz. Yamuna (5421.18 sq.km), Ganga (25757.74 sq.km), Ram Ganga (11466.34 sq.km) and Sharda (11024.81 sq.km) spread over Uttarakhand. Rainfall is the primary source of the water availability in the area. The artificial recharge structures proposed is based on the available water resources. There is enormous quantity of surplus water flows down to the southward plain area. The total water available from these four river basins as surface runoff is 67302 MCM. The surplus water usually generated by run-off, base flow and snow melt. The actual assessment of volume of surface water by such river basins has not been quantified due to paucity of data, but it is obvious that rivers, rivulets, streams and nallas of Himalayan Mountains are very much perennial. Only the first and sometime second order of streams is seasonal in nature. Hence, the volume of source water available for recharge has been computed on the basis of 50% of the average annual rainfall (1254 mm) in Uttarakhand, which is feasible in the area. So on this account; it has come to 5335MCM as source water for recharge.

8.23.3 Recharge Structures and Cost Estimates

The major part of Uttarakhand is hilly with localized small valleys through which the entire run-off passes. As the area is hilly with high relief, the major part of the rainfall is lost as surface run-off. Apart from this the small rivers, nallas also act as carriers for base flow and spring water. In spite of good rainfall in hilly areas there is acute shortage of water especially during the summers. Further availability of water is restricted in these streams only. Thus, the water in the streams should be harvested and tapped for irrigation and domestic needs through various rainwater harvesting structures and water conservation measures be adopted. The broad valleys in hilly area are the feasible locales for check dam construction where gentle slope (less than 20%) prevails, whereas in the plain area, check dams and percolation tanks are more appropriate interventions to be adopted. Roof top rainwater harvesting can be practiced in both the terrains; rather this should be given more emphasis in hilly areas specially to combat the water crisis. Udham Singh Nagar district has, by and large, plain topography with very shallow water levels; hence roof top rainwater harvesting is the only feasible option available in this area. Haridwar district on the other hand possess deeper water levels in Bahadarabad, Roshanabadand and Lal Dhang areas giving thereby the scope for artificial recharge through construction of appropriate interventions like gabions, recharge shafts, injection wells, check damsand gully plugs etc., whereas in the southern part, the rooftop rainwater harvesting may be practiced. Doon Valley covering parts of Dehradun district is most suitable area for interventions to be made for getting recharge to the groundwater bodies artificially through constructing suitable site specific structures. In the remaining hilly districts of Uttarakhand, contour bunding, brushwood check dams, gully plugs, continuous contour trenches, chalkhal, percolations tanks etc. may be adopted for augmenting the groundwater resources and harvesting the rainwater as well.

Efforts of State Government in water conservation

The State Government (Avas and Shahri Vikas) has formulated mandatory regulations for installation of Rainwater Harvesting System and directed to adopt rules in building by-laws. Accordingly, all the development authorities have made amendments in the prevalent house building and development by-laws/ regulations. Further, through different schemes, water conservation measures have been taken up in the State by the Directorate of Watershed Management and the rainwater harvesting and water conservation structures have been constructed under the Uttarakhand Decentralized Watershed Development Projects (UDWDP), Integrated Livelihood Support Program (ILSP), PMKSY-Watershed Development Program and Gramya. Besides these schemes basin/sub-basin catchments programme has been taken up by the Project Management Unit (PMU), Swajal Project under the Catchments Areas Conservation and Management Plan (CACMP). Considering the structures already constructed (Table 8.22.2) or under construction in various schemes and the availability of source water, various artificial recharge structures along with their cost estimates have been proposed for the State. (Table 8.22.3).

Table 8.23.2 Artificial Recharge and RTRWH Structures constructed In Uttarkhand under Catchment Area Conservation Program (CACMP)

S. NO.	District Name	Number of structures					Total cost (in lakhs)					Total Cost (in lakhs)
		CD	CK	RTRWH	PT	CT	CD	CK	RTRWH	PT	CT	
1	**Dehradun**	38	0	20	0	1675	3.8	0	7.3	0	0.1	11.2
2	**Haridwar**	0	0	3	0	0	0	0	1	0	0	1
3	**Tehri Garhwal**	76	19	112	4	0	7.6	0.57	39.2	0.08	0	47.45
4	**Chamoli**	0	0	50	0	1000	0	0	17.5	0	1	18.5
5	**Pauri Garhwal**	850	0	133	11	0	85	0	46.55	0.22	0	131.77
6	**Uttarkashi**	147	0	0	2	40	14.7	0	0	0.04	0.04	14.78
7	**Rudraprayag**	97	41	40	23	525	9.7	1.23	14	0.46	4.9	30.29
8	**Almora**	133	30	486	43	150	0.4	0.9	170.1	0.86	0.15	172.41
9	**Nainital**	91	0	270	5	100	9.1	0	94.5	0.1	0.53	104.23
10	**Bageshwar**	12	62	88	0	0	1.2	1.86	30.8	0	0	33.86
11	**Ptihroragarh**	166	29	84	0	0	16.6	0.87	29.4	0	0	46.87
12	**Champawat**	90	25	44	13	1675	9	0.75	15.4	0.26	1.68	27.09
13	**Udham Singh Nagar**	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	TOTAL	1700	206	1330	101	5165	157.1	6.18	465.8	2.02	8.4	639.5

CT- Contour Trench, CK- Chal Khal, RTRWH- Rooftop Rain Water Harvesting, CD- Check Dam, PT- Percolation Tank, NA- Data not Available

Table 8.23.3 Artificial Recharge and Cost Estimate in Uttarakhand

District Name	Structures proposed					Unit cost Estimate (in lakhs)					Total Cost (in lakhs)					Total cost (in lakhs)
	RTRWH	CD	PT	CK	CT	RTRWH	CD	PT	CK	CT	RTRWH	CD	PT	CK	CT	
Dehradun	250	150	30	100	200	0.5	0.3	0.07	0.15	0.015	125	45	2.1	15	3	3
Haridwar	400	100	10	0	225	0.5	0.3	0.07	0.15	0.015	200	30	0.7	0	3.375	234.075
Tehri Garhwal	350	250	90	225	450	0.5	0.3	0.07	0.15	0.015	175	75	6.3	33.75	6.75	296.8
Chamoli	375	275	100	250	500	0.5	0.3	0.07	0.15	0.015	187.5	82.5	7	37.5	7.5	322
Pauri Garhwal	325	220	150	375	750	0.5	0.3	0.07	0.15	0.015	162.5	66	10.5	56.25	11.25	306.5
Uttarkashi	450	350	60	150	300	0.5	0.3	0.07	0.15	0.015	225	105	4.2	22.5	4.5	361.2
Rudraprayag	300	200	30	75	150	0.5	0.3	0.07	0.15	0.015	150	60	2.1	11.25	2.25	225.6
Almora	1168	275	110	275	550	0.5	0.3	0.07	0.15	0.015	584	82.5	7.7	41.25	8.25	723.7
Nainital	250	125	80	200	400	0.5	0.3	0.07	0.15	0.015	125	37.5	5.6	30	6	204.1
Bageshwar	350	350	30	75	150	0.5	0.3	0.07	0.15	0.015	175	105	2.1	11.25	2.25	295.6
Ptihroragarh	425	375	80	200	400	0.5	0.3	0.07	0.15	0.015	212.5	112.5	5.6	30	6	366.6
Champawat	200	150	40	100	200	0.5	0.3	0.07	0.15	0.015	100	45	2.8	15	3	165.8
Udham Singh Nagar	700	50	0	0	0	0.5	0.3	0.07	0.15	0.015	350	15	0	0	0	365
	5543	**2870**	**810**	**2025**	**4275**						**2771.5**	**861**	**56.7**	**303.75**	**64.125**	**4057.075**

CT- Contour Trench, CK- Chal Khal, RTRWH- Rooftop Rain Water Harvesting, CD- Check Dam, PT- Percolation Tank

8.23.4 Total Cost

The total cost for proposed artificial recharge is Rs 40.57 Cr, out of which Rs 12.86 Cr is in rural areas and Rs 27.72 Cr is urban areas. The unit as well as total cost of the structures may vary depending upon the size and terrain in which they are constructed.

8.23 WEST BENGAL

The State of West Bengal, is having a geographic area of 87,853 Sq. Kms covering 23 Districts. The State has a total population of 9,12,76,115, with a population density of 1028 persons per Sq. Km (Census 2011). The normal annual rainfall is around 1923 mm out of which, the State receives 1618 mm in the Monsoon Season (June to September) and rest 305 mm in the non-monsoon season. The hilly Himalayan region receives the heaviest rainfall ranging from 2,500 to 6,000 mm, the southern districts in the plains receive on an average rainfall from 1125 to 1875 mm. It is the only state of India that extends from the Himalaya to the Bay of Bengal. A large portion of the state occupies the transitional zones between the Himalayas in the north and the Chhotanagpur plateau in the west to the plains of the Ganga-Brahmaputra delta in the southern and eastern sections. There are three major river basins in the State, viz., Ganga, Brahmaputra and Subarnarekha. The Himalayan tracts of West Bengal comprise the districts Darjeeling &Kalimpong and parts of Jalpaiguri and Alipurduar districts and occupies a total geographical area of 3017.34 SqKms. The area is drained by perennial Tista, Torsa, Mahananda, Balason, Jaldhaka, Kaljanias also many other small rivers. In spite of copious rainfall received to the tune of 3000 mm or more per annum, extreme water scarcity is felt in the area during the lean periods (January to April).Groundwater development in this tract is negligible and it is mostly catered through springs. Two third of the State is underlain by alluvial sediments mainly deposited by Ganga & Brahmaputra rivers. The rest of the State is underlain by crystalline rocks.

8.23.1 Identification of Area

The State is grouped into plain areas, drought prone areas and Himalayan Area and different criteria have been adopted in the identification of area, in these areas. In the plain areas, area characterized by water levels more than 9m bgl with or without declining water level trends and areas with water level more than 3m bgl with declining water level trends >10cm/yr have been considered. In the drought prone district underlying by hard crystalline basement rocksand semi consolidated to consolidated formationsin Purulia, Western parts of Bankura, Birbhum and PaschimMedinipur district, the area with declining trend have been considered for recharge. In the urban areas, area has been identified for roof top rainwater harvesting (RTRWH) and dealt separately. In the hilly areas of North Bengal mostly in the Darjeeling and Kalimpong District, areas have been identified for Springshed management initiatives, with twin objectives of assured water supply during non rainy seasons and sustainability of the springs whose discharge reduces considerably during non rainyseason.An area of 3017.34 sq.km has been identified in the Himalayan Hilly Terrain. The area identified for artificial recharge has been provided as Fig 8.23.1 & in Table 8.23.1

Table 8.23.1 Scope of Artificial Recharge in West Bengal

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Alipurduar	3383.00	742.09	6878.58	1375.72	1829.70	595.45
2	Bankura	6882.00	928.06	2784.17	259.46	345.08	259.46
3	Birbhum	4545.00	2013.45	10295.51	1134.79	1509.27	612.46
4	Cooch Bihar	3387.00	199.71	599.14	89.87	119.53	89.87
5	Dakshin Dinajpur	2219.00	104.51	313.54	31.35	41.70	31.35
6	Darjeeling	2093.00	66.00	131.99	19.80	26.33	19.80
7	Hooghly	3149.00	1909.14	17182.27	3238.06	4306.62	614.27
8	Howrah	1467.00	485.30	4367.67	655.15	871.35	174.90
9	Jhargram	3037.00	88.76	266.28	26.63	35.42	26.63

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
10	Kolkata	187.00	41.76	501.06	75.16	99.96	16.49
11	Malda	3733.00	2.32	13.91	2.09	2.78	0.78
12	Murshidabad	5324.00	2121.49	25457.83	5091.57	6771.78	703.36
13	Nadia	3927.00	151.52	454.57	90.91	120.91	43.97
14	North 24 Parganas	4094.00	872.72	7854.44	1178.17	1566.96	312.88
15	Paschim Barddhaman	1603.00	185.14	1110.82	111.08	147.74	57.46
16	Paschim Medinipur	6306.00	1838.50	16546.47	3062.24	4072.78	643.41
17	PurbaBarddhaman	5433.00	3256.30	39075.64	7815.13	10394.12	1010.55
18	Purba Medinipur	4736.00	3319.72	29877.48	4481.62	5960.56	1293.79
19	Purulia	6259.00	493.46	1480.38	44.41	59.07	44.41
20	South 24 Parganas	9960.00	4068.72	36618.45	4394.21	5844.31	1981.57
	Total	**81724.00**	**22888.67**	**201810.20**	**33177.41**	**44125.96**	**8532.86**

8.23.2 Sub-Surface Storage

The unsaturated zone up to 3m bgl is determined by the product of average thickness up to 3m and the area. The product of specific yield and the unsaturated volume gives the space available for artificial recharge and is of the order of 33177.41 MCM. Considering the 75% efficiency, the water required for artificial recharge has been worked out and is 44125.96 MCM. (Table 8.23.1)

8.23.3 Source Water Availability

The availability of non-committed source water is one of the primary requisite for designing any artificial recharge project. However, the data on the surplus runoff is available only on the basin or the sub basin level. Hence, based on the terrain slope, vegetation, land use / land cover pattern, suitable runoff coefficients have been adopted from the standard norms and the non-committed runoff has been calculated, with normal monsoonal rainfall as the source. The surplus available for recharge has been worked out as 8532.856 MCM (table 8.23.1)

8.23.4 Artificial Recharge & Cost Estimates

Considering the terrain conditions, Percolation tanks, Check Dams, Gabion Structures /Contour bunds, Sub-surface dyke, recharge shaft/dug well recharge are proposed for hard rock terrains, while in alluvial areas, percolation tanks, re-excavation of existing tanks (renovation) with recharge shaft & injection wells and in urban area, RTRWH are proposed. The district wise number of different structures have been determined based on the source water availability and given in Table 8.23.2.

Roof Top Rain Water Harvesting

As per the Census data of 2011, in the State of West Bengal, there are a total of 252 Census Towns and 123 Municipal Bodies(includes both Municipalities as well as Municipal Corporations). Based on the average roof top area, normal monsoonal rainfall and assuming the roof top runoff coefficient to be 0.8, the computations have been made for Roof Top Rain Water Harvesting in Urban & Peri Urban areas. The total cost of RTRWH works out to be Rs 67.02 Cr.

8.23.5 Total Cost

The total cost of artificial recharge for the State of West Bengal is of the order of Rs1698.17 Cr, out of which, cost estimate for Rural area is of the order of Rs1631.15 Cr and Urban area is 67.02 Cr.

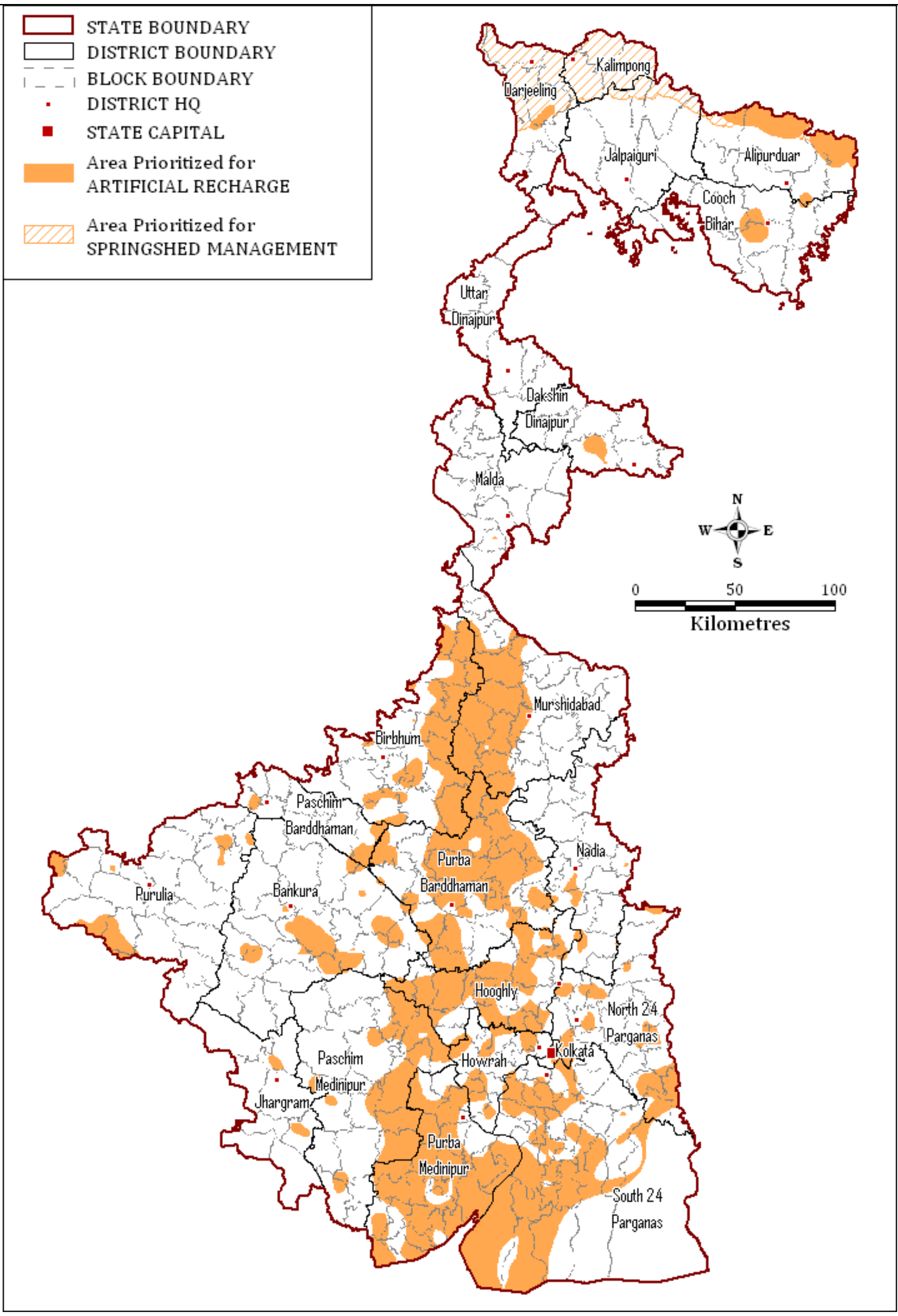


Fig 8.23.1 Area identified for Artificial Recharge in West Bengal

Table 8.23.2 Artificial Recharge in West Bengal

S.No	District	Number Of Structures									Unit Cost of Structures (Lakh)								
		CD	REET with RS	RTRWH	PT in CT & MC	G/CB	IW	SSD	DWR	RTRWH in census towns	CD	REET with RS	RTRWH	PT in CT & MC	G/CB	IW	SSD	DWR	RTRWH in census towns
1	Alipurduar(including Jalpaiguri)	0	1191	100	596	0	596	0	0	130	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
2	Bankura	38	499	75	262	95	250	48	10	20	1.5	4.0	0.8	8 ,12	0.5	3.0	1.0	1.1	0.4
3	Birbhum	186	1131	150	629	465	568	233	46	10	1.5	4.0	0.8	8 ,12	0.5	3.0	1.0	1.1	0.4
4	Cooch Bihar	0	179	150	90	0	90	0	0	40	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
5	Dakshin Dinajpur	0	63	50	31	0	31	0	0	0	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
6	Darjeeling(including Kalimpong)	0	39	500	20	0	20	0	0	120	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
7	Hooghly	0	1228	360	615	0	615	0	0	280	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
8	Howrah	0	348	150	174	0	174	0	0	500	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
9	Jhargram	0	54	0	26	0	26	0	0	0	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
10	Kolkata City	0	0	500	0	0	0	0	0	0	1.5	4.0	5.5	8.0	0.5	3.0	1.0	1.1	0.4
11	Malda	0	1	50	1	0	1	0	0	30	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
12	Murshidabad	0	1405	175	702	0	702	0	0	220	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
13	Nadia	0	87	200	44	0	44	0	0	150	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
14	North 24 Parganas	0	626	675	313	0	313	0	0	200	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
15	Paschim Barddhaman	52	89	0	61	131	44	65	14	0	1.5	4.0	0.8	8 ,12	0.5	3.0	1.0	1.1	0.4
16	Paschim Medinipur	0	1288	200	642	0	642	0	0	40	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
17	PurbaBarddhaman	0	2022	330	1009	0	1009	0	0	550	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
18	Purba Medinipur	0	2587	125	1295	0	1295	0	0	50	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
19	Purulia	177	0	75	58	445	0	222	45	90	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
20	South 24 Parganas	0	3962	175	1983	0	1983	0	0	140	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
21	Uttar Dinajpur	0	0	100	0	0	0	0	0	30	1.5	4.0	0.8	8.0	0.5	3.0	1.0	1.1	0.4
	Total	**453**	**16799**	**4140**	**8551**	**1136**	**8403**	**568**	**115**	**2600**									

Remarks: RTRWH in municipalities/ corporations, G/CB: Gabbion /Contour bund, CD: Check Dam, IW: injection wells, SSD: Sub-Surface Dyke, DWR; Dug well Recharge, REET with RS: REET with Recharge Shaft

Table 8.23.2 Cost of Artificial Recharge in West Bengal

S.No	District	Cost of Structures (Lakh)									
		CD	**REET with RS**	**RTRWH**	**PT in CT & MC**	**G/CB**	**IW**	**SSD**	**DW R**	**RTRWH in census towns**	**Total Cost (Lakh)**
1	Alipurduar(including Jalpaiguri)	0.0	4764.0	80.0	4768.0	0.0	1788.0	0.0	0.0	52.0	11452.0
2	Bankura	57.0	1996.0	60.0	2144.0	47.5	750.0	48.0	11.0	8.0	5121.5
3	Birbhum	279.0	4524.0	120.0	5276.0	232.5	1704.0	233.0	50.6	4.0	12423.1
4	Cooch Bihar	0.0	716.0	120.0	720.0	0.0	270.0	0.0	0.0	16.0	1842.0
5	Dakshin Dinajpur	0.0	252.0	40.0	248.0	0.0	93.0	0.0	0.0	0.0	633.0
6	Darjeeling(including Kalimpong)	0.0	156.0	400.0	160.0	0.0	60.0	0.0	0.0	48.0	824.0
7	Hooghly	0.0	4912.0	288.0	4920.0	0.0	1845.0	0.0	0.0	112.0	12077.0
8	Howrah	0.0	1392.0	120.0	1392.0	0.0	522.0	0.0	0.0	200.0	3626.0
9	Jhargram	0.0	216.0	0.0	208.0	0.0	78.0	0.0	0.0	0.0	502.0
10	Kolkata City	0.0	0.0	2750.0	0.0	0.0	0.0	0.0	0.0	0.0	2750.0
11	Malda	0.0	4.0	40.0	8.0	0.0	3.0	0.0	0.0	12.0	67.0
12	Murshidabad	0.0	5620.0	140.0	5616.0	0.0	2106.0	0.0	0.0	88.0	13570.0
13	Nadia	0.0	348.0	160.0	352.0	0.0	132.0	0.0	0.0	60.0	1052.0
14	North 24 Parganas	0.0	2504.0	540.0	2504.0	0.0	939.0	0.0	0.0	80.0	6567.0
15	Paschim Barddhaman	78.0	356.0	0.0	556.0	65.5	132.0	65.0	15.4	0.0	1267.9
16	Paschim Medinipur	0.0	5152.0	160.0	5136.0	0.0	1926.0	0.0	0.0	16.0	12390.0
17	PurbaBarddhaman	0.0	8088.0	264.0	8072.0	0.0	3027.0	0.0	0.0	220.0	19671.0
18	Purba Medinipur	0.0	10348.0	100.0	10360.0	0.0	3885.0	0.0	0.0	20.0	24713.0
19	Purulia	265.5	0.0	60.0	464.0	222.5	0.0	222.0	49.5	36.0	1319.5
20	South 24 Parganas	0.0	15848.0	140.0	15864.0	0.0	5949.0	0.0	0.0	56.0	37857.0
21	Uttar Dinajpur	0.0	0.0	80.0	0.0	0.0	0.0	0.0	0.0	12.0	92.0
	Total	**679.5**	**67196.0**	**5662.0**	**68768.0**	**568.0**	**25209.0**	**568.0**	**126.5**	**1040.0**	**169817.0**

8.24 ANDAMAN AND NICOBAR ISLANDS

Andaman and Nicobar group of Islands comprise 572 large, medium and small islands,out of which 36 are inhabited. UT has been divided into three districts, viz., (1) North-Middle Andaman District (2) South Andaman and (3) the Nicobar district. The former two constitute the Northern or Andaman group of Islands while the latter forms the southern or Nicobar group of Islands. The Island groups are separated by a deep-sea channel at 10° latitude also called the 10° channel. A& N Islands spread over an area of 8293 Sq. Km. area out of which 7171 Sq. Km is covered by equatorial rain forest. The Andaman group of Islands occupy an area of 6340 sq. km. while the Nicobar group covers 1953 sq. km. The islands receive mean annual rainfall of about 3000 mm. Inspite of copious rainfall, the islands face acute scarcity of fresh water especially in the periods of non-monsoon. The major Perennial streams in South Andaman district are Dhanikhari, Mithakhari, Burmanala, Premanala,Prothrapurnala, KamsaratNala& Sona Phar nala. In North-Middle Andaman district KalpongNala,Korangnala,Betapurnala, Rangatnala&SankarNala are the important perennial streams. In Nicobar District, Galathea, Alexandria, Dhillon Nala,MagarNalaare important perennial streams/rivers. Streams are rudimentary in Car Nicobar island while in Chowra,Kondul and Pillow Millo islands the drainage channels are obscured. However, incipient to moderately developed drainage channels are available in Little Nicobar and in all the other islands of Nancowriegroup.Since the islands are underlain predominantly by impervious marine sedimentary(turbidite) group of rocks, deeper infiltration of ground water cannot take place and profuse base flow from the shallow aquifers, formed in numerous stream valleys could be seen which are flowing unabatedly to the sea. The weathered residuum down to a depth of 15m and at places shallow fractures also yield water for water supply in islands. In many Islands perennial springs are generated along the surface openings of fractures/sink holes and topographic lows which cater to a great extent to the rural population. Even the sustainable water supply of the capital city of Port Blair is poised on inter-island spring water supply from contiguous Rutland Island. Keeping in view of the importance of springs in the Islands, the development of springs is needed along with catchment area treatment through construction of proper recharge structures at appropriate locations especially in the upstream side of the spring discharge area which is popularly known as Spring shed area. An individual spring shed may incorporate an area of 5 hectares.

8.24.1 Identification of Area

In spite of copious rainfall, the proximity to sea on all sides, the islands face water scarcity during non-rainy periods due to limitations of land availability. The continuous base flow also makes the sustainability of springs a major issue. Hence, it is proposed to identify areas, where water conservation and water harvesting structures can be made, which can supplement not only water supply but also groundwater recharge. The identified areas have been provided as Fig 8.24.1 (a & b) and in Table 8.24.1

Table 8.24.1 Scope of Artificial Recharge in Andaman & Nicobar Islands

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Availabe Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	North & Middle Andaman	3227.00	242.20	968.80	116.26	154.62	2053.11
2	South Andaman	3181.00	350.00	1750.00	262.50	349.13	1315.99
3	Nicobar	1841.00	200.70	602.10	120.42	160.16	1066.95
	Total	8249.00	792.90	3320.90	499.18	663.90	4436.05

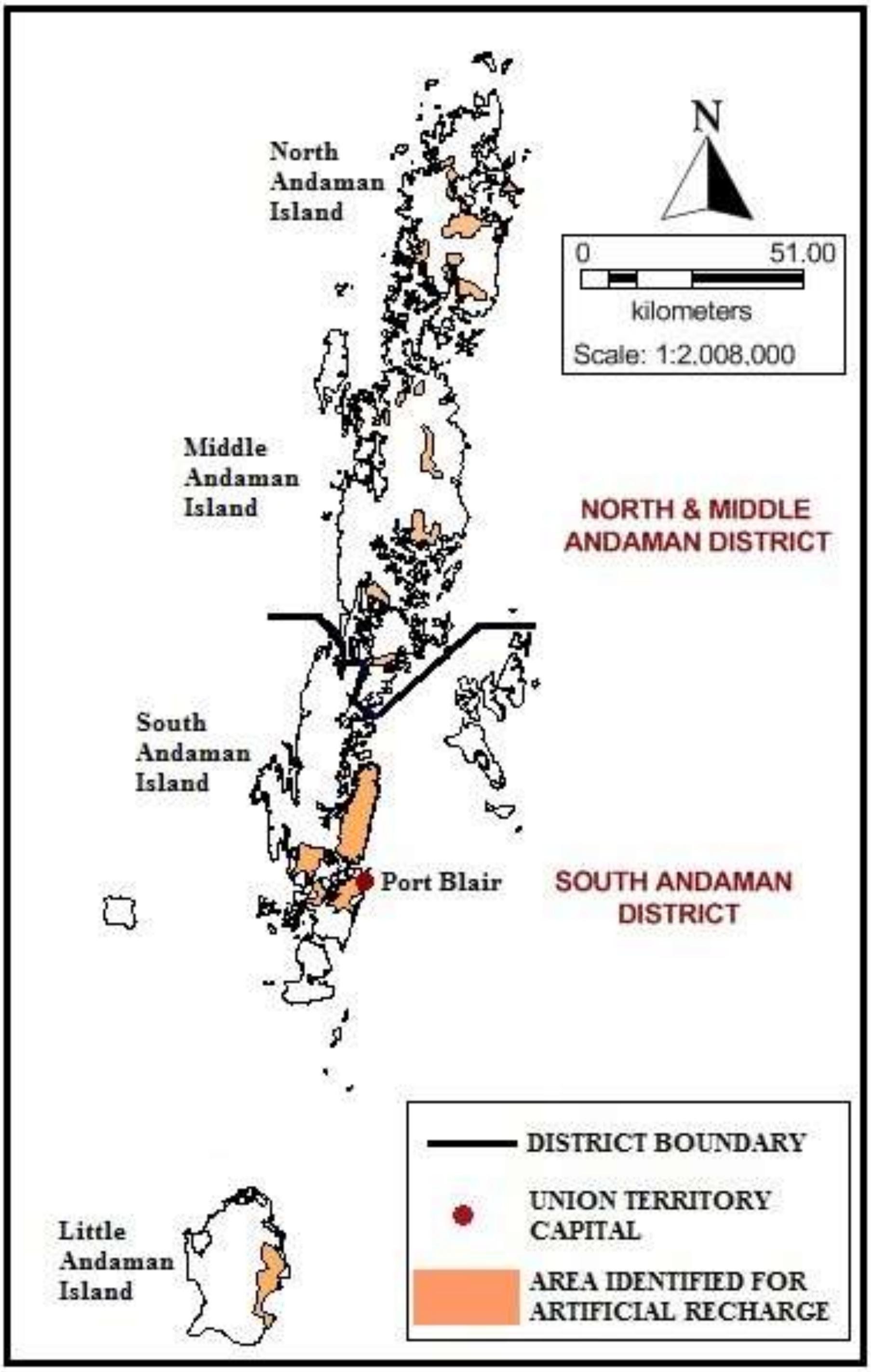


Fig 8.24.1 (a) Area identified for Artificial Recharge/Water Conservation in Andaman & Nicobar Islands

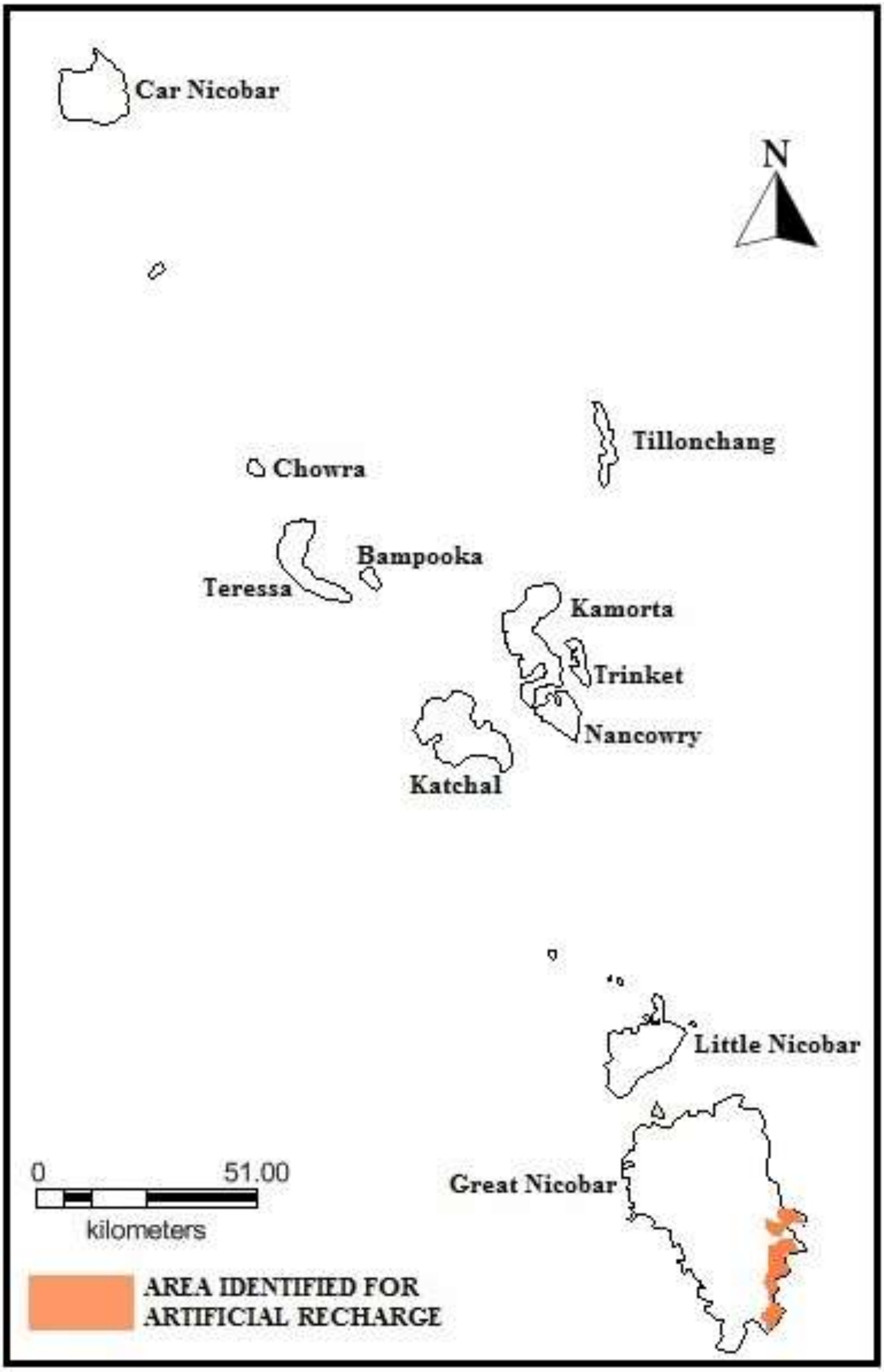


Fig 8.24.1 (b) Area suitable for Artificial Recharge/Water Conservation in Nicobar Group of Islands

8.24.2 Artificial Recharge and Cost Estimates

In order to facilitate water storage in surface and also to augment recharge, Spring Shed Development with catchment area treatment, Micro- watershed management (only in parts of Port Blair Tehsil(South Andaman Island), Roof top rain water harvesting, percolation ponds, check dam, Cement plugs, Sub-surface dykes have been proposed in the in all the streams passing along the inhibited areas islands. Micro-watershed recharge practices will be highly useful in parts of Port Blair Tehsil falling in South Andaman Island, in which site specific structures like contour terracing, contour trench, staggered trench, recharge pit, nala bund can be made. Each micro-water shed will incorporate an area of about 100 hectares. The plan includes making provisions in the islands for spring shed development (150 nos.), roof top harvesting for conservation purposes (1,500 nos.), roof top harvesting for artificial recharge purposes with needful site specificschemes(750 nos.), Micro-Watershed recharge plan(20nos), check dam (350 nos.), Percolation tank (1,000 nos.) and cement plug (150 nos) and sub-surface dykes/dam (150 nos.). The details is given in table 8.24.2.

Rainwater Harvesting

While the Islands are facilitated with the downpour from dual monsoon i.e South-West and North east monsoons, similarly occasional scarcity of water is also felt during the lean period (Dec-March/April). Consequently harvesting of rainwater forms a very old practice of the Islanders. The tribes in the remote Chowra Island in Nicobar district collect rainwater in coconut shells since age old time. As per the building bye law in Port Blair Municipal council area, designing the roofs for harvesting of rainwater from the roof top has been initiated. Similarly,provisions for rooftop rainwater harvesting cum recharge may be implemented in the islands like Neil, Havelock, Little Andaman, Long Island underlain by limestones as also in parts of South Andaman Island, underlain by igneous rocks (Ophiolites) in Port Blair Tehsil where ground water is under steady exploitation through bore wells. In Chowra and Car Nicobar Islands in Nicobar District artificial recharge through rooftop rainwater harvesting may form the best option for sustainable water supply apart from using of conserved rainwater from roof top.

8.24.3 Total Cost

Total estimated cost is Rs 334.73 Cr for construction of the proposed structures in the islands.

Table 8.24.1 Artificial Recharge in Andaman & Nicobar Islands

		Number of Structures						Cost of Structures (Lakh)						
S.No	District	Check dam	PT	Gabion /Contour bund	Sub-Surface Dyke	Spring Shed Development with catchment area treatment and Micro-watershed management	RTRWH	Check dam	PT	Gabion /Contour bund	Sub-Surface Dyke	Spring Shed Development with catchment area treatment and Micro-watershed management	RTRWH	Total Cost
1	Andaman & Nicobar Island	350	1000	150	100	170	2250	5250.00	10000.00	225.00	250.00	2749.92	14998.50	33473.42

Proposed Structures	Unit Cost(Lakh)
Check dam	15.0
RTRWH	6.7
PT	10.0
Gabion /Contour bund	1.5
Sub-Surface Dyke	2.5
Spring Shed Development with catchment area treatment and Micro- watershed management	16.2

8.25 CHANDIGARH

Chandigarh is located at the foothills of Shivaliks and derives its name from the temple of "Chandi Temple" which is located in the vicinity of the site selected for the City. It is located about 250 kms north of New Delhi. It lies between the North latitudes of 30º40' and 30º46' and East longitudes 76º42' and 76º51' and falls in the Survey of India Toposheet No. 53B/13 & 53B/14. Punjab state borders the UT in the south and south-western sides and Haryana state on the eastern side. The city has an area of 114 sq. km, out of which 34 sq. km is rural and remaining 80 sq. km is urban.

Chandigarh is a highly urbanized city and the rooftop rainwater harvesting can be an ideal technique to augment the groundwater availability. There is lot of green area too and some waterbodies that can be effectively utilized for recharging the rainfall runoff. In Chandigarh, there are two distinct aquifer systems–shallow and deep. Shallow aquifer occurs under semi-confined conditions and exists down to 20 to 30 m below land surface. Deep aquifers below 40m are under confined conditions. The aquifer in the area are under semi-confined to confined conditions. It is evident from the fact the ground water extraction for drinking purpose through 200 nos. of tube well is mainly from deeper aquifers (200 m), however the decline in shallow water table can be observed. Hence, recharging of shallow aquifer can also induce recharge deeper aquifer due to head difference.

8.25.1 Identification of Area

Based on the post monsoon depth to water level of the year 2018 and long term ground waterlevel trends (2013 to 2018),it has been estimated that the whole city area (114 sq. km) is feasible for artificial recharge.

8.25.2 Sub-Surface Storage & Water Requirement

The total volume of unsaturated strata is calculated by multiplying the area with the unsaturated thickness of aquifers and is in the order of 455 MCM. The volume available for artificial recharge is given by the product of volume of unsaturated zone and specific yield and is found to be 55 MCM. Considering an efficiency of 75% for these structures, the water required to saturate the aquifer up to 3 m. bgl will be 73 MCM. (Table 8.25.1)

8.25.3 SOURCE WATER AVAILABILITY

It is estimated that about 34.38 MCM surface runoff is available in the city during monsoons from the roads (15.89sq. km), from rooftops of residential areas (30.19sq.km) from shopping areas (3.97sq.km) and public and institutional building (7.94sq.km)..

Table 8.25.1 Scope of Artificial Recharge in UT of Chandigarh

S.No	UT	Area (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	UT of Chandigarh	114	114	455	55	73	0

8.25.4 Recharge Structure and Cost Estimates

The Chandigarh city is an urban area underlain by a potential aquifer system. It is proposed to use the harvested rainwater for recharging the groundwater system through recharge trench with recharge well. In view of the space constraints, no storage of water is envisaged and all the harvested water is proposed to be recharged. The dimensions of the trench would be site specific and will depend on the water availability. In general, a recharge trench of 8m X 2m X 3m capacity with twin recharge wells of 40–80m depth would store and recharge~100m^{3}of rainfall run-off water (Taking 0.30 as run-off coefficient). It is estimated that a total of 10300 recharge structures are required to be constructed to harness 1.03MCM runoff per hour at a cost estimate of Rs.875.50 crores at the rate of Rs.8.50 lakh per structure (Table 8.25.2).

Table 8.25.2 Artificial Recharge in UT of Chandigarh

S.No	UT	District	Number of Recharge Structure	Cost Number of Recharge Structure (lakhs)	Cost of Recharge Structure (lakhs)	Total Cost (Lakh)
1	UT of Chandigarh	Chandigarh	10300.00	8.50	87550.00	87550.00

8.26 DADRA NAGAR AND HAVELI (DNH)

The Union Territory of Dadra Nagar and Haveli (DNH) has geographical area of 491 sq. km. The Union Territory comprises of 2 parts, viz., (i) Dadra which has only 3 villages and (ii) Nagar Haveli having 69 villages. The Eastern part of the DNH is hilly with elevation ranging from 40 – 400 m amsl. The western part is plain with elevation upto 40 m amsl. The hilly terrain constitutes about 114 sq. km. of the total area. Annual rainfall is about 2311 mm. As per Census 2011, the total population of DNH is around 3,42,853 out of which around 1,83,024 is rural population while 1,59,824 is Urban population. DNH is rich in forest wealth having 53% area under forest. The area is drained by Damanganga river and its tributaries namely PipariaNadi, SakartondNadi and DudhniNadi flowing towards west and Dongarkhadi towards east.

The area is underlain by Deccan Trap (basaltic lava flow) and is intruded by dolerite and trachyte dykes. Small and localised patches of alluvium also occur along river's bank but they do not form potential aquifers. The thickness of alluvium is within 5 m. The water level data analysis for the period 2009-18 indicates that the average depth to water level is 3.74 to 12.83 m bgl during pre-monsoon however, during post-monsoon it is comparatively shallow and ranges between 1.22 and 7.65 m bgl. The average water level fluctuation is 0.39 to 9.40 m bgl. The premonsoon water level rising trend is observed in the range from 0.12 to 1.35 m/year for an area of 195 sq.km, whereas declining trend ranging from 0.06 to 0.39 m/year was observed in 282 sq.km area. During the post monsoon season rising trend is ranging from negligible to 0.09 m/year covering an area of 136 sq.km, whereas decline trend of 0.01 to 0.58 m /year is observed in 341 sq.km.

8.26.1 Identification of Area

The area for artificial recharge was identified based on long term decadal post monsoon (November- 2009-18) depth to water levels, long term post monsoon decadal water level trend, aquifer type, local physiography and other issues etc. The areas with depth to water level more than 3 m bgl and areas with declining water level trend of more than 0.10 m were identified as feasible areas for artificial recharge. An area of 281.50 Sq.Km. had been identified for artificial recharge in the UT of DNH. The areas feasible for artificial recharge are shown in Fig.8.26.1.

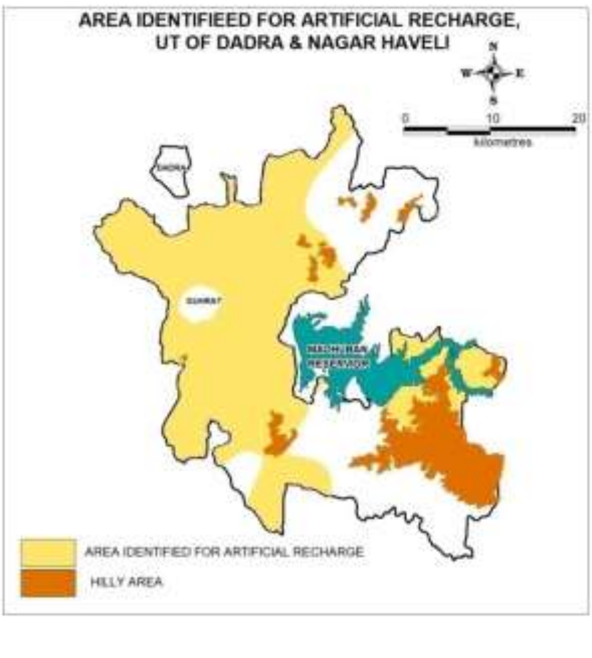


Fig.8.26.1. Identified Area for Artificial Recharge

8.26.2 Sub-Surface Storage and Water Requirement

The thickness of available unsaturated zone (below 3 m bgl) is estimated by considering the mean water levels in the taluka/block below 3m bgl. The product of unsaturated thickness and the area provides the volume of unsaturated zone, which on multiplying with specific yield provides available space for artificial recharge. Considering the efficiency of 75% of the structures, water required to saturate the aquifer is determined. The volume of unsaturated strata is calculated as 563 MCM in of UT of DNH, while the available space for artificial recharge works out to be 11.26 MCM. The water required for artificial recharge to saturate the aquifer up to 3m bgl is 15.01 (Table 8.26.1).

8.26.3 Source Water Availability

The surface water resources available in the sub basin was calculated based on information provided by the State / UT government. The data available for each sub basin included committed runoff, reserved for future planning and surplus water available. A total of 6.50 MCM run off/surface water is available in the UT of DNH and can be utilized for artificial recharge. Invariably the proportionate surface water availability is less (6.50 MCM) and the requirement of surface water for AR is more (15.01 MCM). Further, only 75% of the surface water available was considered as available for artificial recharge since the entire surface runoff availability cannot be considered as many un-planned recharge activities through NGO's and other private organizations are also being taken-up in the UT of DNH. Thus, the proportionate surface water availability for artificial recharge is 7.0 MCM. (Table 8.26.1)

Table 8.26.1 Scope for Artificial Recharge in UT of DNH

S.No	UT	Area (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	U.T. of D&H	491	281.50	563	11.26	15.01	6.50

8.26.4 Recharge Structures and Cost Estimates

In the entire UT of DNH which is occupied by hard rock areas the surface spreading techniques consisting of percolation tanks and cement plugs/bunds are most appropriate. Accordingly, these structures have been recommended for artificial recharge.

The amount of surface water considered for planning the artificial recharge is 4.87 MCM. Based on the field situation it has been considered that 70% storage would be through percolation tanks and remaining by check dams. Accordingly, 3.41 MCM (70%) will be stored in percolation tanks, 1.46 MCM will be stored in Cement plugs/check dams. Therefore, 17 percolation tanks, 49 check dams/cement plugs in the identified areas of UT of Dadra and Nagar Haveli (Table 8.26.2). The percolation tanks should be constructed on second and third order drainage, on favorable hydrogeological and physiographical locations. The cement plugs can be constructed on 1st and 2nd order of drainage. The density of structures per sq.km. is to be planned realistically to make it implementable on practical considerations.

The average cost of construction of a percolation tank (100 TCM single filling storage capacity) was taken as Rs.1.47 Cr, whereas that of cement plugs or masonry check dam of 10 TCM single filling capacity was taken as Rs. 0.15394 Cr as per Common Schedule of Rates (CSR). The estimated cost of Rs. 32.53 cr. is required to take up artificial recharge (Table 8.26.2).

8.26.5 Roof Top Rain Water and Runoff Harvesting In Urban Areas

Considering the over-all demographic, climatic, hydrogeological, physiographic and socio-economic set up and quality of the source water available in the urban areas, following recharge techniques are proposed: Roof Top Rainwater Harvesting (RTRWH), Runoff Rainwater Harvesting

Table 8.26.2 Artificial Recharge and Cost Estimate

S.No	U.T.	Number of Recharge Structures				Unit Cost of Recharge Structures (lakh)				Cost of Recharge Structures (lakh)				Total Cost (Lakh)
		Cement plugs /check dams	Roof Top Rain Water Harvesting	percolation tanks	Urban Runoff Harvesting	Cement plugs/ check dams	Roof Top Rain Water Harvesting	percolation tanks	Urban Runoff Harvesting	Cement plugs/ check dams	Roof Top Rain Water Harvesting	percolation tanks	Urban Runoff Harvesting	
1	U.T. of Dadar & Nagar Haveli	49	12109	17	30	15.40	0	147	7.50	754	3633	2499	225	7111

Roof Top Rainwater Harvesting

These techniques are feasible in densely populated urban pockets where land availability for construction of tanks/reservoirs etc. is almost non-existent and quality of surface water is very poor due to domestic pollution. As per 2011 census there are 6 urban towns the UT of Dadra and Nagar Haveli viz., Silvassa (MCl), Dadra (CT), Naroli, Samaravarni (CT), Masat (CT), Rakholi (CT). In these 6 urban towns there are 40364 households. The exact size of individual house is not available, therefore an average roof size is adopted as 50 sq.m. for calculation of roof area. The estimation of water available from roof top harvesting is worked out by multiplying the district wise roof area with average annual rainfall for the period 2009-18.

The number of households in all the 6 urban towns are 40364. The households having dugwell or borewell etc. are targeted for recharging the ground water reservoir through roof top rainwater harvesting. It is observed that around 30% of the houses are having their own wells in the premises, which can be utilized for harnessing roof top rain water. Thus 12109 households in 6 urban towns shall be covered under this scheme. The average cost for providing the necessary arrangements through pipe fittings etc. in the houses where dugwells/borewells are already existing, shall be around Rs. 30,000 per house. The estimated total cost comes out to be Rs. 36.33 crores for covering all the 6 urban towns.

The total roof area of these households (12109) comes out to be 0.605 sq.km., which will be able to harness 1.489 MCM of rainwater annually. The plan of roof top rain water harvesting is given in Table 8.26.3. The above quantity of rainwater is received at rooftop but same is not available down the roof due to various losses in the form of moisture absorption, evaporation losses and leakage etc. Therefore 80% of the above figure i.e., 1.191 MCM is considered available for harvesting the rainwater which will be taken as source for artificial recharge to ground water. The recharge efficiency of the structures is considered 75%, thus ultimate recharge potential available by RTRWH is about 0.893 MCM. It is estimated that about 48,436 additional urban population would get adequate water supply round the year by implementing this scheme.

Runoff Water Harvesting

The rainfall runoff flowing from the roads and open grounds is substantial during rains. This water often creates the water logging and the drainage system is put under stress in the urban agglomerates. This ultimately flows out of the city unutilized. This water if conserved and utilized properly for recharging the ground water reservoir may bring much needed relief to the water scarcity areas of the city. A scheme suitable for artificial recharge in urban area was prepared by C.G.W.B and was successfully implemented and operated at Nagpur Municipal Corporation ground. In this scheme about 15000 sq.m of residential catchment was intercepted and runoff generated was diverted into the specially constructed recharge well in the public garden. The runoff water was filtered silt free by providing a filter pit. Number of such locations can be identified within city areas where such structure may be constructed to provide a sustainable ground water based water supply in the city.

It is estimated that in 6 urban areas of UT of DNH around 30 schemes would be needed with an average of 5 schemes per town/city. The cost of each scheme will be around Rs. 7.5 lakh. Therefore, an expenditure of Rs. 2.25 crores is estimated for taking up the scheme. These recharge potential of these 30 schemes is considered as 1 ham / scheme and thus the total recharge potential will be 0.30 MCM. The plan of roof top rain water harvesting and runoff rain water harvesting is given below. It is estimated that about 3000 additional urban population would get adequate water supply round the year by implementing this scheme.

8.26.6 Total Cost

The total cost estimate for artificial recharge in UT of DNH is Rs 71.11 Cr with a break up of Rs 34.78 Cr for rural areas & Rs 36.33 Cr for urban areas.

8.27 DIU & DAMAN

The Union territory of Diu & Daman is constituted by two districts, namely Diu & Daman. Both the Districts of Diu and Daman are near Gujarat State, separated by about 700 kms from one another. The District of Daman is situated on the western –coast of India between North latitude 20°27′ 58″ and 20°22′00″ and between East longitude 72°49′42″ and 72°54′43″. It is surrounded by Valsad District of Gujarat State in North, East and South. Damanganga River passes through middle of Daman district dividing it into two parts namely Moti Daman and Nani Daman. It has total area of 72 sq km; its north to south stretch is 11 kms and width from east to west is 8 kms. The altitude is 12 metres above the sea level. Diu district is an island on southern portion of Gujarat Peninsula. It is joined with Una Taluka of Gujarat State by two bridges over a sea creek. The district of Diu is situated between the North latitude 20°44′34″ and 20°42′00″ and East longitude 71°00′24″ and 70°52′26″. Its total area is 40 sq km with length from the extremes north and south, measures 4.6 kms and width from east to west measures 13.8 kms. The altitude is 6 metres above sea level and the topography is generally plain. As per census report of 2011, population of Daman is 1,91,173 while Diu island has population of 52,056 souls. Most of the Diu Island area (44 %) is urbanised with tourism and fishery business while Daman district area is relatively semi urban type and also have fishery and various type of industry as main occupation.

The area of Diu Island is underlain by Quaternary formation consisting of Milliolite rocks and stabilised sand dunes. The Milliolite rocks (Lime Stone) form the main aquifer system of the area. Most of the aquifer system down to 6 to 12 m depth below ground level is brackish to saline. The main source of water for both domestic and industries is through piped water supply from inland areas of Gujarat State. The area of Daman is underlain by the Cretaceous – Eocene age Deccan Trap formation, which occur as main basement rocks. The area along Damanganga River estuary and Kalu Nadi, Moti Daman part, is overlain by 10 to 18 m thick river terrace type alluvium formation. Like Diu Island, Daman area also has shallow ground water condition with brackish to saline ground water below 10 to 15 m depth. Daman area gets piped water supply from Damanganga Weir projects from inland Vapi area of Gujarat State and for irrigation, canal water is available.

Taking into consideration of shallow water level condition and more or less, stable ground water conditionand predominately semi urban and urban types habitat system, roof top rain water harvesting is suggested for augmenting the availability of water for supply. The Diu Island gets average monsoon rainfall of 750 to 850 mm while Daman area gets around 1800 to 2000 mm by south west monsoon system during mid June to September / October months. As per 2011 census data number of urban household in Diu and Daman are 5,249 & 52,074 respectively. Estimating 25 % houses are suitable for harvesting and considering 40 sq m area per house, total 5.00 lakh sq m areas is available for roof top harvesting in Diu and Daman. The source water available for harvesting has been taken as 60 % of average annual rainfall of the area, after making allowance for storm rain etc., total source water available for roof top harvesting has been estimated as 0.54 MCM /year. The average cost of making the rooftop harvesting arrangements is @ Rs 10,000 /- per house. In addition, rooftop rainwater harvesting system is also feasible around 100 government and institutional buildings at an unit cost of Rs 50,000/-. Thetotal estimated cost of roof top harvesting in UT of Daman & Diu is Rs 14.40 cores (Table 8.27.1)

Table 8.27.1 Roof top Rainwater Harvesting in UT of Diu & Daman

S.No	District	Urban Population (Census 2011)	Urban Household (Census 2011)	Roof Area considering average 40 sq.m @ 25% of House Hold (sq.m)	Average Rainfall (mm)	Volume of harvestable water (MCM)	Unit Cost (Lakh)	Total Cost (Lakh)
1	Diu	52074	5249	47241	800	0.02	0.1	131.23
2	Daman	191173	50376	453384	1900	0.52	0.1	1259.40
3	Institutional Area		100				0.5	50.00
Total								1440.63

8.28 JAMMU & KASHMIR AND LADAKH

The Union Territory of Jammu & Kashmir and Ladakh is a mountainous UT in North- western Himalaya, except for about a five kilometers wide stretch of Kandi and Sirowal Zone (Terai Zone) south of Siwlik foot hills. Traditionally people dependent on rainwater and snow melt for meeting their daily requirements of water either for domestic and drinking purposes or irrigational requirements. Traditionally springs and perennial nalas are the main sources of water supply in the scattered settlement in hills and higher elevations. Because of global warming associated with indiscriminate development in the UT resulted into drying up of most of springs and even perennial springs have become seasonal and fluctuating springs. This has necessitated the searching for alternative sources and methods for water supply.

Ground water development in LehandKargil district is on moderate scale restricted to the valley portions. All the major irrigation and drinking water supplies depend on natural springs and rivers and nalas. Recently PHE department constructed handpumps in villages to mitigate the drinking water problems. Public Health Engineering and Irrigation and Flood control departments are the nodal agencies in the district concerned with the water supplies for drinking and irrigation respectively. The depth of the hand pumps is about 60 to 70 m bgl. Few tubewells tapping valley fill deposits are also present in this district which are being used mainly for domestic water requirements.

Rain water harvesting either for storage in surface tanks or artificial recharge to ground water in depleted aquifer areas have become very essential. Even in urban areas of J&K and Ladakh, water required for domestic uses is mostly drawn from surface water bodies, groundwater is also tapped for water supply. In few pockets, it has led to declining trend in ground water levels. This necessitates the urgent need to take appropriate remedial measures in the form of artificial recharge to ground water in these pockets so that the problems can be solved at initial level. Moreover, in hilly areas and remote areas, roof top rainwater harvesting is an ideal alternative to meet the daily water requirements.

Appropriate storage facilities can be created to store roof top rainwater depending on availability of space. Rainwater harvesting in urban areas helps not only in meeting at least a part of the water requirement but also prevents storm runoff. In rural area, ponds, streams and wells have traditionally been used as sources of water for drinking and other domestic uses in outer plains, whereas, in hilly areas, seasonal nalas and springs arethe sources of water supply. In recent years, bore wells with hand pumps and small water supply schemes have almost replaced these traditional sources of water.

In cold desert area spreading whole of Ladakh region, 80% of largely agrarian population rely upon glacial melt water for irrigation, domestic supply and even hydropower. Less snowfall and melt water are already affecting the lives of farmers here. Receding glaciers due to global warming means less recharge to ground water and less discharge in springs. Kuhlas supply water to farmers on turn basis for one or two hours in a month or so. Recently, artificial glaciations and snow water harvesting are being considered as an alternative solution for retreating glaciers. One of the major advantages of this artificial glaciations and snow water harvesting is that the field get water way before the actual glaciers start to melt in May- June.

In Kandi region of outer plains, high altitude Karewa Plateaus spread around the Kashmir valley and Intermountain Plateaus like Dada, Kishtwar, Baderwah, Banihal plateaus where average rainfall is more than 1000 mm, these areas face acute water scarcity especially during summer due to very high runoff resulting from high topographic gradient of 1:60 to 1:100. The fragile eco-system of these region is prone to erosion and as a result, high rate of siltation takes place in the ponds which necessitates periodic de-silting. The problem of water scarcity is more acute in higher reaches of these areas as the villages are located on high slopes of hilly belt and rivers and streams flow through deep cutvalleys.

8.28.1 Identification of Area

Jammu & Kashmir and Ladakh is divided in to three distinct regions from the agro climatic point of view, viz.,

Humid North-Western Himalayas region
Himalayan Foot Hillsregion.
Cold-desert climaticregion

The main criteria for identifying the critical areas for rain water harvesting and artificial recharge to ground water shall be driven and guided by the difficulties/hardships people are facing for meeting the water requirements for domestic and irrigational requirements. For example, in hilly districts like, Poonch, Ramban or Kargil, even though the ground water development is at nascent stage, availability of water for meeting the domestic and irrigation requirements is meager and people are dependent on meager sources like springs and seasonal nalas. In such districts, areas with water crisis are identified and the areas for rain water harvesting may be delineated. The criteria for rain water harvesting shall not be dictated by the criteria of declining water levels or availability of surplus monsoon runoff. Construction of check dams, storage ponds and surface storage of roof top rain water etc are identified based on the utility of these structures for solving the water supply problems in the areas instead of recharge oriented. The ponds present in the Kandi belt and high plateau Karewa table lands can also be good recharge structures. But the water thus recharged flows out as sub- surface flows to the neighboring areas without much use to the local people. The schemes prepared in this district are taken into consideration of the hardships being faced by local people and modification shall be done to the recharge schemes as per the local conditions. Thus large scale artificial recharge to ground water is not feasible in these Union Territories and instead small schemes prepared in mitigating the water supply problems are recommended.

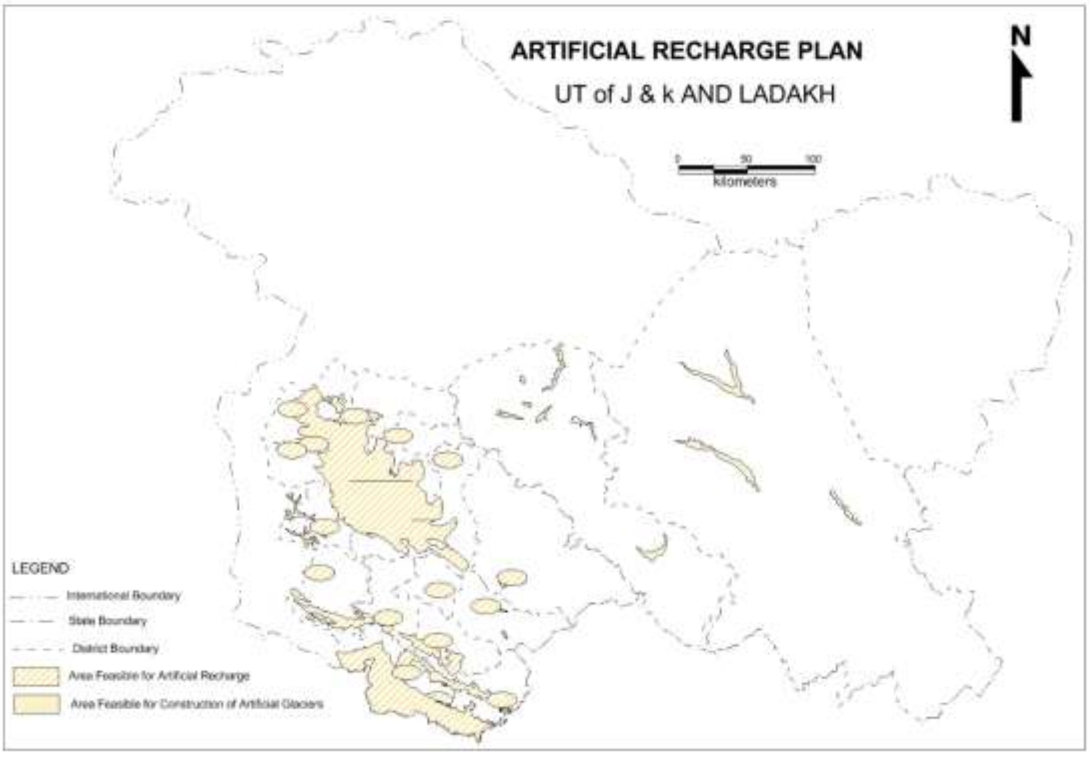


Fig. 8.28.1. Feasible Artificial Recharge areas in UT of J & K and Ladakh

8.28.2 Source Water Availability

Jammu & Kashmir UT is water surplus as it receives bountiful precipitation in the form of rainfall and snowfall. The entire UT of J & K and Ladakh is drained by the rivers of Indus river system and the only exception is the small area in the extreme north-east which is part of

QaraQash river basin. The mean annual surplus runoff in Chenab sub-basin is 27,220 MCM while in Tawi sub-basin it is 1953 MCM. Thus the total runoff available is 29,173 MCM.

8.28.3 Rainwater Harvesting Structures and Cost

Based on detailed hydrogeological investigations carried out by Central Ground Water Board in Union Territory of J & K and Ladakh, it is concluded that five types of rainwater structures can be feasible which need to be constructed in large scale to mitigate the water supply crises. The different rainwater harvesting structures appropriate for three agro climatic zones in the UT are described below.

Humid North-Western Himalayas Region

The region comprises of maximum part of Jammu & Kashmir including Kashmir valley and Ladakh. This region has skeletal soils, podsolic soils, mountain meadow soils and hilly brown soils. The terrain is highly undulating with steep slopes. The soils are silty loam and are prone to erosion. The water harvesting measures recommended for the region are as follows.

Himalayan Foot Hills Region

The region is characterized by slope-wash material comprising loose soil deposits underlain by boulders and pebbles. These deposits generally have moderate to high percolation rates where the soil cover is thin. In topographic lows the thick soil cover provide scope for ponds with fairly good water retention capacity. Often the ground water gradient is steep which is conducive to quick drainage of ground water into nearby streams.

Cold Desert Ladakh Region

This region is characterized by cold climatic conditions where hill tops are covered with snow in large part of the year. The hills are devoid of any soil cover and valley fills are mainly clastic fragmented material. Sand hills are common formed due to erosion activity of glaciers.
The district wise feasible ground water recharge structures are worked out based on the available data of 20 districts of the Jammu & Kashmir and 2 districts of Ladakh as given below.

- Revival and restoration of village ponds in Kandi area as well as in High table Karewa plateau lands and plateau lands within the mountainous terrains
- Gabion structures/ Nala bunds/Sub-surface bandharas in seasonal nalas, perennial nalas in kandi area, Dun area and nalas of Himalayan ranges of Kashmir and Ladakh regions.
- Diversion of flows from Perennial Nalas/Springs in RCC storage tanks in Terrace farming areas spreading all over the region.
- Rooftop rainwater harvesting structures and artificial recharge structures
- Construction of artificial glaciers in Ladakh region

Based on the preliminary surveys, the tentative number of structures and nature of the structures are proposed in Jammu & Kashmir and Ladakh and shown in table-8.9.1 & 8.9.2 respectively. These figures are referred from the Master Plan of Artificial Recharge published in 2013. However, the number of structures proposed in this report has been projected from the report according to the area of newly formed districts.

The Total Financial outlay for water conservation/management intervention for Union Territory of J & K and Union Territory of Ladakh is given in Table 8.3 & 8.4respectively. The Total Financial outlay for water conservation/management intervention for Union Territory of J & K and Union Territory of Ladakh is given in Table 8.3 & 8.4 respectively. The cost estimates in UT of J&K is of the order of Rs 307.13 Cr & in Ladhak is Rs 69.59 Cr.

Table 8.28.3: Cost of water conservation/management intervention in UT of J&K

S.No	District	Number of Structure				Unit Cost structure (lakhs)				Cost of Structure (lakhs)				Total Cost (Lakh)
		RTRWH &AR	Gabbion/ NB/SS Bhandara	Rev & Res. Pond	Diversion of flows from Perennial Nalas/Springs	RTRWH	Gabbion/ NB/SS Bhandara	Rev & Res. Pond	Diversion of flows from Perennial Nalas/Springs	RTRWH &AR	Gabbion/ NB/SS Bhandara	Rev & Res. Pond	Diversion of flows from Perennial Nalas/Springs	
1	Anatnag	45	18	45	22	10.5	52.5	6.0	10.5	472.50	945.00	270.00	231.00	1918.50
2	Kulgam	5	2	5	3	10.5	52.5	6.0	10.5	52.50	105.00	30.00	31.50	219.00
3	Pulwama	39	16	47	12	10.5	52.5	6.0	10.5	409.50	840.00	282.00	126.00	1657.50
4	Shopian	11	4	13	3	10.5	52.5	6.0	10.5	115.50	210.00	78.00	31.50	435.00
5	Srinagar	178	18	9	22	10.5	52.5	6.0	10.5	1869.00	945.00	54.00	231.00	3099.00
6	Ganderbal	22	2	1	3	10.5	52.5	6.0	10.5	231.00	105.00	6.00	31.50	373.50
7	Budgam	50	10	10	10	10.5	52.5	6.0	10.5	525.00	525.00	60.00	105.00	1215.00
8	Baramulla	92	18	92	23	10.5	52.5	6.0	10.5	966.00	945.00	552.00	241.50	2704.50
9	Bandipura	8	2	8	2	10.5	52.5	6.0	10.5	84.00	105.00	48.00	21.00	258.00
10	Kupwara	50	20	60	20	10.5	52.5	6.0	10.5	525.00	1050.00	360.00	210.00	2145.00
11	Jammu	125	19	76	11	10.5	52.5	6.0	10.5	1312.50	997.50	456.00	115.50	2881.50
12	Samba	40	7	30	5	10.5	52.5	6.0	10.5	420.00	367.50	180.00	52.50	1020.00
13	Udhampur	80	15	12	15	10.5	52.5	6.0	10.5	840.00	787.50	72.00	157.50	1857.00
14	Reasi	60	10	8	10	10.5	52.5	6.0	10.5	630.00	525.00	48.00	105.00	1308.00
15	Kathua	150	24	94	24	10.5	52.5	6.0	10.5	1575.00	1260.00	564.00	252.00	3651.00
16	Doda	40	15	8	11	10.5	52.5	6.0	10.5	420.00	787.50	48.00	115.50	1371.00
17	Kishtwar	10	3	1	2	10.5	52.5	6.0	10.5	105.00	157.50	6.00	21.00	289.50
18	Ramban	5	2	1	2	10.5	52.5	6.0	10.5	52.50	105.00	6.00	21.00	184.50
19	Rajouri	80	20	30	15	10.5	52.5	6.0	10.5	840.00	1050.00	180.00	157.50	2227.50
20	Poonch	60	20	10	15	10.5	52.5	6.0	10.5	630.00	1050.00	60.00	157.50	1897.50
	Total	**1150**	**245**	**560**	**230**					**12075.00**	**12863**	**3360.00**	**2415**	**30712.50**

Table 8.28.4: Cost of water conservation/management intervention in UT of Ladakh

S.No	District	Number of Structure				Unit Cost structure (lakhs)				Cost of Structure (lakhs)				Total Cost (Lakh)
		Gabbion/NB/SS Bhandara	Rev & Res. Pond	Diversion of flows from Perennial Nalas/Springs	Artificial Glaciers	Gabbion/NB/SS Bhandara	Rev & Res. Pond	Diversion of flows from Perennial Nalas/Springs	Artificial Glaciers	Gabbion/NB/SS Bhandara	Rev & Res. Pond	Diversion of flows from Perennial Nalas/Springs	Artificial Glaciers	
21	Leh	16	11	5	100	52.5	6.0	10.5	21.0	840.00	66.00	52.50	2100.00	3058.50
22	Kargil	30	20	10	100	52.5	6.0	10.5	21	1575	120.00	105	2100	3900.00
	Total	**46**	**31**	**15**	**200**					**2415**	**186.00**	**157.5**	**4200**	**6958.50**

8.29 LAKSHADWEEP ISLANDS

The Union Territory of Lakshadweep is a group of islands scattered in west coast of India and lies about 220 to 440 km from coastal city of Cochin in Kerala. It is an archipelago consisting of 12 atolls, three reefs and five submerged banks. The Lakshadweep group consists of a string of 36 islands covering an area of 32 sq. km., of which only 10 are inhabited. They are Andrott, Amini, Agatti, Bitra, Chetlat, Kadmat, Kalpeni, Kavaratti, Kiltan and Minicoy. Apart from the ten inhabited islands, Bangaram, the only island open to international tourists, is seasonally inhabited. Total population of Lakshadweep is 64473 (2011 Census) with population density of 2015 persons per sq.km. About 74 percent of the population resides in urban area.

8.29.1 Availability of Subsurface Storage for Artificial Recharge

Lakshadweep islands have a delicate ecosystem with very limited freshwater resource. The fresh groundwater resource of this densely populated tiny coral atolls of Lakshadweep, by and large, occurs as lenses floating in hydraulic continuity with seawater. The hydro-geological environment of these islands is complex hence availability of freshwater depends on factors such as size and shape of the islands, groundwater draft and rainfall pattern. Further the elevation of the island is very small due to which the storage capacity of the aquifer is limited with no additional storage space for artificial recharge. All these factors makes fresh water a prime commodity.

Rainfall, averaging about 1640mm annually, is the sole source of groundwater recharge in these islands. The rainfall distribution pattern of the Lakshadweep islands shows that the average monthly rainfall is more than 40 mm for eight months a year, from May to December. As the thickness of fresh water lens shrink during summer, the quality of groundwater becomes brackish resulted in water scarcity in the islands. Hence rainwater harvesting and storage is the most suitable and cost-effective solution to the water scarcity problems in the Lakshadweep islands in view of the limited sub-surface storage available and the shallow water table conditions. Further, most of the buildings are tiled roof or RCC roofs and hence ideal for roof water harvesting.

8.29.2 Recharge Structures & Cost

Lakshadweep administration has widely recognized the role of rain water harvesting as most suitable and adoptable way in supplementing the water supply very long back and it was widely implemented in all islands. Government buildings including schools, quarters, and non-residential buildings and some private houses had implemented community rain water harvesting systems by building tanks of various capacities ranging from 5m^3 to 10 m^3 or some places up to 50 m$^{3.}$ At present, rain water harvesting structures are implemented in 4532 buildings which includes the entire government buildings. Apart from these, desalinization plants and Sea Water Reverse Osmosis plant have been established in three islands and one island of Lakshadweep, which has the capacity of supplying 1 lakh and 25,000 litre desalinated water/day respectively.

Considering the rainfall pattern and existing water supply measures prevalent in the Island, the rainwater harvesting systems may be designed to harvest the rainfall received in any two months of the year, except January, February, March and April to collect and store water enough to meet the requirements of the population for about 100-120 days. The island wise status of roof water harvesting in operation, future scope and financial out lay required, taking November and December months as the collection period for Minicoy and October and November for remaining 9 islands, are worked out and presented in Table 8.29.1. Rainwater harvesting for the above two months are considered as it is sufficient enough to fill the storage tanks so as to supplement water needs in the ensuing summer months. Water storage during monsoon season is not that significant as the well water cater the domestic needs. Thus by considering the monthly rainfall of two proposed months, harvestable volume was calculated Considering the water supply from desalinization plant the storage capacity of tanks has been restricted to 5m^3. The proposed rain water storage in each island is worked out based on the number of new buildings. The cost involved in construction of roof water harvesting structure is around Rs. 12/litre of tank capacity inclusive of eve gutters and fittings, calculated as per schedule of rates for the UT. The total cost of installation of rainwater harvesting systems for disaster preparedness/mitigation in the islands is of the tune of about Rs.57.58 Cr.

Table.8.28.1 Scope of Rainwater Harvesting in Lakshadweep Islands

Island Name	No: of buildings	Roof Area (m^2)	Avg. Ann. Rainfall (mm)	Volume of Rainwater Harvestable (MCM)	Harvestable volume during proposed month (MCM)	Proposed Storage (m^3)	Total cost (Rs.lakh)
Kavaratti	2068	124080	1504	0.149	0.020	10340	1240.8
Agatti	1695	101700	1504	0.122	0.018	8475	1017
Androth	1625	97500	1504	0.117	0.018	8125	975
Minicoy	1070	64200	1640	0.084	0.012	5350	642
Kalpeni	579	34740	1504	0.042	0.006	2895	347.4
Amini	1038	62280	1504	0.075	0.011	5190	622.8
Kadamat	795	47700	1504	0.057	0.009	3975	477
Kiltan	485	29100	1504	0.035	0.005	2425	291
Chetlat	242	14520	1504	0.017	0.003	1210	145.2
Bitra	0	0	1504	0.000	0.0000	0	0
Total	9597	575820		0.700	0.102	47985	₹ 5,758.20

8.30 UT OF PUDUCHERRY

The Union Territory of Pondicherry consists of four regions, namely Pondicherry Region (293 Km^2), Karaikal Region (161 Km^2) and Yanam Region (20 Km^2) located along the east coast of India and Mahe (9 Km^2) located along the West Coast, covering a total area of 483 Km^2. All the four regions are at different locations, geographically separated from each other. Pondicherry and Karaikal are enclaves of Tamil Nadu, while Yanam and Mahe are enclaves of Andhra Pradesh and Kerala respectively. Total population of the UT is 12,44,464 (2011 census) and 45% it is engaged in agriculture. Irrigation in Puducherry is mainly through tanks and tube wells.

Puducherry has average rainfall of 1205 mm. Geomorphology of the area is characterized by Coastal Plain, Flood Plains and Pediments. Sandstone and Limestone are main geological formations in the area. Depth to water level ranges between 5 to 42m bgl.

Ground water quality is not potable at places. As per the water table and vulnerability to sea water ingress, need for artificial recharge has been inferred and accordingly Pu33ducherry and Karaikal region are consideredthe details of proposed artificial recharge structures in the UT of Puducherry is given in Table – 8.30.1.

Table – 8.30.1 Scope for Artificial Recharge in UT of Puducherry

S.No	District	Area of District (Sq.Km.)	Area Identified for AR (Sq.Km.)	Volume of Unsaturated Zone (MCM)	Available Subsurface Space for AR (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Puducherry Region	293	201.14	309.88	6.20	8.24	21.90
2	Karaikal Region	161	99.00	222.70	4.45	5.92	10.15
	Total	454	300.14	532.58	10.65	14.17	32.05

Based on the hydrogeology and terrain conditions, Percolation Pond, Check Dam/ NalaBund, Recharge Shaft, Borewell, Recharge Tube Well, Recharge Trench, Farm Pond & Recharge Pit are considered for facilitating artificial recharge. Roof Top Rainwater structures are not considered in the Master Plan, because it has been made mandatory in the building by laws for all Resident, Industrial, Commercial and Govt. Establishment. The total cost of the recharge schemes proposed in the UT of Puducherry is Rs.20.89 crores (Table 8.30.2).

Table – 8.30.2 Artificial Recharge in UT of Puducherry

		No of artificial recharge structures						Unit Cost (Lakh)						Cost of Structures (Lakh)						
S. No	District	CD / NB	RS/ BW	FP/ RP	RTW	PP	RT (km)	CD/ NB	RS/ BW	FP/ RP	RTW	PP	RT (km)	CD/ NB	RS/ BW	FP/ RP	RTW	PP	RT (km)	Total Cost (Lakh)
1	Puducherry Region	41	165	62	55	8	2	15.0	1.0	1.0	3.0	25.0	1.0	615.00	165.00	62.00	165.00	200.00	2.00	1209.00
2	Karaikal Region	30	118	44	39	6	1	15.0	1.0	1.0	3.0	25.0	1.0	450.00	118.00	44.00	117.00	150.00	1.00	880.00
	Total	**71**	**283**	**106**	**94**	**14**	**3**							**1065.00**	**283.00**	**106.00**	**282.00**	**350.00**	**3.00**	**2089.00**

Note
PP:Percolation Pond; CD/NB: Check Dam/ NalaBund RS/BW: Recharge Shaft/ Bore well; RTW: Recharge Tube Well; RT: Recharge Trench; FP/ RP: Farm Pond/ Recharge Pit;

CHAPTER 9.0

9.0 SUMMARY OF MASTER PLAN & ROADMAP FOR IMPLEMENTATION

9.1 SUMMARY

The revised master plan is macro plan formulated to work out the feasibility of various structures for the different terrain conditions of the country and respective estimated cost, providing a broad outline of the project and expected investments. DPR has to be prepared at an implementable level like any other water supply project or city development project.

The area for artificial recharge has been identified based on post monsoon water level (2018) and long-term post monsoon water trend in most of the States & UTs. However, due to paucity of data and local groundwater issues, additional/different criteria were used in different States/UTs. In the case of NE States, UT of Jammu & Kashmir & UT of Ladakh, the criteria of water scarcity have been used and structures have been suggested to harness the run off generated from the rain. In case of UT of Lakshadweep & UT of Daman & Diu, due to shallow groundwater level, only RTRWH has been suggested. An area of 11.23 Lakh sq.km has been identified for artificial recharge.

The scope of artificial recharge depends on the available sub surface space for recharge, water required for recharge and surplus water available for recharge. The volume of space available up to 3m bgl or 5m bgl depending on the criteria adopted in different States multiplied by the specific yield of the aquifers will provide the space available for recharge. Considering an efficiency of 60% or 75% as deemed fit in different States, the water required for artificial recharge has been worked out for each State. The surplus available for recharge after deducting the committed supply has been estimated for each State. The available sub-surface space for artificial recharge 537.349 BCM, while the water required to saturate the aquifer up to 3 to 5m bgl is 716.917 BCM. The surplus source water available for recharge is of the order of 185.092 BCM. The availability of source water for recharge is not uniform and in many districts in the States of Rajasthan, Punjab, Haryana, Gujarat etc., the source water available is less than the requirement and artificial recharge structures are restricted to the source water availability. State wise scope of artificial recharge is given as Table 7.1, which is reproduced below for ready reference.

Table 7.1 Scope for Artificial Recharge

S.No	State	Area identified for Artificial Recharge (Sq.km)	Available Sub Surface storage for Artificial Recharge (MCM)	Water Required for Recharge (MCM)	Surplus Available for Recharge (MCM)
1	Andhra Pradesh	83914.18	15948.69	21211.74	1246.95
2	Bihar	25959.57	8750.77	13476.25	66352.03
3	Chhattisgarh	25667.94	1030.12	1370.05	8609.63
4	Delhi	824.50	982.48	1306.73	94.62
5	Goa	1267.84	627.01	833.93	393.16
6	Gujarat	53123.19	14825.31	19717.69	4459.26
7	Haryana	39381.20	77964.29	103692.51	679.26
8	Himachal Pradesh	5468.80	2671.71	3553.38	0.00
9	Jharkhand	28748.31	1323.78	2197.47	4898.06
10	Karnataka	143453.00	10233.74	13610.88	12874.17
11	Kerala	11957.00	810.37	1080.48	12455.00
12	Madhya Pradesh	146053.45	24957.34	33193.23	9188.29
13	Maharashtra	123884.45	13621.24	18081.12	3871.98
14	Odisha	4043.61	669.46	890.41	1786.49

Table 7.1 Scope for Artificial Recharge					
S.No	**State**	**Area identified for Artificial Recharge (Sq.km)**	**Available Sub Surface storage for Artificial Recharge (MCM)**	**Water Required for Recharge (MCM)**	**Surplus Available for Recharge (MCM)**
15	Punjab	45592.00	86789.21	115429.65	1200.99
16	Rajasthan	113498.00	159115.00	211626.00	5305.00
17	Sikkim	1834.00	249.94	332.41	332.41
18	Tamilnadu	91224.09	8700.80	11572.06	959.33
19	Telangana	42155.89	3342.80	4445.97	1186.47
20	Uttar Pradesh	97338.00	66970.00	89069.00	2743.00
21	Uttarakhand	13372.00	4012.00	5335.00	33449.00
22	West Bengal	22888.67	33177.41	44125.96	8532.86
23	UT-Lakshadweep	0.00	0.00	0.00	0.00
24	UT-Puducherry	300.14	10.65	14.17	32.05
25	UT-DNH	281.50	11.26	15.01	6.50
26	UT-Chandigarh	114.00	54.60	72.61	0.00
27	UT-Andaman & Nicobar Islands	792.90	499.18	663.90	4436.05
		1123138.24	537349.16	716917.60	185092.56
Note:					
The area has been identified for AR in NE States, UT of J&K, UT of Ladhak & UT of Daman & Diu, quantification of area could not be made.					
Himachal Pradesh - The source water availability could not be assessed, as the data is confidential					
Sikkim - Surplus Available for artificial recharge is taken as equal to water required, in view of the rugged Himalayan terrain, which is 0.1 % of surplus available. Hence source water availability is considered as Harnessable water for artificial recharge					

The types of structures are decided by the terrain conditions and the number of structures are decided by the source water availability. The different type of structures suitable for different terrain conditions and the use of different terminology for the similar structures in various States have resulted in more than 25 types of structures. In order to group different structures and bring in standardization, the structures were studied and grouped in to 10 groups and in the group “Others” all the uncommon structures are classified. About 75% of structures are towards RTRWH, while 17% is for “Others”, with 3% for RS, 2% of structures are in the category of CD & Gabion structures and 1% under PT category. The unit cost of structure also is found varying within the States for different districts for some States, while in some States/UTs they have assumed a uniform rate. RTRWH accounts for 28% of cost, while “others” category is for 23% of cost and CD & PT account for 19% & RS for 07% of cost. The total cost for implementation of this revised master plan is Rs 133529.69 Cr, with Rs 96735.45 Cr (72%) for rural areas and Rs 36794.23 Cr (28%) for Urban areas and the state wise break up given as Table 7.5 is reproduced below for ready reference.

Table 7.5 Cost Estimate for Artificial Recharge in Urban & Rural Areas (Rs in Cr)					
S.No	State	Rural	Urban	Total	%
1	Andhra Pradesh	3276.67	527.39	3804.06	3%
2	Bihar	2106.44	500.00	2606.44	2%
3	Chhattisgarh	3095.12	591.70	3686.82	3%
4	Delhi	683.58	1522.50	2206.08	2%
5	Goa	279.30	146.54	425.84	0%
6	Gujarat	820.84	2641.89	3462.73	3%

Table 7.5 Cost Estimate for Artificial Recharge in Urban & Rural Areas (Rs in Cr)

S.No	State	Rural	Urban	Total	%
7	Haryana	3457.32	913.13	4370.45	3%
8	Himachal Pradesh	1018.65	36.75	1055.40	1%
9	Jharkhand	4053.57	1304.23	5357.80	4%
10	Karnataka	7111.64	2870.02	9981.66	7%
11	Kerala	2535.64	724.18	3259.82	2%
12	Madhya Pradesh	9708.66	817.88	10526.54	8%
13	Maharashtra	13893.74	16940.31	30834.06	23%
14	NE States	6206.28	1683.49	7889.77	6%
15	Odisha	597.55	204.10	801.65	1%
16	Punjab	5119.63	1653.92	6773.55	5%
17	Rajasthan	19318.10	0.00	19318.10	14%
18	Sikkim	123.87	75.00	198.87	0%
19	Tamilnadu	2463.14	0.00	2463.14	2%
20	Telangana	2750.60	1110.20	3860.80	3%
21	UT-Andaman & Nicobar Islands	184.75	149.99	334.73	0%
22	UT-Chandigarh	875.50	0.00	875.50	1%
23	UT-DNH	34.78	36.33	71.11	0%
24	UT-Jammu & Kashmir	186.38	120.75	307.13	0%
25	UT-Ladakh	69.59	0.00	69.59	0%
26	UT-Lakshadweep	0.00	57.58	57.58	0%
27	UT-Puducherry	20.89	0.00	20.89	0%
28	Uttar Pradesh	5099.23	2057.22	7156.45	5%
29	Uttarakhand	12.86	27.72	40.57	0%
30	West Bengal	1631.15	67.02	1698.17	1%
31	UT-DIU & Daman	0.00	14.41	14.41	0%
	Total	96735.45	36794.23	133529.69	

9.2 ROADMAP FOR IMPLEMENTATION

The revised master plan for artificial recharge to groundwater has been made for the whole country at the level of district/Block level. The plan is macro plan formulated to work out the feasibility of various structures to different terrain conditions and the estimated cost, when the action is expected to be taken for the whole country. At the outset CGWB would like to state clearly that this master plan is like any other master plan prepared for a State or city, which brings out the broad outline of the project and expected investments and for implementation, DPR has to be prepared at an implementable level like any other water supply project or city development project.

The water stress is being felt at different parts of the country owing to the increasing demand resulting from the population explosion. In order to meet the demand, the share of groundwater has increased exponentially, it has far exceeded the natural recharge in many parts of the country, necessitating the both central and State government to take up water conservation effort through many schemes. The revised master plan will provide general guidance for terrain specific structures considering the availability of surplus source water and indicate a rough ball park figure for culminating such efforts.

In the revised master plan, the areas of water scarcity, areas with deeper water levels, highly exploited areas have been considered, providing different types of structures as per terrain conditions. Central State agencies have already many schemes, which have included the component of water conservation as given below

- Mahatma Gandhi National Rural Employment Guarantee programme (MGNREGS)
- Integrated Watershed Development programme for rain fed areas (NWDPRA)
- Bharat Nirman
- Irrigated Agriculture modernization, water bodies restoration and management project (IAMWARM)
- Drought prone area programme (DPAP)
- NABARD assisted rainwater harvesting programme for augmentation of ground water recharge
- Rehabilitation of tanks identified by MLAs
- Command area development & Water Management program
- Water conservation in reserved forest area
- Local area development programme of M.P & M.L.A

In addition, the scheme of Atal Jal has been initiated and the scheme aims at sustainable management of ground water through community participation by addressing the supply side (augmenting the ground water table or arresting its decline) and demand side (by introducing water conservation technologies/practices like drip, sprinkler, pressurized pipes to reduce ground water consumption) interventions through convergence of ongoing schemes, along with capacity building and institutional strengthening initiatives in identified over-exploited / water scarce areas in about 193 Blocks in parts of 78 Districts in Haryana, Rajasthan, Gujarat, Uttar Pradesh, Madhya Pradesh, Maharashtra and Karnataka. Another scheme under preparation is the comprehensive measures for water conservation in select water stressed districts in the country, resulted out of Budget announcement of the Government. All these ongoing and also the proposed schemes can utilize the revised master plan for preparation of DPR and take it further towards implementation.

9.2.1 Documentation of Water Conservation Efforts

Owing to the over dependence on groundwater, both State & Central Government Agencies are dovetailing their activities towards water conservation. Consequently, construction of the artificial recharge structures has increased over the years. Further construction of structures also depends on the surplus water availability and hence it becomes imperative that geotagging of these structures are made and their functional status monitored. It I high time that one of State agencies be made a nodal department for maintaining the database of artificial recharge structures and its functional status. The committee strongly feels that one Nodal agency be identified for each State/UT by the respective States /UTs, which will function as a focal point for all water conservation database and documentations.

9.2.2 Community Participation

The success of the scheme depends on the participation of community in the efforts of water conservation. Many NGOs/PRI/VOs are already working actively in many States and if the participation is effected from the grass root level, the operation and maintenance of the structures would be successful. Atal Jal Scheme is in that direction that it envisaged to be implemented in participatory mode. RTRWH is one scheme, where every individual can be taken on his own in his/her house or taken as a community, if the building has a common roof. The harvested water can be used even for drinking purposes and if treated waste water is also supplied in a separate pipe line, reducing the use of fresh water, community can greater leap towards optimal utilization of water resources.

9.2.3 Industry Participation

The industries, while taking NOC in OCS Blocks, make provisions for artificial recharge/RWH and also as a part of CSR programme. The revised master plan can be used for preparing the DPR, if industries want to take up water conservation projects on larger areas. The recycle/reuse of water has not been included in this study, as the quality of water available for recharge needs to be ensured or else it would lead to the contamination of groundwater system. The industries may consider the use of treated waste water for uses other than drinking so that the industrial demand can be made bare minimum and water saved is water conserved. Thus slowly, the industries should turn towards treated waste water for their use, instead of fresh water for purposes other than drinking.

9.2.4 Funding Mechanism

There are many existing schemes and a new scheme is under preparation in respect of comprehensive measures for water conservation in select water stressed districts in the country, resulted out of Budget announcement of the Government, which can cater to the implementation of the revised master plan. No separate funding is required for executing the revised master plan. The different scheme can take the cue from the master plan and construct these structures as per the norms of the schemes. The execution of these structure may take a period of 10 years, if the schemes dovetail their activities for convergence towards water conservation.

9.2.5 Guidelines for implementation of Artificial Recharge Projects

A Water Quality Guide to Managed Aquifer Recharge in India was prepared as a result of DFAT Project through the Public Sector Linkages Programs involving CSIRO Land and Water Flagship in Australia and UNESCO International Hydrological Programme. (https://publications.csiro.au/rpr/download?pid=csiro:EP149116&dsid=DS2)

A detailed guide has been prepared with the following objectives.

To develop and apply methods to assess impacts of recharge structures on water availability and quality, social and economic resellience and local ecosystmes.

To enhance governance capacities and institutional and legal frameworks to aid effective MAR implementation.

The Minsitry had desired that the guidelines given in the report may be included so as to make the implementation of the master plan effective. The guidelines have given emphasis on the water quality of the source water, formation water in the aquifer and impact of contamination of the aquifer from the environment. In this section, the methodology adopted in the master plan vis-a-vis the guidelines are discussed.

The guidelines provide a simple check list as water quality guide as given below.

1. Simple Assessment
    a. Which source is being supplemented, Scale of Recharge, quality of source water
2. Viability Assessment
    a. Demand for water
    b. Adequate source availability
    c. Suitability of Aquifer for recharge
    d. Availability of Space
3. Guidelines applicability Assessment
    a. Source water from RT or Natural catchment

   b. Nature of Aquifer & pollution status
   c. Distance to Drinking water source
4. Sanitary Survey
   a. Location of latrine, sewer within catchment area w.r.t recharge structure
   b. Landfills. Industrial and agricultural activities disposal mechanism
   c. Presence of barriers around structures to prevent contamination
5. Aquifer Assessment
   a. Quality of source water –physical parameters
   b. Shallow WT
   c. Location of nearby GW user within 100m
   d. Geogenic contamination of aquifer
   e. Rocktype- hard rock, alluvium
   f. Any Approval required from authority
6. MAR – Safety Plans
   a. *Human sewage entrainment in source water*
   b. *Animal faecal matter entrainment in source water*
   c. *Leaching of microbial contaminants into aquifer*
   d. *Entrainment of chemicals in source water for recharge*
   e. *Leaching of chemicals into groundwater*
   f. *Bypassing or failure of pre-treatment in recharge facility*
   g. *Bypassing or failure of post treatment at recovery well*

In the master plan, essentially, we consider only the source water from Rooftop and natural catchments, which are generally of good quality in nature. The fresh water aquifers are only considered for recharge and further, the area identified for recharge is based on two factors, viz., Need and Scope for artificial recharge. The need is indicated by the water levels (>3m bgl during post monsoon period) so that the area does not get waterlogged. The scope for artificial recharge is indicated by the availability of surplus source water and the ability of the aquifer to accept the recharge. Hence, the simple assessment, viability assessment, guidelines applicability assessment and aquifer assessment of the check list given in Guide to Managed Aquifer Recharge are inherently included while preparing the master plan. However, as the master plan document is proposed to be used as a guiding factor in formulating site specific artificial recharge projects, it is prudent to provide a check list in the master plan considering following points

Aquifer Assessment – deeper water level, fresh/brackish aquifers (improvement of water quality, when the EC is $\geq$ 750µS/cm & $\leq$1500 µS/cm), suitability for aquifer recharge considering the potential, possibility of recharge and extraction.

- **Viability Assessment**- Availability of source water, availability of space for recharge, type of structures based on terrain conditions.
- **Quality Assessment** – Quality of source water, quality of formation water, prevention of contamination of source water from landfills, sewers & industrial waste disposal sites. The use of treated water or grey water is not being considered for direct recharge as foolproof mechanism is not existing in India to ensure the requiste quality of water as per the Drinking water standards or irrigation standards.

Considering the Indian conditions, a following checklist is suggested for carrying out prior assessment while formulating the artificial recharge projects.

S.No	Assessment	Factors to be considered
1	Simple Assessment	• <u>Which source is being supplemented</u> - *Domestic water supply / irrigation / general groundwater system* • <u>Scale of Recharge</u> - *Specific Source Recharge or General Recharge* • <u>Quality of source water</u> - *Free from contamination*

S.No	Assessment	Factors to be considered
2	Viability Assessment	• Demand for water - Usage of water for domestic / irrigation / industrial purposes • Adequate source availability - *Availability of surplus source water* after deducting the committed water supply for the existing structures • Suitability of Aquifer for recharge - *Potential of the Aquifer so as to accept the recharge* • Availability of Space – *Post Monsson Water level >3m bgl in unconfined aquifer*
3	Guidelines applicability Assessment	• Source water from Rooftop or Natural catchment • Nature of Aquifer & pollution status - *Unconfined or confined aquifer and quality of formation water* • Distance to Drinking water source - *Distance of the proposed structure from the source proposed to be recharged to ascertain the effectiveness*
4	Sanitary Survey	• Location of latrine, sewer within catchment area w.r.t recharge structure – To locate *the proposed structure away from the sewer etc to prevent contamination* • Landfills. Industrial and agricultural activities disposal mechanism - To locate *the proposed structure away from the disposal sites to prevent contamination* • Presence of barriers around structures to prevent contamination – *Possibility of arresting the contamination from reaching the source water through barriers.*
5	Aquifer Assessment	• Quality of source water –physical parameters – *To ensure quality through filters* • Shallow Watertable - *Post Monsson Water level >3m bgl in unconfined aquifer* • Geogenic contamination of aquifer – *Contaminant Free aquifer or to study the possibiulity of dilution through recharge* • Aquifer Potential for acceptance of the recharge – *Yield of the aquifer is generally considered as ability of aquifer to accept the recharge*
6	MAR – Safety Plans	• Prevention of source water contamination from sewer, landfills and industrial waste disposal sites – *Keep it away form the disposal sites to prevent contamination*
7	Clearance from Authority	• Any Approval required from authority – *Requird approval to be taken from the concerned Authority*

9.2.6 Recommendation of the Committe

Each State may nominate a Nodal Agency, for maintaining the data base and documentation of water conservation efforts being undertaken by the respective States and Nodal Agency will remain a focal point for contact in respect of water conservation in the States.

CHAPTER 10

10.0 WAY FORWARD

The master plan for artificial recharge to groundwater has been revised considering the existing data availability. This is a broad conceptual plan, formulated to work out the feasibility of various Water conservation & recharge structures for the different terrain conditions in diverse hydro-geomorphological settings of the country. The information on respective estimated cost of the recharge structures, a broad outline of conceptualization of the project and expected investments are provided. Considering, the technological advancement and various scientific activities being implemented parallely under different programs in various states in the country, it is prudent to revise the methodology to incorporate scientific techniques for different terrain conditions. In the past, the identification of suitable areas for water conservation & recharge was selected by overlaying different thematic maps of the area prepared manually. GIS technology is now in practice & can be successfully utilized to demarcate the recharge areas by superimposing various thematic maps / layers using the Drastic approach by giving weights to various thematic layers on GIS platform. In the past, several efforts had been made by CGWB for implementation of pilot & demonstrative artificial recharge projects in coordination with state agencies with the view of their capacity building to replicate the similar structures in adjoining similar terrain conditions. The Board is implementing National Aquifer Mapping & Management programme (NAQUIM) in the country to understand aquifer disposition & their characteristics to prepare aquifer maps & management plans. The output of NAQUIM studies are shared / being shared with state agencies as well as at district level for suitable implementation through ongoing water conservations programs / schemes in such areas. NAQUIM studies also will provide information on groundwater extraction from different units' / aquifer layers and thus areas of the identified stressed aquifer units can be taken up for implementation of water conservation & artificial recharge measures by the state agencies. It would be prudent to recharge the pertinent water stressed aquifers on priority so that adequate water is available to meet ever increasing water demand. In this regard, the outputs of NAQUIM can provide excellent aquifer information inputs for conceptualising & implementing groundwater recharge projects. Many states agencies have successfully utilized the NAQUIM outputs provided by CGWB in the identification of recharge sites and structures type based on the aquifer disposition and terrain conditions. So far, the Master plan for artificial recharge to groundwater is a conceptual document, however by utilizing the available technological advancements of GIS & remote sensing techniques, it would be feasible to have micro-level information on area-specific feasible recharge structures & their location. The same can be refined during preparation of Detailed Project Reports (DPRs) by the implementing agency in the state. To take up water conservation & recharge measures at country-level, system-approach would be appropriate, which can be adopted by all the states uniformly to have maximum benefit in water conservation & artificial recharge. In order to create such a system, the following issues need to be taken into consideration:

1. **Implementation Approach**

The implementation approach of artificial recharge projects shall depend on various factors and hence cannot be uniform. The major factors controlling the approach are hydro-geomorphological settings which varies in different terrain conditions. The watershed approach is best fit for hard rock terrains, while the basin/sub basin approach is practically feasible for alluvial/sedimentary terrain having large & thick aquifers. Further, in hilly terrains, springshed approach can be more scientific & useful in implementation of spring rejuvenation projects. Depending upon the type of terrain conditions, the plan need to be conceptualised by collecting various information as described below:

2. **Scale for collecting information & conceptualising artificial recharge plan**

The demarcation of feasible recharge areas at macro-scale is pre-requisite in any exercise of preparation of master plan on artificial recharge. However, for implementation of the plan, detailed project report (DPR) is the basic scientific document which includes location specific sites of recharge structures, their type, design and costing, etc. For selection of watershed / area in a basin/ sub-basin / springshed for recharge activities, master plan on a large scale is required which can provide basic information of feasible recharge areas, so that any implementation agency can initiate preparation of DPRs for such areas under any running program / scheme of water conservation & recharge in the state / UT.

The Plan needs to be not only scientifically informative, but also to be easily understood by the executing agencies, viz., state line departments, local municipal bodies, non-government agencies, self-help groups etc., to take up such areas for DPR preparation & thereby its implementation. In order to have a reliable accuracy, there is a need to have the plan at a larger scale of 1: 10,000 on GIS platform.

3. **Information / data as inputs Thematic layers**

Most common thematic layers required for identification of the suitable sites of artificial recharge are Topographic map, Soil Map, Land use/Land cover, Geomorphology, Aquifer maps, water level maps etc. along with other layers depending upon the watershed / area of interest. In order to prepare a recharge plan at a scale of 1:10;000 scale such inputs are also required to be collected through micro-level surveys on same scale.

The GIS, remote sensing & LIDAR through Drone technologies can be utilized along with groundtruthing surveys for collation of data and its translation into information & thematic layers using GIS on 1: 10,000.

In view of the non-availability of such detailed information, large scale exercise was not possible in preparation of present master plan, however it is envisaged that designated state agencies will work on local scale for preparation of thematic layers on a large scale so that comprehensive plan including tentative site locations and type of recharge structures can be prepared in the next version of the plan.

4. **Standardized database**

It is essential to have detailed database on water bodies and already existing recharge structures, so that assessment of surplus water can be worked out. NWIC under DoWR, RD & GR has already prepared a module for creation of database on artificial recharge structures and have intimated to all States to update the database, which is yet to be initiated by the States. It is suggested that a State Level Nodal Agency (SLNA) be identified by the State, to coordinate all water conservation related work in the State and maintain the database.

SLNA can be entrusted to pursue state line agencies implementing water conservation & recharge projects / schemes to regularly update the information through mobile app / sharing through other platforms. The database will be managed and validated by the SLNA. Such information will also need to be available for direct access to the other departments implementing the different schemes/projects in the respective state / UT at a regular interval.

5. **Outputs**

The outputs of such studies will be in the form of maps and plans depicting area feasible for artificial recharge, availability of source / surplus water, site demarcation / location of proposed recharge structures & their type. The information can be translated into Detailed Project Report (DPRs) with field investigations/validations for actual measurements for design / drawings and cost estimates of the structures.

6. **Frequency of Revision**

The preparation of thematic maps on a larger scale by the identified State Agency may require at least 02 years for each State and preparation of master plan on a larger scale another 01 year. Keeping a period of impact assessment of 2 years, the revision can be taken up every five years.

10.1 FORMULATION OF MASTER PLAN

It is pertinent to note that though the approach will be different for different terrain conditions but the basic methodology for formulation of the plan will remain same for all the terrains / hydro-geomorphic settings. The Hard rock terrain will opt for the watershed approach, viz., valley to ridge approach, while for areas of alluvial terrain, the sub basin/basin approach and Springshed approach for the hilly terrains. The basic methodology irrespective of the scale will be the same and is schematically represented below.

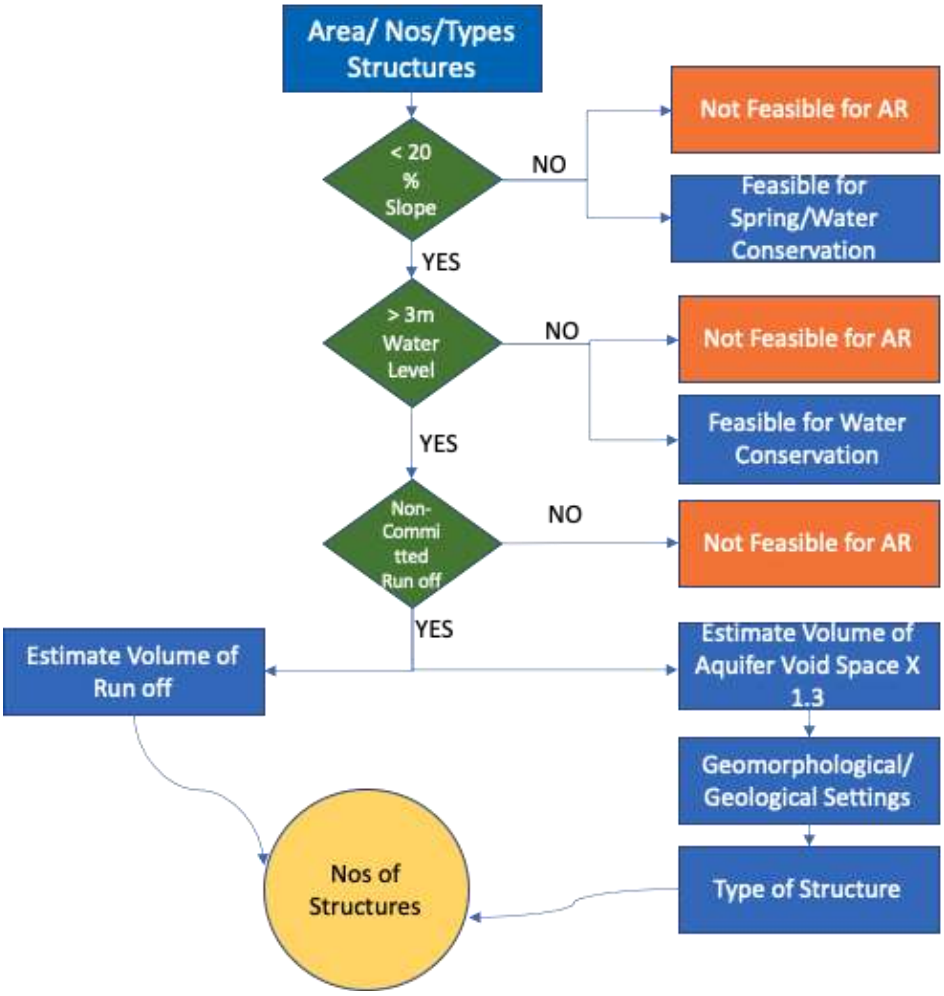
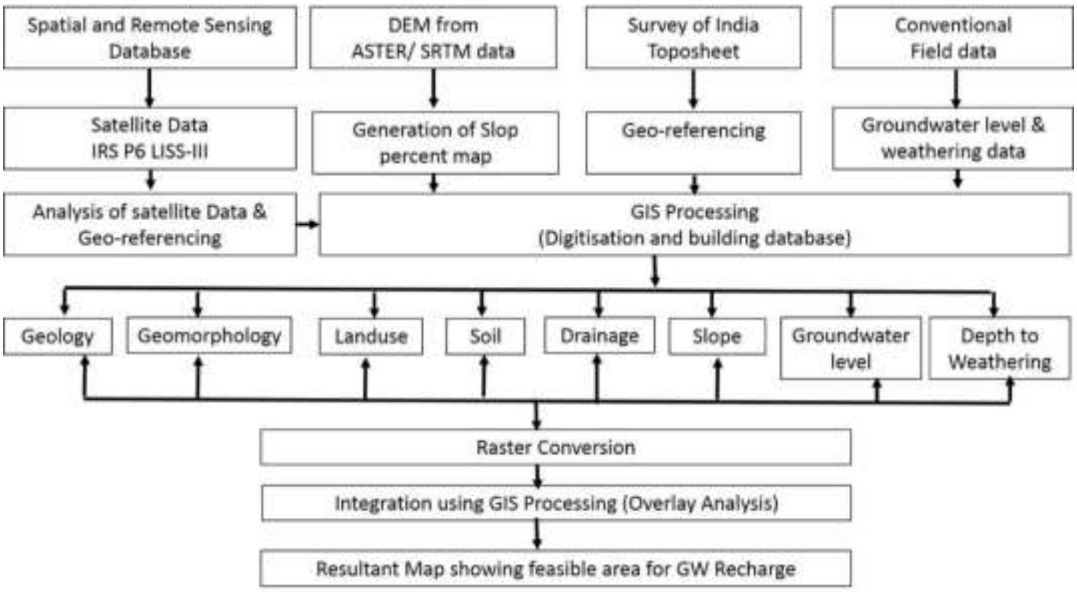


Fig. 10.1 Methodology for formulation of Master Plan

The above methodology would be able to provide broad information on the terrain condition, however the identification of feasible areas on a larger scale requires a detailed analysis of data and its collation to translate into information. There are other methods available which have been utilized for smaller area various researcher and academicians. These methods have their limited applicability due to huge data requirements in GIS forms at local scale.

10.1.1 DRASTIC GIS Models

GIS technology can be utilized effectively to identify the areas for artificial recharge. GIS based DRASTIC Model is one such tool to identify suitable areas for recharge. The acronym **DRASTIC** stands for the seven parameters used in the model which are: Depth to water, net Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone and hydraulic Conductivity. Various thematic maps provide the information on different DRASTIC parameters. A generalized methodology to be adopted in collation of data from various sources is schematically given below.



(Source: Senthilkumar etal., 2019 : https://doi.org/10.1186/s42834-019-0014-7)

The different themes are assigned weights to come out with feasible areas for artificial recharge as given below in table.

Theme	Features	Rank (in words)	Rank (in number)	Weightage
Geomorphology	Pediments-Moderate	Moderate	2	15
	Pediments-deep	Moderate	2	
	Pediment-shallow	Low	1	
	Dissected Plateaus	Very low	1	
	Valley fills	High	3	
	Bazada zone	High	3	
Land use / Land cover	Settlements	Low	1	10
	Barren land/rocky	Low	1	
	Fallow land	Moderate	2	
	Water body	High	3	
	Plantation	High	3	
	Forest	Moderate	2	
	Vegetation	moderate	2	
	Wet lands	High	3	
Soil	Clayey soil/loam	low	1	10
	Silty soil	low	1	
	Red soil	Moderate	2	
	Lateritic soil	Moderate	2	
	Gravely soil	high	3	
	Sandy loam	High	3	
Slope (%)	< 3	Nearly levelled /Very gentle	3	15
	3 to 5	Gently sloping	3	
	5 to10	Moderate	2	
	10 to 15	Moderate to steep	2	
	> 15	Steep	1	
Post monsoon Groundwater level	< 3 m bgl	No space – low	1	15
	> 3&< 6 m bgl	Moderate	2	
	> 6&< 9 m bgl	High	3	
	> 9 m bgl	Very high	3	
Geology	Charnockite	low	1	10

Theme	Features	Rank (in words)	Rank (in number)	Weightage
	Granitic Gneiss	low	1	
	BGC/BM	Low	1	
	Highly weathered Gr.gneiss	Moderate	2	
	Alluvium	high	3	
Drainage	Other regions	Low	1	10
	Drainage lines	High	3	
Weathering	> 6	Low	1	15
	6–10	Moderate	2	
	10–20	High	3	
	> 20 m	Very High	3	

(Source: Senthilkumar etal., 2019, op.cit.)

The above analysis provides suitable area for recharge considering the terrain condition & aquifer characteristics. However, the availability of source water / harnessable surplus run off needs to be linked to terrain conditions to arrive at the number of feasible structures. Inter basin/intra basin transfer can be used in case of less source water.

The effectiveness of the any artificial recharge structures will be very much enhanced, if the treatment of watershed in hard rock terrain, and treatment of springshed in hilly terrain is taken up prior to implementation of the artificial recharge projects. The treatment work will result in increased soil moisture conditions in upper reaches, which will supplement the artificial recharge works undertaken on downstream side. However, the factor of slope stability needs to kept in mind while taking up treatment work in upper reaches, so that excavation should not result in loosening up of soils leading to landslides.

The preparation of master plan should have bottom to top approach, wherein the information at the level of the watershed/sub basin/springshed is collated to get the basin wise information. In order to have administrative control over execution of schemes, the information collated on watershed/sub basin basis can also be translated at the district level and State level, as the data is being processed on GIS platform and scientific procedures are adopted in the computation of basic information.

10.1.2. NAQUIM as Input to the Artificial Recharge Plans

CGWB has taken up prestigious NAQUIM program throughout India. The objective of the NAQUIM is to provide scientific inputs for sustainable management of ground water resources in the country. The outputs of the NAQUIM are being prepared by CGWB on 1:50,000 and shared with States / UTs.

Aquifer management plans prepared under NAQUIM, propose both supply side and demand side interventions and water conservation measures are covered in supply side measures. Aquifer Management Plans prepared under NAQUIM provides the information on vertical and horizontal extent of aquifer units, available saturated aquifer thickness for developmental purposes and at the same time it also indicates available unsaturated thickness and using the storage parameters of the aquifer units, available unsaturated volume, for taking up artificial recharge studies can be worked out. These outputs have been included in NAQUIM reports and have been shared with State agencies and District Administration and also have been hosted in CGWB website. The augmentation of spring discharge is also similar to that the aquifer at depth, as most of the springs lie beneath the natural recharge area, it would be appropriate therefore to treat the natural recharge area to augment the spring discharge. These plans are being utilized by the State Agencies in siting of the recharge structures as well as implementation of other management interventions as suggested.

In the focus areas the aquifer mapping is being proposed at much finer scale i.e. 1:10,000 scale. The master plan of such areas shall be prepared on 1:10,000 and the thematic maps as listed below shall be collected/prepared.

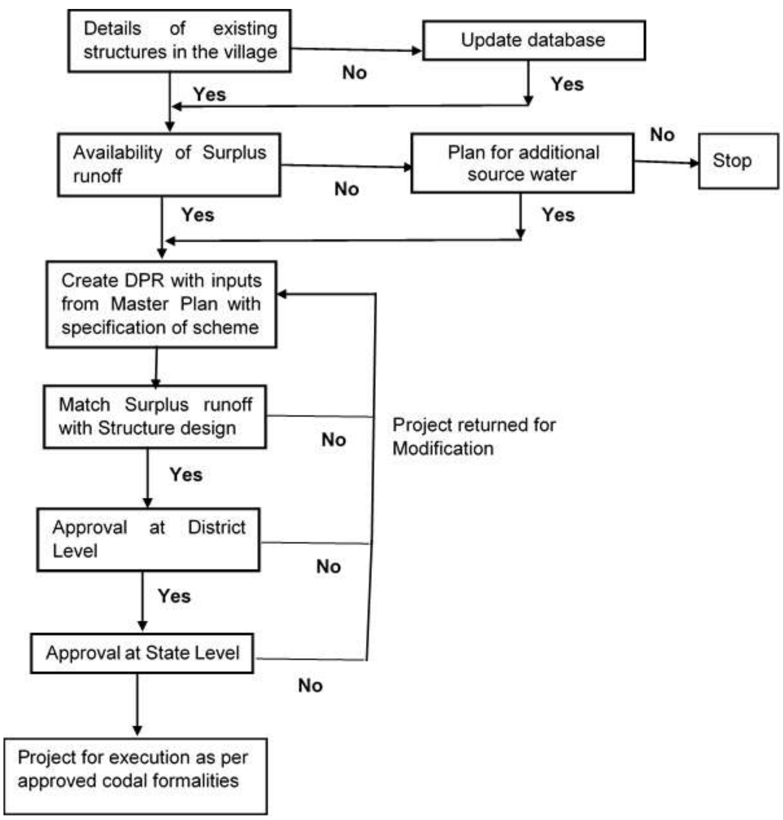
S.No	Issue	Proposed Action
1	Thematic Maps (1:10,000)	• Nomination of SLNA by every State for preparation of thematic maps • Allocation of requisite fund • Hiring of GIS Experts at District & State Levels • Focused work programme
2	Standardized database	• A Module for artificial recharge has already been prepared by NWIC and is to be tested with data by States • Creation of database by respective States through SLNA • Regular updating of database through web portal link or by SLNA

3	Frequency of Master Plan Preparation	• 05 years may be kept for revision considering,
		  • Period for execution of proposed structures
		  • Impact Assessment
		  • Updation of database

4	Linkage of NAQUIM outputs	• NAQUIM need to be completed for the whole country as envisaged in the scale of 1:50,000 • Using the technique of interpolation and additional data generation based on requirement, the aquifer maps can be refined to larger scale. • Aquifer Management Plan provides information on Aquifer Disposition and stress and combining it with source water availability, the type and number of structures can be indicated

10.2 DPR PREPARATION

The Detailed Project Report (DPR) may be prepared village wise considering the data of existing structures, availability of surplus run off and inputs from the master plan prepared with NAQUIM outputs. The process of DPR preparation is schematically presented below.



Nowadays lot of technological innovations have come up which can help in conceptualization of proposals, processing of proposals and its final implementation. Further, timely executuion of works is also very important with suitable resource/manpower interventions for which project monitoring software can also be used by states/UTs to achieve the desired outcomes.

An attempt has been made in this direction by Rajasthan to automate the DPR processing/preparation & its implementation etc by using latest technological tools. Under Mukhyamanthri Jal Swavlamban Yojna (MJSA), they have developed a web-based application for online processing of case from preparation of project proposal to approval to execution which can be studied by various states/UTs for its efficacy/usefulness.

The critical factors which can make such technological applications successful is input of data of the existing recharge structures, surplus source water availability and other thematic layers on a scale of 1: 10,000. CGWB has prepared the NAQUIM outputs at a Scale of 1:50000 in around 70 % areas of the country and also working on to reduce the scale to 1:10000 in certain water stressed Arid/Semi-arid areas. States/UTs are encouraged to use more and more CGWB data in their DPR preparations for water harvesting purposes. Needless to mention here that designating Nodal agency in each State is most essential to coordinate the various activities of water conservations in the respective State through existing schemes / programs.

10.3 INSTITUTIONAL MECHANISM

In order to have a seamless project preparation, approval and execution, there should be a committee at district and State level. The district level committee will function under District Collector and will have all the line departments executing the schemes as members with a representative from SLNA as Member Secretary. The State Level Committee will function under the Principal Secretary responsible for GW and Heads of all Line Departments in the State as members and Head of SLNA as Member Secretary. CGWB will be a member of both State & District level Level committees to provide technical guidance. The master plan revision, project preparation, approval and execution will be supervised by the State Level Committees.

10.4 DOCUMENTATION

The success of any project depends on the ability to evaluate the impact of the project and make necessary modifications to resolve any unforeseen issues, which has arisen during the execution. The proper documentation at various stages of execution and creation of robust database is the first step in the project. SLNA for each State should be made responsible for the repository and regular updation through line implementing agencies at district-level. The artificial recharge module developed by NWIC, which is in the testing stage may be utilized for the purpose. Each State needs to provide input to update the database on regular basis through designated SLNA.

10.5 CRITICAL FACTORS IN EXECUTION OF ARTIFICIAL RECHARGE PROJECTS

Government of India is aiming not only at the revision of Master plan on a larger scale but also seamless project preparation, approval and execution of artificial recharge projects. There are many critical factors, which will affect the aspirations of Government of India unless it is dealt with appropriate measures.

- Identification SLNA by each State
- Establishment of GIS Lab and provision for hiring of GIS experts for both District & State Level
- Creation of database on water conservation efforts & Regular updation of the database in the respective States.
- Allocation of fund by each State to SLNA for establishment of GIS Lab and for hiring of GIS experts for both District & State Level

- Systematic treatment of catchment of watershed, springshed through the existing schemes as precursor to taking up artificial recharge projects.
- Finding efficacy of existing recharge structures, their operation & maintenance
- Capacity building of local stakeholders on O&M structures
- Dissemination of knowledge to local public on benefits of water conservation

10.7 IMPACT ASSESSMENT

The impact of water conservation efforts on groundwater system need to be assessed so as to bring out the effectiveness of supply side interventions. Central Ground Water Board can take up the impact assessment as a third party evaluator, as the implementation is being made through State Agencies. The updation of database on artificial recharge is mandatory for talking up impact assessment and updation of database should be the responsibility of SLNA. CGWB can take up impact assessment work after one-year of completion of artificial recharge projects, if the database is regularly updated. A general guideline for impact assessment has been published by CGWB and uploaded in cgwb website (http://cgwb.gov.in/AR/Final-Guideline-IA-AR-Studies-submitted-website-hosting.pdf). The impact assessment report can be used by the State agencies to improve project formulation and execution.

Annexure 1

File No.H-11013/5/2019-GW Section 1

I/30737/2019(1)

Government of India
Ministry of Jal Shakti
Department of Water Resources, RD & GR
(Ground Water Section)

Shram Shakti Bhawan, New Delhi
Dated: 03.10.2019

ORDER

Subject: Constitution of Committee for estimation of rainwater harvesting works in different States/UTs.

Parliamentary Standing Committee in its recommendations on the subject 'Rainwater Harvesting in Metropolitan Cities' has directed for complete assessment of existing as well as likely demand of Rain Water Harvesting works along with cost involved in different States/UTs.

2. Master Plan for artificial recharge to Groundwater in India was prepared by CGWB during 2013. However, due to various artificial recharge works being undertaken by States/UTs in last five years it is felt that the Master Plan needs improvement/updation because of changed ground situation/requirements. In view of this, a committee is hereby constituted to prepare and finalize a master Plan for Artificial Recharge to Ground Water in India (both rural and urban areas) with tentative list of possible artificial recharge structures for ground water recharge with tentative cost on pan-India basis. The composition of the committee shall be as under:

1.	Sh Sunil Kumar, Member, CGWB	Chairman
2.	Dr S Suresh Kumar, Scientist 'D', CGWB	Member Secretary
3.	Director level officer of CWC (as nominated by Chairman, CWC)	Member
4	Sh M K Garg, Scientist 'D', CGWB	Member
5	Sh N C Naik, Scientist 'D', CGWB	Member
6.	Representative of NIH, Roorkee	Member
7.	Representative of Ministry of Housing & Urban Affairs (MoH&UA)	Member
8.	Representative of Ministry of Rural Development	Member
9.	Representative of Water Resources Department/concerned Department of the concerned State/UT	Member
10.	Concerned Regional Director of the CGWB	Member

The committee may co-opt any other Member(s) including maximum two non-official members proficient in the field of ground water related matter and having work experience of not less than twenty five years in the field.

3. The Term of Reference of the committee shall be as under:

i. To prepare a detailed report for creation of possible artificial recharge structures and its expected benefits based on similar works carried out by CGWB in the past.

ii. Finalization of tentative list of artificial recharge structures with types of structures (through MGNREGS funds or, otherwise) on pan-India basis.

iii. To work out the tentative cost of structures keeping the current market price in view.

iv. To finalize consolidated cost of structures on pan-India basis with tentative expected outlays

Annexure 1 (Contd…)

File No.H-11013/5/2019-GW Section

I/30737/2019(1)

from various existing Government schemes (both Central State).

4. The Committee will submit its report by **31st December, 2019.**

5. Expenditure on account of TA DA to official Members of the Committee will be met from the source from which they draw their salaries and that of non-official Members (if any), will be borne by the Central Ground Water Board as per extant provisions of Department of Expenditure, Ministry of Finance.

6. This issues with the approval of Secretary (WR, RD & GR).

(Arun Kumar Gurung)
Under Secretary (GW)

To

1. Secretary, MoH & UA, New Delhi
2. Secretary, Ministry of Rural Development, New Delhi
3. Chief Secretary, all the States/UTs
4. Chairman, CWC, New Delhi.
5. Chairman, CGWB, New Delhi
6. Director, NIH

Copy to:

1. PPS to Secretary (WR, RD & GR)
2. PPS to AS(WR)
3. PPS to JS&FA
4. PPS to Joint Secretary (IC & GW)
5. PPS to JS(Admn)
6. PS to Director (GW)

Signature Not Verified

Digitally signed by ARUN KUMAR GURUNG
Date: 2019.10.03 11:52:51 IST

Annexure 2

Minutes of Meeting

A meeting of the committee constituted for estimation of rainwater harvesting works in different States was convened on 28.05.2020 at 11.30 Hrs through VC. The revised master plan had been prepared with the data obtained from State agencies and the report was shared with all State Agencies. The meeting was convened to discuss about the agreement of State Agencies for the plan and suggestions if any for refinement. The meeting was attended by 82 Officers from State & Central Agencies and the list is given as Annexure.

The meeting started with introductory note by Member, CGWB & Chairman of the committee briefly explaining the mandate of the committee, thereafter a presentation was made on the revision of Master Plan. The presentation was divided into four parts, viz. background information, methodology, National Scenario & State wise Scenario and deliberation was held after each part and in State wise scenario, concerned, RD & State counter parts participated in the discussion. Finally, the Members from Central Agency put forth their opinions/suggestions. The suggestions from the State & central agency are given below.

AP	The State representative requested to revise the norm of area identification of recharge area from earlier to >5m used in the revised plan to >3m. Consequently, the area, number and cost need to be revised. It was agreed that report portion will be revised and submitted for inclusion by 30.05.2020
Gujarat	Additional Secretary, WR Department, Gujarat informed that the report was prepared in consultation with GWRDC, which is a corporation and WR Department, Gujarat is pure Govt. agency and the report needs to be studied by them. RD, CGWB was advised to discuss the matter with WR Department and submit the report with the consent of WR department within 2-3 days.
J& K, Meghalaya Uttarakhand	The State agency requested to revise the unit Cost for the structures and informed that the cost would be revised and RD would submit the revised report by 30.05.2020
Telangana, Maharashtra & TN	The State representative suggested that a provision may be made for repair & renovation of already constructed structures, similar to RRR. CWC suggested that proposal may be submitted to CWC under RRR or alternatively, it may be adjusted in other schemes. Many States have already included desilting and repair of existing water bodies.
Punjab	The man power constraints were discussed for construction and maintenance of structure. It was informed to the Member that it is a plan only and any scheme during execution will take care of the constraints. RD is advised to revise the report and send it by 29.05.2020.
Arunachal Pradesh	NE States was found missing in the Table of Content of the report and may be included. It was informed that needful will be done.
UP	The water level more than 5m has been considered and Director, UP GW Department, requested that criteria be revised to more than 8m. The matter deliberated and was informed that presently 5m may be kept as it is and later can be revised if required.
WB	Rd informed that the issues raised by the State agency has been discussed and resolved and revised report will be sent by 29.05.2020
Chandigarh	The proposed injection wells are for shallow aquifer and State agency wanted the deeper aquifer to be recharged through injection well. RD to discuss and resubmit the revised plan by 30.05.2020
NIH	Minor corrections suggested and will be incorporated.
CWC	Surplus Water Availability may be checked, Caution to be exercised while constructing AR structures in catchment areas of Big Dams. It was informed that matter will be taken into consideration.

Rest of the States had expressed their consent for the report. The following decisions were taken after lots of deliberations.

1. The committee approves the report for submission to DoWR, RD & GR, after incorporating the corrections suggested by respective States.
2. Each State may nominate a Nodal Agency, for maintaining the data base and documentation of water conservation efforts being undertaken by the respective States and Nodal Agency will remain a focal point for contact in respect of water conservation in the States.

The meeting ended with acknowledgement of all officers who had been involved in the revision of the Master Plan and with thanks to the Chair.

Annexure 2 (Contd…)

List of participants

Members:

Shri. Sunil Kumar, Member (HQ), CGWB, CHQ, Faridabad- In Chair

State Name	CGWB	State Department /Central Agency
Uttar Pradesh	1. Shri P.K.Tripathi, Head of Office, NR	2. Shri V.K.Upadyaya, Director, GW Department, UP
Uttarakhand	3. Dr. Waseem Ahmad , Head of Office, UR, Dehradun	4. Sri Mukesh Mohan, E & C, Deptt of Irrigation, Govt. of Uttarakhand
West Bengal	5. Shri Amlanjyoti Kar, Head of Office, ER, Kolkata	6. Smt Aparna Samaddar, Suptg. Engineer(A-I), IP & D Circle, SWID, West Bengal
A&N Island		
Sikkim		
Bihar	7. Shri A. K. Agarwal, Regional Director MER, Patna	
Jharkhand	8. Shri G.K. Roy, Head of Office, SuO, Ranchi	
Chhattisgarh	9. Dr.S.K.Samanta, Head of office, NCCR, Raipur	10. Sh. Ajay Thakur, Suptg. Engineer, Ground Water Survey & Water Resources Circle, WRD, Raipur
Assam	11. Shri Biplob Roy, Head of Office, NER, Guwahati	No State Representative
Arunachal Pradesh		12. Er L. Angu, Chief Engineer, WRD, Itanagar
Tripura		
Manipur		
Nagaland		
Mizoram		
Meghalaya		13. Er. Law, Chief Engineer, WRD,WRD, Shillong
Odisha	14. Shri P.K. Mohapatra, Head of office, SER, Odisha	15. Shri. Pravash Chandra Pattnaik,Director,GWD. Govt. of Odisha
Jammu & Kashmir	16. Shri Ashok Kumar, Head of Office, NWHR, Jammu	17. Er. M.S.Khorana, EE(GW), Jal Shakti Dept. Jammu Division.J&K
Madhya Pradesh	18. Shri. P.K.Jain, Head of Office, NCR, Bhopal	19. Dr Sashikant Dhanoria, Scientific Officer, State GW Data Centre, Bhopal
Himachal Pradesh	20. Shri O. N. Tiwari, Head of office, NHR, Dharamshala	21. Shri Anil Jaswan , EE, Jal Shakti Department, Government of HP
Haryana	22. Shri Anoop Nagar , Regional Director, NWR, Chandigarh	23. Sh. Rakesh Kumar, Chief Hydrogeologist, Agriculture & FW Deptt, Haryana
Punjab		24. Sh. Singla, Director, Punjab Water Resources
Chandigarh		25. Sh. Shailender Singh, Chief Engineer, MC, Chandigarh
Maharashtra	26. Shri P K Jain ,Head of Office, CR, Nagpur	27. Dr. Vijay Pakmode, Deputy Director, GSDA, Pune
Dadra & Nagar Haveli		
Karnataka	28. Shri V.Kunhambu ,Regional Director, SWR, Bangalore	29. Sh. H Raveendrappa, Chief Engineer & Director, GWD, Govt. of Karnataka
Goa		No State Representative
Tamil Nadu	30. Shri Paul Prabhakar, Regional Director, SECR, Chennai	31. Shri Raja, EE, SGSWRDC, PWD, Govt. of TN
Puducherry		32. Shri S.Manohar, Hydrogeologist 1, SGU & SC, Department of Agriculture, Govt. of Puducherry
Andhra Pradesh	33. Shri D Subba, Rao, Regional Director SR, Hyderabad	34. Sh. Purushotham Reddy, Director, GWD, Govt. of A.P
Telangana		35. Dr. Pandith Madhnure, Director, GWD, Govt. of Telangana

Annexure 2 (Contd…)

State Name	CGWB	State Department /Central Agency
Kerala	36. Shri. Subbu Raj, Head of Office, KR, Trivendrum	37. Smt. Ancy Joseph, Suptg. Hydrogeologist, GWD, Kerala
Lakshadweep		38. Shri Shajahan, Suptg. Engineer, PWD
Delhi	39. Shri. S.K.Junejha, Head of Office, SUO, New Delhi	40. Sh. Rakesh Sahni, Chief Engineer(Water Bodies),Delhi Jal Board
Gujarat	41. Shri. Sourabh Gupta, Head of office, WCR, Ahmadabad	42. Dr. Dhinant B.Vyas, Additional Secretary, GWRD, Govt. of Gujarat
Daman & Diu		No State Representative
Rajasthan	43. Dr. S. K. Jain, Regional Director WR, Jaipur	44. Sh. Gopal Sharma, Supt. Hg., GWD, Jaipur
CHQ	45. Dr S.Suresh, Suptg. HG & Member Secretary 46. Shri M.K.Garg, Scientist-D	47. Shri Dorje, Director, CWC 48. Dr Sumant Kumar, Scientist-D, NIH

Other Participants

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