MANUAL ON AQUIFER MAPPING

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GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES
CENTRAL GROUND WATER BOARD

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1.INTRODUCTION

India is the second most populous country in the world, with a population exceeding 1.2 billion and has an agriculture-based economy. It has 2.45 % of the total land area of the world, 16% of the world population and is estimated to be endowed with about 4% of its water resources. Annual average rainfall in the country is 1170 mm, which corresponds to annual precipitation, including snowfall of about 4000 billion cubic meters (bcm). Out of this, about 1869 bcm is estimated as the average annual potential flow in rivers. On account of various constraints, only about 1122 bcm of water is assessed as the annual utilizable water, having surface water resources component of 690 bcm and ground water component of 433bcm.

Rapid expansion in the use of ground water, primarily for irrigation, has contributed significantly to its agricultural and economic development. The irrigation potential created from ground water has increased from 6.50 Million hectares (m.ha.) in 1950 to about 70 m.ha.at present. The net area irrigated by different sources in the country has increased from 22.80 m ha during 1955-56 to about 60.20 m ha (provisional) during 2005-06. A comparative study of the percent area irrigated by surface water sources (including Canals, tanks and other sources) and the ground water sources (tube wells and other wells)indicates that ground water has been the major source of irrigation in the country since the 1970s. Average area irrigated from surface water sources has decreased from about 70 percent during1955-65 to about 40 percent in 1996-2005, whereas area underground water irrigation has registered an increase from 30 percent to about 60 percent during the period. It is seen that ground water has been the major source of irrigation in India from 1976-77 onwards and the difference in the area irrigated by surface and ground water has since been steadily.

India is a vast country with a large number of distinct hydrogeological settings. The occurrence and movement of ground water in various aquifer systems are highly complex due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Two broad groups of water bearing formations have been identified depending on their hydraulic properties, Viz.*Porous Formations* which can be further classified into unconsolidated and semi consolidated formations having primary porosity and*Fissured Formations* or consolidated formations which are characterized by the absence of primary porosity.

1.1 Ground Water Occurrence:

Physiographic and geomorphologic settings are among the important factors that control the occurrence and distribution of ground water. Based on these factors, the country has been broadly divided into five distinct regions viz. Northern Mountainous Terrain and Hilly areas, Indo-Gangetic-Brahmaputra Alluvial Plains, Peninsular Shield Area, Coastal Area and Cenozoic Fault Basin & Low Rainfall Areas. The ground water regime shows marked variations in these regions. The highly rugged mountainous terrain in the Himalayan region in the northern part of the country extending from Kashmir to Arunachal Pradesh, is characterized by steep slopes and high runoff. Though this area offers very little scope for groundwater storage, it acts as the major source of recharge for the vast Indo-Gangetic and Brahmaputra alluvial plains.

The Indo-Ganges- Brahmaputra Alluvial Plains, covering the states of Punjab, Haryana, Uttar Pradesh, Bihar, Assam and West Bengal has a vast and thick alluvial fill, exceeding 1000 m at places, constituting the most potential and productive ground water reservoir in the country. Ground water development in this region is still sub-optimal, except in the states of Haryana and Punjab. The deeper aquifers available in these areas offer good scope for further exploitation of ground water. The Peninsular Shield is located south of Indo-Gangetic-Brahmaputra plains and consists mostly of consolidated sedimentary rocks, *Deccan Trap* basalts and crystalline rocks in the states of Karnataka, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa and Kerala. Occurrence and movement of ground water in these formations are restricted to weathered residuum and interconnected fractures at deeper levels and have limited ground water potential. Coastal tracts have a thick cover of alluvial deposits of Pleistocene to Recent age and form potential multi- aquifer systems in the states of Gujarat, Kerala, Tamil Nadu, Andhra Pradesh and Orissa. However, inherent quality problems and the risk of seawater ingress impose severe constraints in ground water development from these aquifers. The Cenozoic Fault basins have been grouped separately owing to its peculiarity in terms of presence of three discrete fault basins, the *Narmada, Puma* and *Tapti* valleys, all of which contain extensive valley fill deposits. The aquifer systems in arid and semi-arid tracts of this region in parts of Rajasthan and Gujarat receive negligible recharge from the scanty rains and the ground water occurrence in these areas is restricted to deep aquifer systems, most of them tapping fossil water.

1.2 Ground Water Development Scenario:

Rainfall is the major source of ground water recharge in India, which is supplemented by other sources such as recharge from canals, irrigated fields and surface water bodies. A major part of the ground water withdrawal takes place from the shallow unconfined aquifers, which are also the active recharge zones and holds the dynamic ground water resource. The dynamic ground water resource in the active recharge zone in the country has been assessed by Central Ground Water Board jointly with the concerned State Government authorities. The assessment has been carried out with *Block/Mandal/TalukafWalershed* as the unit and as per norms recommended by the Ground Water Estimation Committee (GEC)-1997. As per the latest assessment, the annual replenishable ground water resource in this zone has been estimated as 431 billion cubic meter (bcm) as in March 2009, out of which 396 bcm is considered to be available for extraction for various uses after keeping 35 bcm for natural discharge during non-monsoon period for maintaining environmental flows in springs, rivers and streams (Central Ground Water Board, 2011).

Ground water extraction for various uses and evapotranspiration from shallow water table areas constitute the major components of ground water extraction (draft). In general, the irrigation sector remains the main consumer of ground water. The ground water extraction for the country as a whole has been estimated as 243 bcm as in March 2009 (Central Ground Water Board, 2011), about 91 percent of which is utilized for irrigation and the remaining 9 percent for domestic and industrial uses. Hence, the stage of ground water development, computed as the ratio of ground water draft to total replenishable resource, works out as about 61 percent for the country as a whole. However, the development of ground water in the country is highly uneven and shows considerable variations from place to place.

As a part of the resource estimation following the GEC norms, the assessment units have been categorized based on the stage of ground water development and long term declining trend of ground water levels. As per the assessment, out of the total of 5842 assessment units in the country, ground water development was found to exceed 100 % of the natural replenishment in 802 units, which have been categorized as 'Over-exploited'. Ground water development was found to be to the extent of 90 to 100 percent of the utilizable resources in 169 assessment units, which also showed significant decline of ground water levels during pre- and post-monsoon periods. These units have been categorized as 'Critical'. 523 assessment units with stage of ground water development in the range of 70 to 100 % and long-term decline of water levels either during pre- or post-monsoon period have been categorized as 'Semi-Critical' and 4277 assessment units with stage of ground water development below 70% have been categorized as 'Safe'. 71 assessment units have been excluded from the assessment due to salinity of ground water in the aquifers in the dynamic zone.

1.3 What is Aquifer Mapping?

Aquifer mapping can be defined as a scientific process, wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the potability of ground water. Results of these studies will contribute significantly to resource management tools such as long-term aquifer monitoring networks and conceptual and quantitative regional ground-water-flow models used planners, policy makers and other stakeholders.Aquifer mapping at the appropriate scale can help prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development in the country as a whole. Various on-going activities of Central Ground Water Board, such as ground water monitoring, ground water resource assessment, artificial recharge and ground water exploration in drought, water scarcity and vulnerable areas can also be also integrated in the aquifer mapping project.

1.4 Need for Aquifer Mapping

Various development activities over the years have adversely affected the ground water regime in many parts of the country. There is a need for scientific planning in development of ground water under different hydrogeological situations and to evolve effective management practices with involvement of community for better ground water governance. Though a vast amount of hydrological and hydrogeological data have been generated through scientific investigations by Central Ground Water Board and other Central/State agencies, these mostly pertain to administrative units and have addressed the issues of the whole aquifer systems in very few cases. In view of the emergent challenges in the ground water sector in the country, there is an urgent need for comprehensive and realistic information pertaining to various aspects of ground water resources available in different hydro-geological settings through a process of systematic data collection, compilation, data generation, analysis and synthesis.

1.5 International Practices

Understanding the importance of sustainable management of ground water resources, several countries have taken up and completed mapping of important aquifer systems. The best known and documented example is that of the USA, where the United States Geological Survey (USGS) has mapped the aquifer systems in the entire country. The aquifer map shows the distribution of the principal aquifers that supply ground water to the coterminous States (commonly called the "lower 48 states"). The aquifer that is shown in each geographic area is generally the uppermost principal aquifer for the area. Each principal aquifer is classified as one of six types of permeable geologic material, viz., unconsolidated deposits of sand and gravel, semi consolidated sand, sandstone, carbonate rocks, inter-bedded sandstone and carbonate rocks, and basalt / other types of volcanic rock. In the State of New Jersey, New Jersey Geological Survey (NJGS) has recently developed a method for delineating aquifer recharge areas by computing the quantum of ground water recharge by integrating data on rainfall, land use, soil types and surface water. The agency is currently engaged in mapping aquifer recharge areas for the State's priority watershed areas.

In Australia, a national geospatial storage and interpretation system for all hydrologic data is being prepared under an initiative known as "Australian Hydrological Geospatial Fabric" or “Geofabric” in short. Geofabric is part of a project called AWRIS aimed at providing nationwide information on water availability, water quality and water usage. The Project envisages collection, integration and organization of spatial ground water data sets produced from available source data sets pertaining to aquifer boundaries, extents, structural contours, ground water quality, hydraulic characteristics etc.

In Canada, aquifers of British Columbia region have been mapped. These maps are on 1:50,000 scale and have been prepared on the basis of surface geology maps and borehole logs. Only those aquifers which are being developed are depicted on the maps and sections are drawn to depict sub-surface aquifer disposition wherever data is available. The maps also come with a disclaimer stating that absence of mapped aquifer in an area does not mean absence of aquifers but that sufficient data is not available to delineate and classify aquifers in that area.

In the United Kingdom, Ground water Protection Policy uses aquifer designations that are consistent with the Water Framework Directive. These designations reflect the importance of aquifers in terms of groundwater as a resource (drinking water supply) but also their role in supporting surface water flows and wetland ecosystems. The aquifer designation data is based on geological mapping provided by the British Geological Survey. It will be updated regularly to reflect their ongoing programme of improvements to these maps.

1.6 Ground Water Studies and Aquifer Mapping in India

Systematic studies of aquifers and ground water resources in India began the Nineteen Fifties when ground water was considered as a source for supplementing surface water resources for developing additional irrigation potential in the country. It was then that the Exploratory Tube Well Organization (ETO) was formed to identify suitable sites and drilling of tube/bore wells for developmental purposes, while the Ground Water Wing of the Geological Survey of India carried out ground water exploration in different parts of the country. These two organizations were merged into a single entity named Central Ground Water Board in 1972, with a mandate to "Develop and disseminate technologies, and monitor and implement national policies for the scientific and sustainable development and management of India's ground water resources, including their exploration, assessment, conservation, augmentation, protection from pollution and distribution, based on principles of economic and ecological efficiency and equity".

Over the years, Central Ground Water Board has been taking up hydrogeological studies aimed at deciphering the extents, characteristics, yield potentials and development prospects of important hydrogeological units in the country. These studies were aided and supplemented by exploratory drillingactivities, surface and sub-surface geophysical investigations and ground water quality analyses. These activities resulted in the identification and demarcation of various hydrogeological units suitable to be developed supplement the surface water sources. A number of projects were taken up in major basins of

India in collaboration with international agencies to carry out the water balance studies in which groundwater regime‟ of aquifers and its development prospects were studied.

With the increasing development of ground water resources to meet rising demands and consequent adverse environmental impacts, the emphasis of hydrological studies of CGWB gradually shifted from development to management aspects from early Nineties. This led to the expansion of activities of CGWB into studies related to ground water augmentation, regulation and integrated water resources management through conjunctive use of surface and ground water resources. Realization of the importance of stakeholder participation in effective ground water management also led to an increase in IEC activities of the Board. In the last decade or so, various activities of CGWB have had „sustainable ground water resource management‟ as the focal theme.

As far as maps depicting aquifers are concerned, the first map on Hydrogeology was published by Geological Survey of India in 1969 under the title "Geohydrological Map of India" on 1: 2Million scale. Subsequently, CGWB published "Hydrogeological Map of India" on 1:5 Million scale with the data updated from the work of CGWB. On the basis of surveys, exploration and special studies undertaken, Central Ground Water Board published its first edition of Hydrogeological Map of India 1:2 Million scale in 1985 and its second edition in 2001. Based on stratigraphy, with the data available at that time, 9 major aquifers (hydrogeological units) were depicted in the map.

Subsequently, realizing the increasing importance of ground water as a source of fresh water in the country and in view of the increasing stress on the available resources, the need for demarcation of aquifer units on a larger scale and formulate strategies for their sustainable development was increasingly being felt. This led to the updating of the database of CGWB with data available from the scientific investigations of its own and of various other organizations, which enabled the Board to come out with the first Aquifer Map of the country on 1: 250,000 scale with 14 Principal Aquifer Systems, further classified into 42 major aquifers in the first phase.However, mapping of these aquifer systems at scales of 1: 50,000 or larger is considered necessary for planning their sustainable development with stakeholder participation, for which the current programme of National Aquifer Mapping has been launched. The Board has also initiated 5 pilot aquifer Mapping projects concurrently with the National Aquifer Mapping in different hydrogeological environs of the country covering coastal, hard rock, basaltic, desert and alluvial terrains to determine the efficacy of application of various geophysical tools and to finalize the protocol for application of various geophysical tools to aid hydrogeological investigations in National Aquifer Mapping.

1.7 Scope and Lay-out

Systematic mapping of an aquifer encompasses a host of activities such as collection and compilation of available information on aquifer systems, demarcation of their extents and their characterization, analysis of data gaps, generation of additional data for filling the identified data gaps and finally, preparation of aquifer maps at the desired scale. This manual attempts to evolveuniform protocols for these activities to facilitate their easy integration for the country as a whole.

This manual has been divided into 6 chapters. A brief introduction on the ground water occurrence and development scenario, need for aquifer mapping, international practices of aquifer mapping and the present status of ground water studies and aquifer mapping initiatives has been given in Chapter – 1. Chapter -2 of the manual deals with the basics of aquifer mapping, with details of aquifer systems in India, approach and methodology of National Aquifer Mapping Program, its expected outputs and outcomes and implementation mechanism. Various aspects of collection, compilation and processing of available data are described in Chapter-3. Detailed procedure of data gap analysis in the context of aquifer mapping is given in Chapter-4. Salient features of data generation for filling up data gaps with regard to important components of aquifer maps are elaborated in Chapter-5. The final chapter (Chapter-6) of the manual deals with the detailed methodology for aquifer map preparation, composition, printing and data storage.

2. BASICS OF AQUIFER MAPPING

2.1 Introduction

As mentioned in the previous chapter, Aquifer Mapping is an attempt to combine a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. The major objectives of aquifer mapping are

- Delineation of lateral and vertical disposition of aquifers and their characterization on 1: 50,000 scale in general and further detailing up to 1: 10,000 scale in identified priority areas.
- Quantification of ground water availability and assessment of its quality to formulate aquifer management plans to facilitate sustainable management of ground water resources at appropriate scales through participatory management approach with active involvement of stakeholders.

2.2 Aquifer Systems of India

The National Atlas on Aquifer Systems of India on 1: 250,000 scale, compiled by Central Ground Water Board in 2012 will form the base for the current programme of National Aquifer Mapping. A total of 14 principal Aquifers have been identified in the National Atlas, which have further been segregated into 42 major aquifers (Table.2.1, Fig.1 &2))

Table 2.1: Principal and Major Aquifer Systems of India (CGWB 2012)

SI.No	**Principal Aquifer System**		**Major Aquifer**	Name	Age
	Code	Name	**Code**		
1	AL	Alluvium (945753 Sq km) (29.82 %)	**AL01**	Younger Alluvium (Clay / Silt / Sand / Calcareous concretions)	**Quaternary**
2			AL02	Pebble / Gravel/ Bazada/ Kandi	
3			AL03	Older Alluvium (Silt / Sand/ Gravel / Lithomargic clay)	
4			AL04	Aeolian Alluvium (Silt/ Sand)	
5			AL05	Coastal Alluvium (Sand / Silt / Clay)	
6			AL06	Valley Fills	
7			AL07	Glacial Deposits	
8	**LT**	Late rite (40925 Sq km) (1.29 %)	**LT01**	Laterite / Ferruginous concretions	
9	**BS**		**BS01**	**Basic Rocks (Basalt)**	**Mesozoic**

10			**BS02**	**Ultra Basic**	**To Cenozoic**
11	ST	Sandstone (260415 sq km) (8.21 %)	ST01	Sandstone/Conglomerate	Upper Palaeozoic To Cenozoic
12			ST02	Sandstone with Shale	
13			ST03	Sandstone with shale/ coal beds	
14			ST04	Sandstone with Clay	
15			ST05	Sandstone/Conglomerate	Proterozoic To Cenozoic
16			ST06	Sandstone with Shale	
17	SH	Shale (225397 Sq km) (7.11%)	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic
18			SH02	Shale with Sandstone	
19			SH03	Shale, limestone and sandstone	
20			SH04	Shale	
21			SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic
22			SH06	Shale with Limestone	
23	LS	Limestone (62898 Sq km) (1.98 %)	LS01	Miliolitic Limestone	Quaternary
24			LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic
25			LS03	Limestone/Dolomite	Proterozoic
26			LS04	Limestone with Shale	Proterozoic
27			LS05	Marble	Azoic to Proterozoic
28	GR	Granite (100991 Sq km) (3.18 %)	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)	Mesozoic to Cenozoic
29			GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.)	Proterozoic to Cenozoic
30	SC	Schist (140934.90 Sq.km) (4.44%)	SC01	Schist	Azoic to Proterozoic
31			SC02	Phyllite	Azoic to Proterozoic
32			SC03	Slate	Azoic to Proterozoic

33	QZ	Quartzite (46904 Sq. km) (1.48%)	QZ01	Quartzite	Proterozoic to Cenozoic
34			QZ02	Quartzite	Azoic to Proterozoic
35	CK	Charnockite (76359 Sq km) (2.41%)	CK01	Charnockite	Azoic
36	KH	Khondalite (32913 Sq km) (1.04 %)	KH01	Khondalites, Granulites	Azoic
37	BG	Banded Gneissic Complex (478382 Sq km) (15.09 %)	BG01	Banded Gneissic Complex	Azoic
38	GN	Gneiss (158753 sq km) (5.01 %)	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic	Azoic to Proterozoic
39			GN02	Gneiss	Azoic to Proterozoic
40			GN03	Migmatitic Gneiss	Azoic
41	IN	Intrusive (19895 Sq km) (0.63 %)	IN01	Basic Rocks (Dole rite, Anorthosite etc.)	Proterozoic to Cenozoic
42			IN02	Ulrta Basics (Epidiorite, Granophyre etc.)	Proterozoic to Cenozoic

Under the National Aquifer Mapping Program, proposed to be taken up by Central Ground Water Board in the 12th and 13th Plan periods, It is proposed to generate aquifer maps on 1:50 000 scale for the country as a whole and on 1:10,000 scale in identified problematic areas. This exercise shall result in the demarcation of several smaller mappable aquifer units within the identified Principal/Major Aquifer Systems. It is envisaged to name the aquifers with local names for easier identification and understanding by the local stake holders.

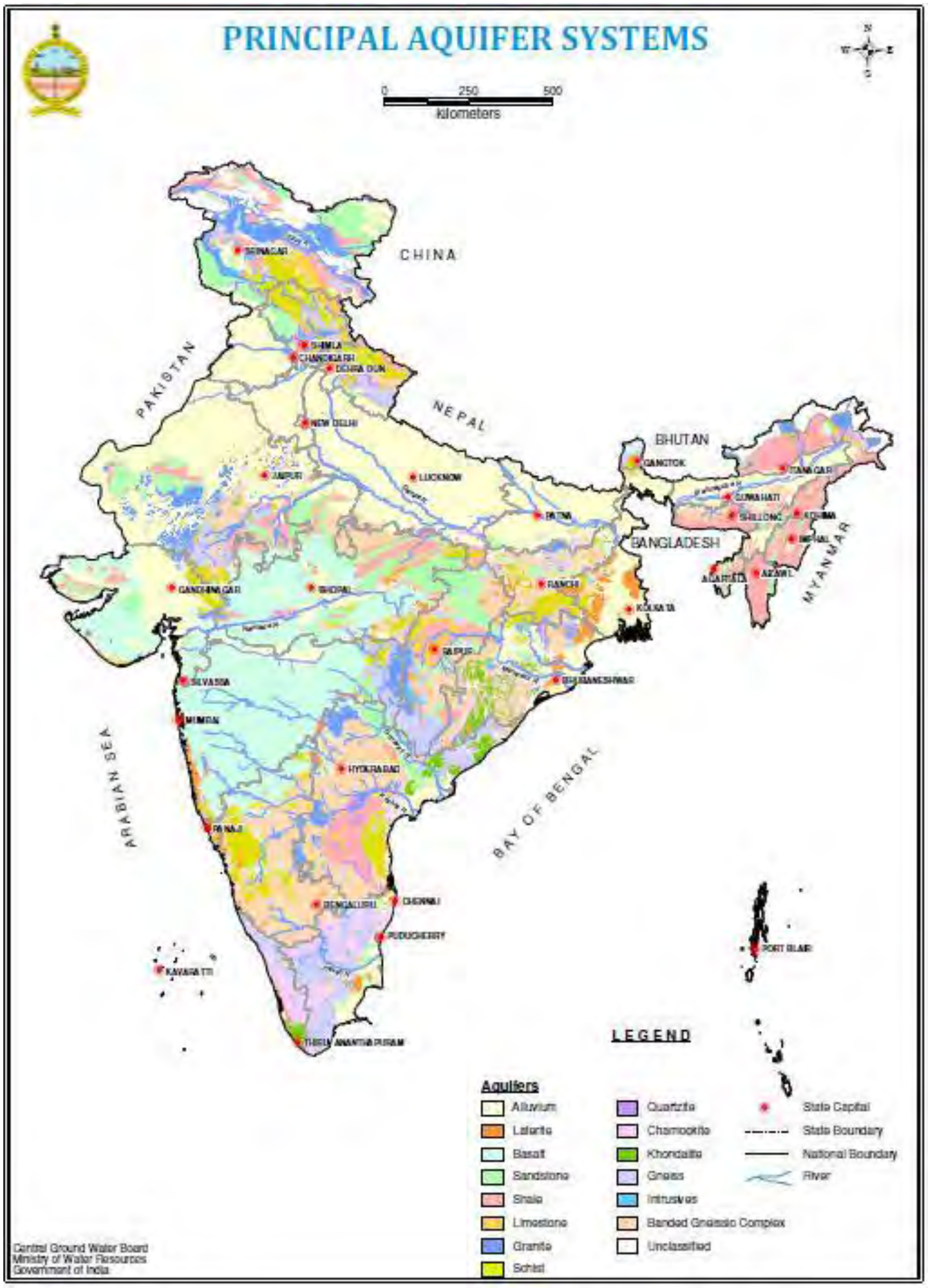


Fig.2.1: Principal Aquifer Systems of India

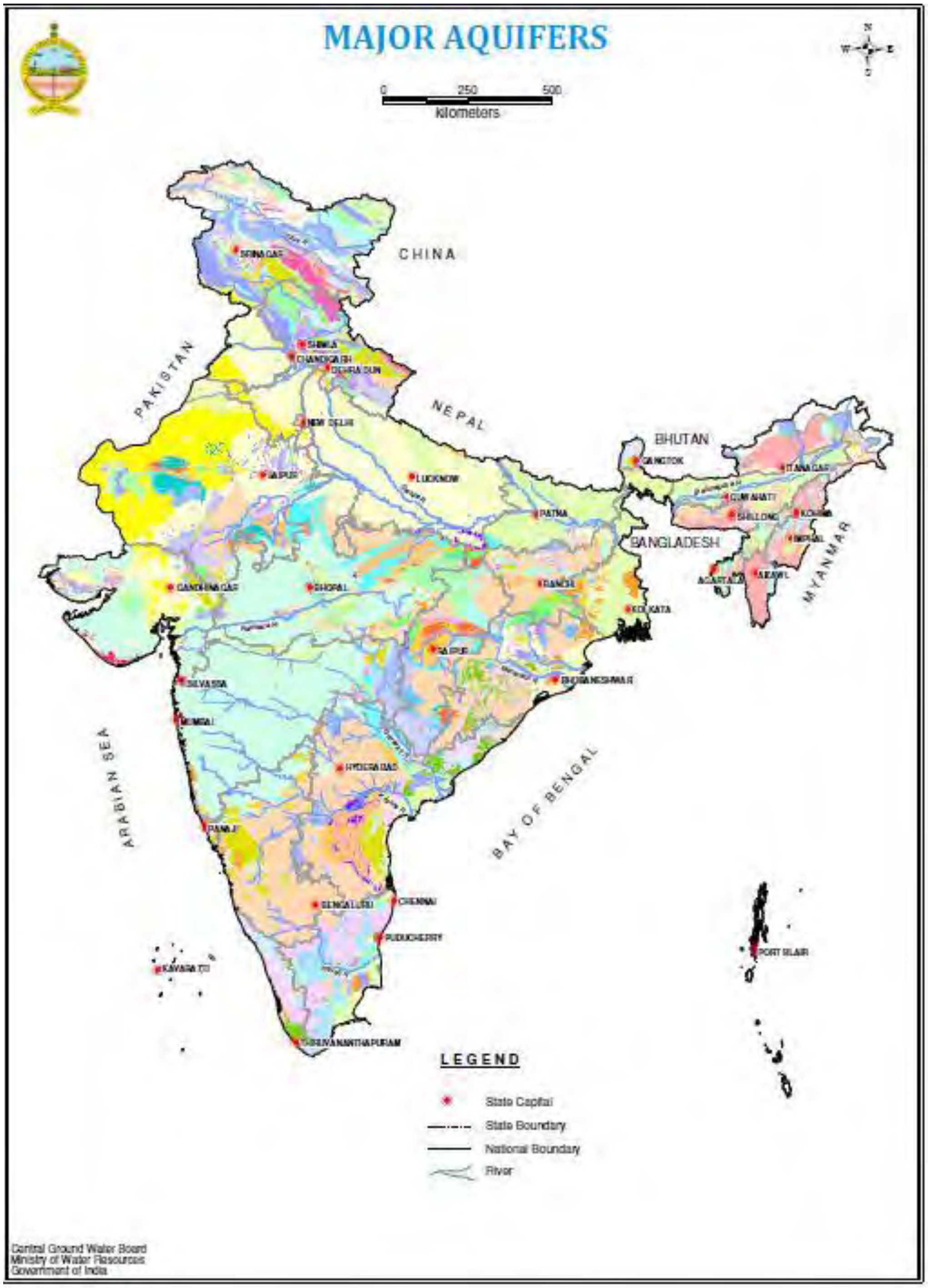


Fig.2.2: Major Aquifers of India

2.3 Approach and Methodology

National Aquifer Mapping Programme basically aims at characterizing the geometry, parameters, behavior of ground water levels and status of ground water development in various aquifer systems to facilitate planning of their sustainable management. The major activities involved in this process include compilation of existing data, identification of data gaps, generation of data for filling data gaps and preparation of aquifer maps. The overall methodology of aquifer mapping is presented in **Figs.2.3**. Once the maps are prepared, plans for sustainable management of ground water resources in the aquifers mapped shall be formulated and implemented through participatory approach involving all stakeholders.

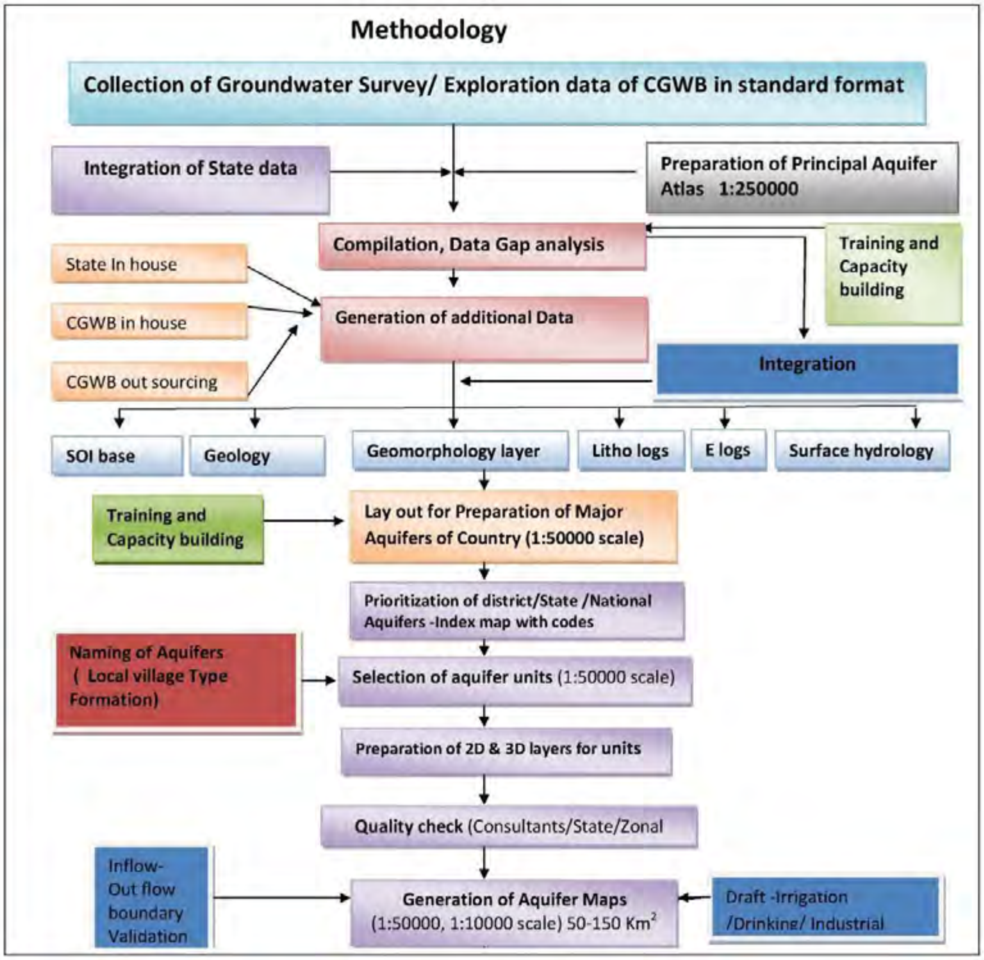


Fig.2.3: Methodology of Aquifer Mapping

2.4 Outputs

The Outputs of Aquifer mapping will be both scientific and social. Some of the Scientific Outputs include:

- **Disposition of Water Bearing Formations**
    - Surface outcrops.
    - Subsurface continuity in vertical and horizontal disposition.
    - Overlay of different litho-units to form a group & aquifer system, E.g. - Alluvium - Gravel, sand, silt & clay in different percentage underlain by compact Sandstone,/shale, hard rock etc.

- **Water Bearing Capacity**
  - Variations with depth
  - Changes in space and time
  - Demarcation of runoff zones, recharge zones and discharge zones
  - Status of ground water abstraction
- **Aquifer (formation water) Quality**
  - In-situ (depositional)
  - Anthropogenic
  - Vertical zonation
  - Blending/Migration of pollutants in aquifers with time
- **Strategies for Sustainable Management**
  - Quantification of water within different layers (Aquifers- 1,2 3 etc)
  - Quality in each aquifer (group)
  - Demand-Supply analysis
  - Estimation of prevailing Development Status
  - Precise assessment of functional wells for agriculture, industries, drinking water purposes (modified well census as village wise by public participation to be translated into aquifer wise & then administrative unit)
- **Identification of Clusters of Aquifers (layers)**
  - Vertical-horizontal flow of recharged water from source - rainfall, canal, applied irrigation etc.
  - Formation of Aquifer Management Unit (clustering of villages & depth units)
  - Preparation of Aquifer Management Plans for sustainable ground water management. The AMPs need to be prepared in a simplified manner so that they are easily understood and implementable by the stakeholders and ensuring wider acceptability. Sustainability necessarily means the reliability, resilience and the vulnerability of the resource. Reliability is the ability of system to meet demands; resilience is the measure of the ability of the system to recover from failure and vulnerability is the measure of loss/damage incurred because of failure.

2.5 Outcomes and Benefits

The Social Outputs and benefits are less tangible but their significance in the contest of sustainable management of ground water resources cannot be underestimated

- Involvement of community and stakeholders would enable the State Governments to manage their resources in an efficient and equitable manner, thereby contributing to improved overall development.

- Demystification of science will result in better understanding of aquifers at community level. The amalgamation of scientific inputs and traditional wisdom would ensure sustainable ground water resource management.
- Community participation and management would ensure sustainable cropping pattern, thereby contributing towards food security.

2.6 Implementation Strategy

A national level programme of this nature has to be essentially decentralized, phased programme following a set of basic norms, criteria and training modules but with sufficient opportunities for addressing local needs and subsequent up-scaling.

The entire exercise of aquifer mapping needs to be structured around three pillars, viz. technology support system, community participation and institutional arrangements.

2.6.1 Technology Support System

The technical/scientific pillar is responsible for the entire aquifer mapping exercise. Following flow diagram (Fig.2.5) shows the sequence of the major activities envisage**d**

2.6.2 Community Participation

Since water is a State subject, execution of such a Project cannot be successful without taking the States *on board.* The involvement of State machinery including various departments, PRIs etc. is essential if the Aquifer Management Plans are to be implemented. The Nodal State Organisations need to be fully involved in preparation of Aquifer Maps. Further, the Aquifer Management Plans need to be developed by the State Government with assistance and support from Central Government.

As India has a large rural and semi-literate population, demystification of the Science of Hydrogeology will be very crucial to enable them to understand the dynamics of ground water availability and its sustainable utilization. The various Stakeholders need to develop a sense of ownership, for only then will such a socially relevant project can be successful. Therefore, the community needs to be made aware of the objectives and benefits of aquifer mapping exercise and their active participation through local people will be fundamental in implementation of the project.

Some of the local educated people may be identified and imparted basic training on ground water, relevance of aquifer mapping, participatory management, etc. These trained persons, called para- hydrogeologists will be responsible for basic data collection like water level monitoring, well inventory, awareness raising etc. They can also be entrusted with activities like water budgeting, assessment of crop water requirements etc. The Aquifer mapping programme is expected to build capacity in the entire country by giving CGWB and State round water personnel hands-on experience in various techniques like aerial surveys, ground water modeling, participatory management etc.

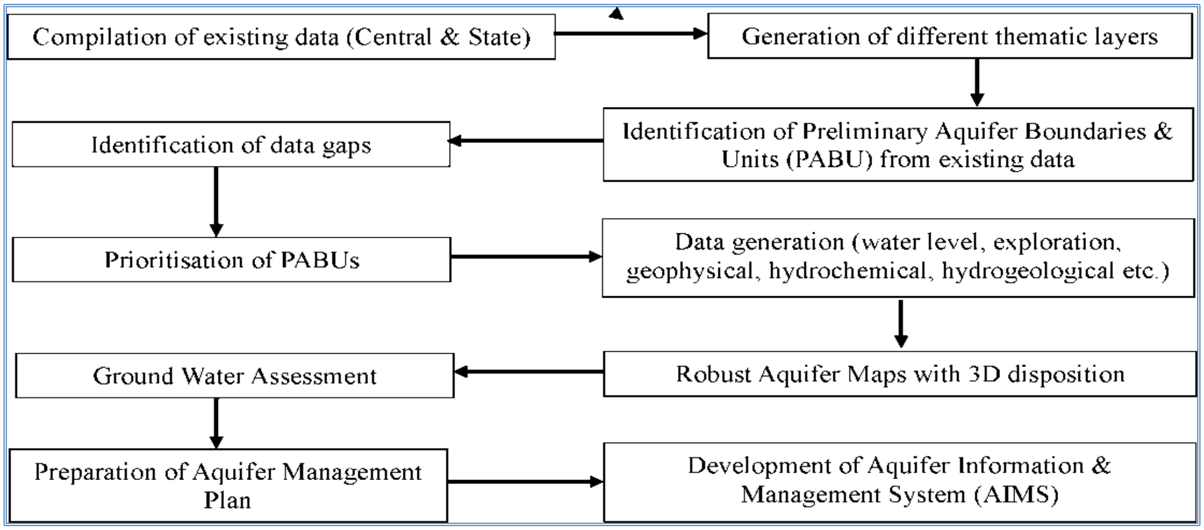


Fig.2.4: Sequence of major activities envisaged in aquifer mapping

2.6.3 Institutional Arrangements

A national level programme of this nature must be sufficiently decentralized. It will be taken up in a phased manner following a set of basic norms, criteria and training modules, but with sufficient opportunities for addressing local needs and the potential for subsequent up-scaling. The programme therefore needs to have a three tier institutional arrangement with a large base and a small apex. The major operational partners proposed are:

NATIONAL INTER-DEPARTMENTAL STEERING COMMITTEE (NISC)

The NISC has already been constituted with the overall objective to provide guidance in the implementation of the Project at national level. Secretary, MoWR will be Chairman, with representatives from related ministries like Science & Technology, Earth Sciences, Rural Development, Drinking Water & Sanitation, etc. The Principal Secretaries of the States shall be members of the NISC. The NISC may also co-opt eminent hydrogeologists and sociologists/economists who have done work on groundwater and people with credibility of implementing groundwater demand-management on the ground.

The NISC shall be responsible to oversee the implementation of the National programme for Aquifer Mapping and Participatory Aquifer Management in the country, to coordinate with various organizations and to integrate various basin level programmes related to water sector with a view to promoting sustainable ground water management.

PROJECT MANAGEMENT GROUP (PMG)

A PMG is proposed to be constituted at Central level within MoWR for the implementation of Project on Aquifer Management. The PMG will be headed by the Secretary, MoWR and will comprise officers from MoWR and CGWB. Central Ground Water Board (CGWB) will be the nodal department and will eventually pull together all the data and information into a centralized database on aquifers by combining existing data available with central and state agencies and the data and information coming up through the aquifer mapping effort.

The PMG will put into action the framework developed by the NISC as well as coordinate the activities between various government agencies and other stakeholders at various levels. All the activities under the proposed programme will be under the overall supervision of the PMG, CGWB.

CGWB will develop aquifer maps on appropriate scales to arrive at aquifer-based strategies for groundwater management, in collaboration with the Central and State level technical and Management consultants. CGWB will also continue to carryout the drilling, ground water regime monitoring and other scientific data generation by in-house and outsourcing the activities. The organogram for the National Project on Aquifer Management is as given below (**Fig.2.5**).

PROJECT MONITORING UNIT (PMU)

The Project Monitoring Unit (PMU) to be constituted within the Central Ground Water Board shall be dedicated to spearhead the monitoring and implementation of National Project on Aquifer Management (NAQUIM). PMU will report to the Chairman, CGWB. At the national level, the PMU will be headed by the National Coordinator of NAQUIM, CGWB. PMU will be supported by the dedicated officers and staff exclusively deployed from CGWB and Consultants/Professionals hired on contractual basis. It will periodically monitor the implementation of procurement of goods, works, services and hiring of contractual professionals/consultants for timely achievement of milestones of NAQUIM.

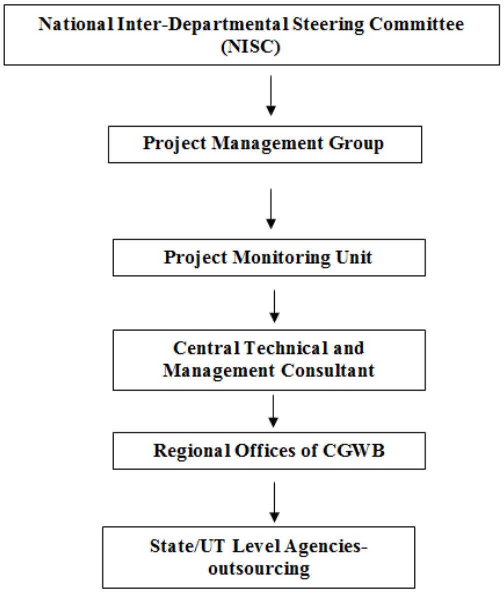


Fig.2.5: Organogram of proposed institutional arrangements for National Aquifer Mapping

Functions

- The PMU will plan and coordinate each activity of the project at national and state level.
- It will supervise andprovidetechnicalguidancetohelp projectimplementation.
- PMU would help in smooth and timely flow of funds for purchase of goods, services to ensure that there are no time and cost over-runs.
- PMU will be responsible for processing the contracts and hiring of services for activities of the project. PMU will facilitate the process for obtaining expenditure sanction from the PMG, Ministry of Water Resources in the cases beyond the delegated powers of the Chairman, CGWB.
- It will monitor the progress of the activities of the project regularly at frequent intervals for reporting to the Chairman. It will also ensure that projects meet planning objectives.

- Inviting experts to provide their inputs during formal interactions in meetings and workshops, based on the need of the project.
- Convening regular meetings to review and coordinate the project activities. PMU will host these meetings. PMU is also responsible for documentation (MOUs, minutes of meeting and agreement etc of the project). These documents will be circulated to NISC, PMG and SGWCC members.
- Liaisoning with Central/state agencies and other stake holders for implementing the NAQUIM.
- Ensuring that project-related capacity building and professional development objectives are met.
- Managing the monitoring database.

Scope of work of PMU

In view of the crosscutting and the sector specific conditions stated above, the PMU will be responsible for the following key functions and outputs at an operational level:

Project Identification / Feasibility process

The co-ordination of the project activities identification and prioritization process for aquifer mapping will be carried out by according priorities as envisaged in the scheme. The appropriate input will be obtained from various government departments to ensure that local issues are taken care of for aquifer management plan. The PMU is responsible for overall planning in close liaison with other Members and functionaries of the Board.

Contract Administration

The co-ordination of the administration of work /service agreements and contracts with contractors, agencies and consultants for each or group of activities outsourced for implementation of the project.

Financial Monitoring

The PMU is responsible for the financial monitoring of progress of expenditure a sper Budgeted Estimates of NAQUIM, within the CGWB accounting systems for implementation of the project under the scheme of Ground water management and regulation.

Programme / Project Management Monitoring and Evaluation:

The PMU will be responsible for the management of the Aquifer mapping and participatory management programme of the NAQUIM, as well as project implementation activities while ensuring that:

- All activities meet overall planning objectives and specific key performance indicators as identified in the Project and determined by the NISC / PMG /MoWR.
- The co-ordination of regular progress meetings at State level and representation at the national progress meetings.
- The associated project management functions from project implementation, evaluation and final project completion in terms of the activities and timeframe envisaged in the EFC.

3. COLLECTION, COMPILATION AND PROCESSING OF AVAILABLE DATA

3.1 Introduction:

The occurrence, movement, storage and availability of ground water in an aquifer depend mainly on two factors, viz. the physical framework of the aquifer systems and the recharge and discharge of water to and from the aquifers. The physical framework of the aquifer system is governed mainly by geological and geomorphological characteristics of the area. The recharge and discharge of ground water from and to the aquifers is controlled by the aquifer characteristics as well as several other factors such as soils, climate, cropping pattern, land use, surface water features, agricultural practices etc. A realistic representation of an aquifer and plan for its sustainable management needs to take into account the influence of all these factors on the aquifer system.

In India, the subject of water resources is being handled by a number of ministries and departments at both national and state levels. In addition, several academic/research institutions, NGOs and private organizations are also working on different aspects of water resources as part of their activities. A huge amount of data on various aspects of water resources has been generated during various activities of these agencies over the years.

As far as ground water resources are concerned, scientific data collection for various studies is being done primarily by Central Ground Water Board under the Ministry of Water Resources, Government of India at the national level and by the State Departments in charge of ground water resources at the State level. State agencies responsible for providing drinking water supplies, research institutions such as National Institute of Hydrology (NIH) and National Geophysical Research Institute (NGRI) and State Government Departments dealing with agriculture, irrigation, soil conservation and watershed management also have considerable amount of data pertaining to occurrence, development and management of ground water resources of the nation.

3.2 Present Status of Data Availability

A Working Group headed by Prof. A Vaidyanathan, Ex. Member, Planning Commission, constituted by the Government of India, on "Water Database Development and Management" in connection with the formulation of XII Plan document, has deliberated in detail on the present availability of water related data (http://planningcommission.nic.in/aboutus/committee/wrkgrpl2/wr/wg_data.pdf), which brings out the present status of data availability in water sector and the wish list including groundwater. The chapter on Ground Water Resources in the said report also deals with the status of availability of ground water related data in the country and an analysis of the data gaps. The table on current status of data availability as given in the report is reproduced below (**Table.3.1**).

Table 3.1: Current status of data availability in the context of aquifer mapping

Sl.No	Description of Data	Present Status of Data Availability
1	Subsurface geometry of aquifers	• Based on the country wide Ground water Surveys, ground water exploration data generated by CGWB and other organizations, Hydrogeological Map of India on 1:2,000,000 Scale has been first prepared in 1982 and subsequently revised in the year 2002. • Aquifer dispositions have been delineated in limited Water Balance project areas in different hydrogeological environments of the country covering ~10% of its total geographical area, based on point data and interpolation of lithology with aquifer characterization. • Lithological and geophysical logs of ~ 12000 exploratory wells available with CGWB. Similar data available with States need to be ascertained. • Aquifer parameters determined through pumping tests by CGWB and the States.
2	Ground water level monitoring	• 15000 ground water observation wells are monitored by CGWB four times a year. 3,500 of these are piezometers with depths ranging from 40 to 100m while the rest are open wells/dug wells. • Nearly 40,000 wells are monitored by various states, with a frequency varying from twice a year to monthly measurements • A limited number of Digital Water Level Recorders (DWLRs)are functional in some States with high frequency data. • Data sets relating to projects/studies carried out by academic institutions and research labs are also available in some cases.
3	Mapping of the specific yield parameter	• Specific Yield of selected lithological formations has been estimated through field tests: pumping tests, dry season water balance and numerical modelling technique. These have been recommended as specific yield norms under GEC-97. • Dedicated projects by CGWB/ states have been taken up to determine specific yield in some of the states.
4	Determination ofrainfall-rechargerelationship	• Rainfall infiltration factors of selected lithological formations have been estimated through field tests. These have been recommended as norms under GEC-97. • Data of infiltration tests carried out by CGWB and other agencies may be available. • Data from studies performed by agricultural institutions and universities may also be available.
5	Determination of seepage factors (canal, irrigation return flow, tanks and ponds, water conservation	• Three type values of canal seepage factors have been recommended based on soil types and lining of canals.

	structures	• Six norms each of surface irrigation return flow and ground water irrigation return flow, have also been determined based on field studies.
6	Groundwater discharge estimates	• Base flow estimates in some watersheds/ sub-basins may exist with CWC/ surface water agencies of states. These can be used to estimate groundwater discharge for specific lithological units.
7	Groundwater quality data	• 15000 ground water observation wells monitored by CGWB once a year. • In addition, one time data on water quality data are also collected during survey and exploration of CGWB. • Data from the states need to be ascertained. • DWS, MORD has hamlet-wise/ scheme-wise, one time data on water quality but not yet geo-referenced. • Limited data is available with CPCB/SPCB. CPCB is monitoring ~ 490 wells half-yearly. • Water quality data are also available water local bodies / PHED
8	Reliable Groundwater utilization (i.e pumping) figures.	• The number of groundwater abstraction structures for minor irrigation are being generated through the MOWR scheme on Minor Irrigation Census. • In addition, State governments are also carrying out well census studies. • Utilization is being assessed by the States using ground water structure-wise unit draft. • Some States use the cropping pattern method to compute ground water utilization for irrigation.

3.3 Data Collection

Collection of ground water related data available with different agencies in a standard format forms an important pre-requisite for data gap analysis as well as for preparation of aquifer maps and development of aquifer management plans. The major data types and sources are shown in **Table 3.2.**

Table 3.2: Major data types for aquifer mapping and their sources

Sl.No	Data Type	Data Sub-type	Data Source	Remarks
1	Maps /Thematic layers	Topography	Survey of India	• Shape (.shp) files of Villages, elevation contours, drainage, roads, water bodies, forest etc. digitized at 1:50,000 scale • Hard copy maps on 1:50,000 scale will also be procured. • For identified priority areas, SOI is taking up preparation of 1:10,000 scale maps which will be also used and efforts will be made to generate more coverage under this project also.
		Geomorpology	National Remote Sensing Centre (NRSC)	• Satellite data (CARTOSAT, LISS-III,LISS IV, RESOURCESAT) • NRIS codes developed by NRSC may be followed in classification of geomorphological units. • GIS layers from 1:50,000 scale available with NRSC will be used as base for updating with more field data
		Geology	Geological Survey of India	• Shape files of Geology may be procured from GSI. • Hard copy maps on the 1:50,000 scale will also be procured
		Soil	National Bureau of Soil Survey (NBSS)	• Maps on 1: 500,000 scale (Available with National Data Centre, CGWB, Faridabad for the entire country)
		Land Use/ Land Cover	Nationa Remote Sensing Centre	• To be generated from LISS-III RESOURCESAT data. The NRIS codes developed by NRSC may be followed in classification of the features class.
2	Database of Ground Water Monitoring Network	Location details	Central Ground Water Board, State Ground Water Departments	• Data available with different agencies to be brought to a standard format and integrated location maps prepared.
		Reduced level data		• Data available with different agencies to be compiled in a standard format
		Water level data		
		Water quality data		

3	Database of Ground Water Exploration	Location details	Central Ground Water Board State Groundwater Department Drilling Contractors Industrial Units Farmers	• Data available with different agencies to be brought to a standard format and integrated location maps prepared
		Reduced Level Data		• Data available with different agencies to be compiled in a standard format
		Lithological logs		
		Vertical Electrical Sounding (VES) and Well Logging data		
		Aquifer Parameter data (T/K/S/Sy)		
		Aquifer-wise water quality data		
4	Surface Water Data	Rainfall / Meteorological data	Indian Meteorological Department / State Water Resource Organizations/ Agricultural Universities/ Research Institutions.	• Data to be collected and compiled in a standard format
		River Gauge/Dischare and Water Quality data	Central Water Commission (CWC) State Water Resources Organizations	• Data to be collected and compiled in a standard format
		Spring discharge & quality	State Water Resource Organizations	• Data on location, discharge, quality and other relevant details to be collected and compiled in a standard format
		Tanks & Surface water bodies		• Details on location, dimensions, storage capacity, number of fillings, use, ownership etc. to be collected and compiled in a standard format.
		Canal particulars / discharge / command area	State Irrigation Departments / CADA	• Hydraulic particulars, length, no. of days of flow, discharge, designed cropping pattern etc. to be collected and compiled.
5	Agriculture	Cropping Pattern	State Agriculture Departments.	• Data on cropping pattern and reasons for major shifts if any
		Source-wise irrigation	State Irrigation Departments	• Data on source-wise irrigation (Surface water, ground water, other sources)
		Minor Irrigation	State Minor Irrigation	• Data on minor irrigation structures, command areas etc.

			Departments	
6	Industries	Location of major industries	State Departments of Industries.	• Data on use of ground water for industries • Mining hydrogeology • Ground water contamination by industrial effluents
		Locations of mines, sand mining areas and abandoned quarries.		
		Raw materials, Products and effluents		
		Water requirement for industries		
		Locations of Effluent Treatment Plants		
7	Socio-economic Data	Population	Census Department	• Village-wise population, population density, population growth etc.
		Water supply schemes		• Details of drinking water sources & quantum of ground water used for drinking & domestic uses.

3.4 Data Compilation and Processing

The data collected from various sources need to be validated as per standard protocols before processing them into meaningful information in reference to geometry, potential, water quality, ground water draft etc of each aquifer units along with the geo-referencing information. Data on drilling of bore/tube wells, inferred geophysical data and interpolated layer information would yield Aquifer Geometry. The data pertaining to groundwater resources estimation would further give value addition to aquifer characteristics. Groundwater extraction data from CGWB data base and village level information available with State government department would provide groundwater draft of each aquifer units.

The processing of data will mainly include i) preparation of georeferenced maps of the data collected from various agencies, validated and compiled in a standard format and ii) Processing of the data to derive useful information pertaining to aquifer geometry and ground water regime. Salient details of the maps to be prepared and processing of data for deciphering aquifer geometry and characteristics are enumerated in **Table 3.3 and Table 3.4** respectively.

3.5 Data Interpretation

Once the available data is collected, validated, compiled in a standard format, the next step is to interpret the available data with the objectives of generating a 3-D visualization of the aquifer systems in the area, understand the ground water regime and to identify the data gaps for planning investigations to generate additional data to fill them. The important components of data interpretation in this regard are given in **Table 3.5.**

3.6 Data sharing mechanism

As data pertaining to various aspects of ground water occurrence, development and management are available with a number of Central & State Government organizations, Research Institutions etc., there is a need to develop a mechanism to ensure hassle-free data sharing between different agencies. An implementation approach has been devised with steps and activities involving nationwide data collection and compilation is described below:

- Identification of Agencies generating the ground water related data including socio economic aspects and water utilization.
- Evolve suitable mechanism for data sharing, within and across the Agencies in consultation with central and state level data generating departments, institutions.
- If required, an exclusive data sharing protocol may be evolved among the participating agencies for the "National Project on Aquifer management" within the ambit of national data sharing policy, ensuring mutual interest of all the agencies.
- Launching of national and state level consultation process and conducting seminars / workshops to bring state Agencies / institutions and stakeholders on board for data sharing and participation.

3.6.1 Role of State Government Agencies & Other Institutions

The data collection for National Aquifer Mapping & Management would involve data sharing among and across the participating agencies and would essentially require resolving various cross cutting issues. In this context it is essential to constitute a steering group at the state level. The implementing mechanism as elaborated in the concept paper (http://cgwb.gov.in/AQM/documents/Concept) on "National Project on Aquifer management " envisages constitution of State Coordination Committee (SCC) with the overall objective of implementation of the project at State level.The SCC is proposed to be chaired by the Principal Secretary in-charge of ground water of the State Government with representatives from related departments like Ground Water, Irrigation, Drinking Water, Agriculture, Forests, etc. The Regional Director, CGWB of the concerned Region shall be the Member Secretary of SCC.

Table 3.3: Methodology of Map preparation

Sl.No	Map details	Methodology
1	Base map	Digitization of base map, depicting administrative boundaries up to block level, locations of important towns, major drainage and transport network.
2	Geomorphology map	Reinterpretation of available maps with value addition from Remote Sensing data and re-grouping of geomorphic units as per Natural Resources Information System (NRIS) codes.
3	Land Use / Land Cover	To be prepared from Remote Sensing data using NRIS coding scheme
4	Canal network and Canal command area map	Digitization of canal network and canal command area maps and demarcation of command and non-command area as per standard norms.
5	Distribution of Rain gauge stations	Digitization of locations of rain-gauge stations of IMD/State agencies
6	Distribution of River Gauge/Discharge Stations	Digitization of river gauge sites for monitoring discharge and water quality with appropriate symbols.
7	Distribution of springs	Digitization of locations of springs
8	Distribution of rainfall (Isohyetal maps)	Preparation of Isohyetal maps depicting distribution of normal/annual/seasonal rainfall over the area
9	Geology and Structure	Maps prepared by Geological Survey of India depicting surface geology to be updated with information available from field investigations, re-interpreted and re-grouped into hydrogeological units.
10	Integrated map of exploratory tube/bore wells of Central Ground Water Board and other agencies	Digitization of maps showing locations exploratory wells of CGWB and other agencies using appropriate symbols and attribute tables.
11	Integrated map of locations of Vertical Electrical Sounding (VES) and Electrical Log	Digitization of maps showing locations of VES and Electrical Logs of CGWB and other agencies using appropriate symbols and attribute tables.
12	Integrated map of ground water observation wells of Central Ground Water Board and other agencies	Digitization of maps showing locations of ground water observation wells of CGWB and other agencies using appropriate symbols and attribute tables.
13	Integrated map of ground water observation wells of Central Ground Water Board and other agencies	Digitization of maps showing locations of ground water quality monitoring wells of CGWB and other agencies using appropriate symbols and attribute tables.
14	Spatial distribution of aquifer parameters (T,K,S, Sy)	Preparation of maps showing distribution of aquifer parameters for each aquifer units as per standard norms & attribute tables
15	Depth to water /piezometric surface maps	Preparation of maps showing the spatial distribution of ground water levels (decadal pre- and post-monsoon) in each aquifer unit, as per standard norms.
16	Water Table/ Piezometric surface	Preparation of maps showing elevation of water table /

	elevation maps	piezometric surface in each aquifer unit with reference to mean sea level as per standard norms
17	Spatial distribution of water quality parameters	Preparation of maps showing distribution of important chemical constituents / parameters relevant to the area as per standard norms.
18	Spatial distribution of ground water recharge and draft	Preparation of maps showing spatial distribution of ground water recharge and draft for each aquifer unit.

Table 3.4: Processing of data

Sl.No	Objective	Data required	Steps involved	Outcome
1	Preparation of composite logs	Bore well/Tube well locations Lithological logs Drill-time logs Geophysical data Other relevant information	Plotting of composite logs in standard templates	Overview of hydrological information related to aquifer units at the drilling sites
2	Preparation of hydrogeological sections	Bore well/Tube well locations Lithological data Reduced levels Water levels/ Piezometric heads.	Plotting of data along identified sections lines.	Depiction of changes in the aquifer thickness and water levels/piezometric heads in space.
3	Analysis of water level / piezometric surface data	Observation well locations Water level / piezometric surface data of observation wells	Preparation of water level maps. Preparation of water table maps Time-series analysis of water level data	Understanding of the spatial and temporal variations in ground water levels in aquifer units and ground water flow direction
4	Analysis of water quality data	Locations of water quality monitoring wells. Water quality data of observation wells	Preparation of maps showing distribution of important chemical constituents in ground water. Time-series analysis of historical water quality data	Understanding of ground water quality regime and temporal variations in ground water quality.
5	Assessment of aquifer-wise ground water recharge.	Aquifer recharge parameters (Rainfall, water level fluctuation, porosity, specific yield, storativity, aquifer thickness etc.)	Assessment of ground water recharge in each aquifer units as per approved methodology	Ground water recharge in each aquifer unit.
6	Assessment of aquifer-wise ground water draft (extraction)	Aquifer draft parameters (No. of abstraction structures in each aquifer unit, unit ground water draft etc.)	Assessment of ground water draft from each aquifer unit.	Ground water draft (extraction) from each aquifer unit.

Table 3.5: Major components of data interpretation for deciphering aquifer geometry.

Sl.No	Objective	Methodology	Deliverables / Outcome
1	Understand ground water regime	Overlaying of relevant layers such as geology, ground water elevation, aquifer characteristics, ground water quality etc.	Hydrogeological Map
2	Demarcation of principal aquifers in 2 dimensions	Aquifers interpolated from the lithologs may be used for demarcation of the principal aquifers in 2 D using occurrence of the major zones/clays/ marker horizons such as saline zones. The top, bottom and thickness of the aquifer may be plotted over these maps.	Hydrogeological cross sections Top & bottom of aquifers Isopachs
3	3 D visualization of aquifer systems	Aquifer disposition i.e. top, bottom of aquifer and their relative occurrence with respect to mean sea level may be used for preparation of the 3D visualisation of the aquifers.	Fence Diagrams/Panel Diagrams

4. DATA GAP ANALYSIS

India is a country with wide variations in hydrogeological, hydrological, geological, topographical conditions;hence a need has been felt to prepare a common and consolidated guideline for aquifer mapping and data gap analysis. The guideline is expected to explain broadly the methodology and data formats for data collection, compilation and data gap analysis so as to ensure uniformity in the analysis and outputs.

It has been attempted to cover entire country broadly under four types of regions viz. Alluvial areas, Hard rock areas, Basaltic/ layered formation areas and Hilly areas. The guideline defines the grid wise and aquifer wise basic requirement for establishing aquifer geometry and characteristics and accordingly the method for data gap analysis to be carried out.

However, due to wide variation in local hydrogeological and geological conditions individual Regions may decide on number of aquifers existing upto 200 m or 300 m, grids where data generation is required, quality parameters specific to the region that need to be included etc.

4.1 Objective

Data gap analysis, in the context of National Aquifer Mapping, has the following major objectives:

- Identification of gaps in the existing data on various aspects of the aquifer being mapped.
- Optimization of additional data requirements for a realistic depiction of the aquifer system and management of its ground water resources.

4.2 Methodology

The process of identification of data gap involves the following steps

- Compilation of available data on the aquifer being studied.
- Compilation of the data collected in a common standardized format.
- Interpretation / Analysis of each data layer
- Identification of data gaps with respect to
  - Thematic layers (Geomorphology, land cover/land use, soils etc.)
  - Sub-surface Data
  - Ground water recharge and draft

4.2.1 Data gaps in thematic layers

After collection of the layer data on various themes from different sources, the data need to be brought to a common platform for examination in respect of correctness and completeness. As aquifer mapping is proposed to be taken up on 1:50,000 scale in general and on 1:10, 000 scale in identified priority areas, all the thematic maps are to be prepared on 1:50,000 scale. Wherever maps are not available in the designated scales, same needs to be generated. Gaps in the data depicted in the maps are then to be identified, which are to be filled up using data available with other agencies, sources such as remote sensing imagery, aerial photos etc. or through value addition through data collected in the field.

4.2.2 Data gaps in sub-surface data

The methodology suggested for analysis of data gap in the subsurface data required is outlined below

4.2.2.1 Preparation of Base Map (Map-1)

- ➢ Taking Survey of India Topo-sheet (**Scale- 1:50,000)** as unit of data presentation, a physical map containing following information should be plotted
  - district & block boundaries,
  - communication network (rail and road),

  - main drainage,
  - major towns including block and district headquarters.

- Data should be presented on A2 size map.
- For hard rock areas, geology and lineaments should be plotted on the map.
- Standard cartography and color code as used in the toposheets of Survey of India should be used for depicting/annotating the above mentioned features.
- For hilly areas spring shed map should be prepared. Areal extent, contacts of lithological zones may be demarcated using Remote Sensing data and GSI Maps and field validation. Fractures, joints, faults, folds, lineaments karst- channels, their density are to be studied using Remote Sensing and GSI Maps.

4.2.2.2 Compilation of Existing Data for Mapping

4.2.2.2.1 Exploratory Data Availability (Map-2):

- The existing wells (EW, OW, PZ, SH) of CGWB and other agencies should be plotted on the base map with different symbols representing source of data and type of well on Map-2.
- Lithologs and electrical logs to be plotted on the map.
- Details of each well including the Reduced Level point data (mamsl) should be tabulated separately.

4.2.2.2.2 Geophysical Information (Map-3):

- The existing VES, profiling and other geophysical investigation data generated by CGWB and other agencies should be plotted on the base map with different symbols representing source of data and type of investigation.

4.2.2.2.3 Ground Water Level Monitoring of Regime/Aquifer (Map-4):

- Water level monitoring wells/piezometers should be plotted on the base map with different symbols representing their source and type of well.
- Details of each well including the Reduced Level point data (m.amsl) should be tabulated separately.

4.2.2.2.4 Ground Water Quality Monitoring of Regime/Aquifer (Map-5):

- The water quality monitoring wells/ piezometers and water quality data should be plotted on the base map showing source of water samples (Map-5).
- Water quality data network needs to be tabulated showing location along with Latitude/Longitude and depth range.

4.2.3 Pre-processing of data

4.2.3.1 Exploratory Data (Map-6, 7 & 8)

A. Alluvial Area

- Based on the lithological logs, electrical logs and other relevant information gathered from the exploratory data, aquifer geometry should be deciphered and plotted on the Map-2.
- The aquifer geometry should clearly define the disposition of the various aquifer groups and should be depicted through fence diagrams and cross sections in different directions (at least four numbers).
- The cross sections must be prepared using the RL values.
- Using these plots, top, bottom and isopachs of different aquifer layers should be identified and drawn. (Map 6 &7).
- Quadrant-wise and Aquiferwise parameter such as T & S/Sy should be tabulated.

B. Hard rock area

- Isopachs of weathered zone/ fractured zones should be drawn (Map 6 &7).
- Available information on fracture density, yields, quality variations etc. should be represented pictorially (Map-8).

4.2.3.2 Ground Water Levels (Map- 9 & 10)

- The depth to water level (DTWL)/ piezometric contour maps for the pre- and post-monsoon period should be prepared **aquifer-wise**to depict the general depth of occurrence of water level (Map-9).
- Using RL values, water table elevation contour maps should be prepared specially to depict flow directions and gentle/ steep ground water gradient areas (Map-10).

4.2.3.3 Ground Water Quality (Map-11):

- Preparation of aquifer wise water quality contours (EC) and Region-specific relevant parameters and Stiff diagram for each monitoring station (Map-11).
- Water quality trends.

4.2.4 Recommended Criteria/ Methodology for Arriving at Data Gap

The hydrogeological setup in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Studies carried out over the years have revealed that aquifer groups in alluvial / soft rocks even transcend the surface basin boundaries. Broadly two groups of rock formations have been identified depending on characteristically different hydraulics of ground water, Viz. Porous Formations and Fissured Formations.

Porous formations have been further subdivided into Unconsolidated and Semi – consolidated formations. The areas covered by alluvial sediments of river basins, coastal and deltaic tracts constitute the unconsolidated formations. These are by far the most significant ground water reservoirs for large scale and extensive development. The semi-consolidated formations normally occur in narrow valleys or structurally faulted basins. The Gondwanas, Lathis, Tipams, Cuddalore sandstones and their equivalents are the most extensive productive aquifers in this category. Under favorable situations, these formations give rise to free flowing wells.

The consolidated formations occupy almost two-thirds of the country. These formations, except vesicular volcanic rocks have negligible primary porosity. From the hydrogeological point of view, fissured rocks are broadly classified into four type‟s viz. Igneous and metamorphic rocks excluding volcanic and carbonate rocks, volcanic rocks, consolidated sedimentary rocks and Carbonate rocks. Thus in view of above scenario the guidelines have been given for four broad categories having different hydrogeological set-up and aquifer geometry and characteristics.

A. **Alluvial Areas**
B. **Hard Rock areas**
C. **Basaltic areas along with layered semi-consolidated formations (as Gondwanas, Lathi etc.)**
D. **Hilly areas**

A. FOR ALLUVIAL AREAS

a. Exploratory Data

- ***Data Required***

i. Desirable spatial scale should be 5'' x 5'' grids and 300 m depth for alluvial areas.

ii. It is recommended that 3 to 4 **"Special Purpose Wells"** (SPW) may be constructed in the corner quadrants of each toposheet (or hydrogeologically required areas) at suitable locations to get the lithological information. (Fig-A1). Quadrants for SPW should be changed in adjacent toposheets to avoid clusters of SPW.

iii. In the centre (or any suitable site) of each toposheet a **"Well field"** with exploratory wells (at least 8" dia) and observation well tapping each aquifer is recommended to find out aquifer disposition.

iv. For the first aquifer 4-5 pumping test are be carried out in the existing dug wells/ if possible in shallow bore wells.

v. Aquifer performance test shall be conducted in the well field, on EW‟s targeting the 2nd/3rd aquifer group to estimate the aquiferwise hydraulic parameters and water quality

Fig.A1:
Sample- Exploratory Data required for <u>Two</u> Aquifer group system in Alluvial areas

Special Purpose Well		Special Purpose Well
	<u>Well Field</u> EW – 2 OW – 2	
Special Purpose Well		Special Purpose Well

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy (Adequacy of available sub-surface information for deciphering aquifer geometry at the desired vertical & horizontal scale) is to be done based on recommended and available information.

ii. Aquifer wise parameters availability (T and S/Sy) *or non-availability* upto the desired depth should be presented in form of square diagram for each quadrant. (Fig-A2)

iii. Quadrant wise recommended and existing EW/OW/PZ/SH should be depicted using square diagram and the additional EW/OW/PZ/SH etc. required for aquifer geometry delineation should be assessed (Fig-A3).

Fig-A2
Sample- Exploratory Data adequacy for <u>Two</u> Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Aq. Gp.	Dpth Rnge	Aq. parameters	EC
Ist			
IInd			

Fig-A3
Sample- Exploratory Data gap analysis for <u>Two</u> Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			

b. Geophysical Data

- ***Data Required***

vi. Desirable spatial scale should be 5'' x 5'' grids and 300 m depth for alluvial areas.

vii. It is recommended that 3 Profiling/VES/TEM having 300 meter interpretation depth should be carried out in each of the nine quadrants of the toposheet totaling to 27 nos. in each sheet to decipher aquifer geometry (Fig-A4).

- ***Existing Data and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-A5)

ii. Quadrant wise recommended and existing Profiling/VES/TEM profiling data should be depicted using square diagram and the additional VES/TEM required for aquifer geometry delineation should be assessed (Fig-A6).

Fig-A4

Sample- Geophysical Data required for Two Aquifer group system in Alluvium areas

3 Profiling/ VES/TEM	3 Profiling/ VES/TEM	3 Profiling/ VES/TEM
3 Profiling/ VES/TEM	3 Profiling/ VES/TEM	3 Profiling/ VES/TEM
3 Profiling/ VES/TEM	3 Profiling/ VES/TEM	3 Profiling/ VES/TEM

Fig-A5

Sample- Data adequacy of Geophysical data for Two Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp. VEM/TEM Ist Y/N IInd Y/N	Aq. Gp. VEM/TEM Ist Y/N IInd Y/N	Aq. Gp. VEM/TEM Ist Y/N IInd Y/N
q. Gp. VEM/TEM Ist Y/N IInd Y/N	Aq. Gp. VEM/TEM Ist Y/N IInd Y/N	Aq. Gp. VEM/TEM Ist Y/N IInd Y/N
Aq. Gp. VEM/TEM Ist Y/N IInd Y/N	Aq. Gp. VEM/TEM Ist Y/N IInd Y/N	Aq. Gp. VEM/TEM Ist Y/N IInd Y/N

Fig-A6

Sample- Data gap analysis for geophysical data of Two Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd	Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd	Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd
Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd	Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd	Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd
Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd	Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd	Aq. Gp. Profiling/VES/TEM Req Exist Gap Ist IInd

c. Ground Water Monitoring Data

- ***Data Required***

i. Desirable spatial scale should be 5'' x 5'' grids.

ii. For 1st aquifer (un-confined/Phreatic) two open/dug wells are recommended for each quadrant of a toposheet. (Fig-A7)

iii. For 2nd and 3rd aquifer the well-constructed in the Well field explained above and Special Purpose wellsmay be used as piezometers for GW monitoring. (Fig-A7)

iv. Minimum four times monitoring annually is recommended as per the state specific schedule of monitoring.

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-A8)

ii. Quadrant wise recommended and existing DW/PZ should be depicted using square diagram and the additional DW/PZ required for ground water monitoring should be assessed (Fig-A9).

Fig-A7

Sample- GW Monitoring Data required for Two Aquifer group system in Alluvial rock areas

Ist Aq - 2 IInd Aq - 1	Ist Aq - 2	Ist Aq - 2 IInd Aq - 1
Ist Aq - 2	Ist Aq - 2 IInd Aq - 1	Ist Aq - 2
Ist Aq - 2 IInd Aq - 1	Ist Aq - 2	Ist Aq - 2 IInd Aq - 1

Fig-A8

Sample- Data adequacy of GW Monitoring data for Two Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N

Fig-A9

Sample- Data gap analysis for GW Monitoring data of Two Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			

d. Ground Water Quality Data

- ***Data Required***

i. Desirable spatial scale should be 5'' x 5'' grids.
ii. For 1st aquifer (un-confined/Phreatic) one sample from open/dug wells are recommended for each quadrant of a toposheet. (Fig-A10)
iii. For 2nd aquifer the sample is to be collected from well-constructed in the Well field explained above and Special Purpose wellsfor GW Quality monitoring. (Fig-A10)
iv. Minimum two times monitoring initially is recommended.

Fig-A10

Sample- GW Quality Data required for Two Aquifer group system in Alluvial rock areas

Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1
Ist Aq - 1	Ist Aq - 1 IInd Aq - 1	Ist Aq - 1
Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information on quality monitoring stations.(Fig-A11)
ii. Quadrant wise recommended and existing quality monitoring stations should be depicted using square diagram and the additional quality monitoring stations required should be assessed (Fig-A12).

Fig-A11

Sample- Data adequacy of GW Quality data for Two Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N

Fig-A12

Sample- Data gap analysis for GW Quality data of Two Aquifer group system in Alluvial areas (quadrant wise)

Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			

B. Hard Rock areas

a. Exploratory Data

- ***Data Required***

i. Desirable spatial scale should be 5‟ x 5‟ grids and 200 m depth.

ii. In hard rock areas 5 EW‟s and 5 OW‟s should be constructed at suitable locations, preferably one in central quadrant and one each in the four corner quadrants for establishing aquifer geometry and determining aquifer parameters. (Fig-B1). Location of EW/OW in corner quadrants can be changed in adjacent toposheets to insure uniform distribution.

iii. For the first aquifer 4-5 pumping test are be carried out in dug wells/ if possible in shallow bore wells.

iv. Aquifer performance test shall be conducted at all the five EW‟s tapping the fractured aquifer to estimate the aquifer hydraulic parameters and water quality.

Fig-B1

Sample- Data required for <u>Two</u> Aquifer group system in Hard rock areas (for IInd Aquifer)

EW – 1 OW – 1		EW – 1 OW – 1
	EW – 1 OW – 1	
EW – 1 OW – 1		EW – 1 OW – 1

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy (Adequacy of available sub-surface information for deciphering aquifer geometry at the desired vertical & horizontal scale) is to be done based on recommended and available information.

ii. Aquifer wise parameters availability (T and S/Sy) *or non-availability* upto the desired depth should be presented in form of square diagram for each quadrant. (Fig-B2)

iii. Quadrant wise recommended and existing EW/OW/PZ/SH should be depicted using square diagram and the additional EW/OW/PZ/SH etc. required for aquifer geometry delineation should be assessed (Fig-B3).

Fig-B2

Sample- Data adequacy of exploratory data for <u>Two</u> Aquifer group system in Hard rock areas (quadrant wise)

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC	Aq. Gp.	Dpth of Aq.	Aq. parameters	EC	Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist				Ist				Ist			
IInd				IInd				IInd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC	Aq. Gp.	Dpth of Aq.	Aq. parameters	EC	Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist				Ist				Ist			
IInd				IInd				IInd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC	Aq. Gp.	Dpth of Aq.	Aq. parameters	EC	Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist				Ist				Ist			
IInd				IInd				IInd			

Fig-B3

Sample- Data gap analysis for exploratory data of <u>Two</u> Aquifer group system in Hard areas (quadrant wise)

Aq. Gp.	EW/OW/SH/PZ			Aq. Gp.	EW/OW/SH/PZ			Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			

Aq. Gp.	EW/OW/SH/PZ			Aq. Gp.	EW/OW/SH/PZ			Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			

Aq. Gp.	EW/OW/SH/PZ			Aq. Gp.	EW/OW/SH/PZ			Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			

b. Geophysical Data

- ***Data Required***

i. Desirable spatial scale should be 5" x 5" grids and 200 m depth.

ii. It is recommended that 2 to 3 Profiling/VES/TEM soundings upto 200 meter interpretation depth should be carried out in each of the nine quadrants of the toposheet totaling to 18 to 27 nos. in each sheet to decipher aquifer geometry (Fig-B4).

Fig-B4

Sample- Geophysical Data required for <u>Two</u> Aquifer group system in Hard Rock areas

2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM
2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM
2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM	2/3 Profiling/ VES/TEM

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-B5)

ii. Quadrant wise recommended and existing VES/TEM profiling data should be depicted using square diagram and the additional VES/TEM required for aquifer geometry delineation should be assessed (Fig-B6).

Fig-B5

Sample- Data adequacy of Geophysical data for <u>Two</u> Aquifer group system in Hard areas (quadrant wise)

<table>
<tr><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td></tr>
<tr><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td></tr>
<tr><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td></tr>
</table>

Fig-B6

Sample- Data gap analysis for geophysical data of <u>Two</u> Aquifer group system in Hard areas (quadrant wise)

<table>
<tr><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td></tr>
<tr><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td><td><table><tr><td>Aq. Gp.</td><td colspan="3">VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td></tr>
</table>

c. Ground Water Monitoring Data

- ***Data Required***

i. Desirable spatial scale should be 5" x 5" grids and 200 m depth.

ii. For 1st aquifer (un-confined/Phreatic) one open/dug wells are recommended for each quadrant of a toposheet. (Fig-B7)

iii. For 2nd aquifer (fractured zone) the OW constructed may be used as piezometers for GW monitoring. (Fig-B7)

iv. Minimum four times monitoring annually is recommended as per the state specific schedule of monitoring.

Fig-B7

Sample- GW Monitoring Data required for <u>Two</u> Aquifer group system in hard rock areas

Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1
Ist Aq - 1	Ist Aq - 1 IInd Aq - 1	Ist Aq - 1
Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-B8)

ii. Quadrant wise recommended and existing DW/PZ should be depicted using square diagram and the additional DW/PZ required for ground water monitoring should be assessed (Fig-B9).

Fig-B8

Sample- Data adequacy of GW Monitoring data for Two Aquifer group system in Hard rock areas (quadrant wise)

Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N
Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N
Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N

Fig-B9

Sample- Data gap analysis for GW Monitoring data of Two Aquifer group system in Hard Rock areas (quadrant wise)

Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			
Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			
Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			

d. Ground Water Quality Data

- ***Data Required***

i. Desirable spatial scale should be 5‟ x 5‟ grids and 200 m depth.
ii. For 1st aquifer (un-confined/Phreatic) one sample from open/dug wells is recommended for each quadrant of a toposheet. (Fig-B10)
iii. For 2nd aquifer (fractured zone) the water sample may be collected from EW constructed for GW quality monitoring. (Fig-B10)
iv. Minimum two times monitoring initially is recommended for quality monitoring.

Fig-B10

Sample- GW Quality Data required for Two Aquifer group system in hard rock areas

Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1
Ist Aq - 1	Ist Aq - 1 IInd Aq - 1	Ist Aq - 1
Ist Aq - 1 IInd Aq - 1	Ist Aq - 1	Ist Aq - 1 IInd Aq - 1

- ***Data Adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information and depicted as in Fig-B11.
ii. Quadrant wise recommended and existing quality monitoring stations should be depicted using square diagram and the additional quality monitoring stations required should be assessed (Fig-B12)

Fig-B11

Sample- Data adequacy of GW Quality data for Two Aquifer group system in Hard Rock Area (quadrant wise)

Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N

Fig-B12

Sample- Data gap analysis for GW Quality data of Two Aquifer group system in Hard Rock areas (quadrant wise)

Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			

C. Basaltic areas

a. Exploratory Data

- ***Data Required***

i. Desirable spatial scale should be 5‟ x 5‟ grids and 200 m depth.
ii. In these areas 7 EW‟s and 7 OW‟s should be constructed at suitable locations. One EW and one OW tapping each of the three aquifers should be constructed in the central quadrant (or any other suitable quadrant). One EW and one OW tapping IInd or IIIrd aquifer should be constructed in the corner quadrants for establishing aquifer geometry and determining aquifer parameters. (Fig-C1) Number of EW/OW can be changed depending on local hydrogeological conditions. . Location of EW/OW in corner quadrants can be changed in adjacent toposheets to avoid clusters and insure uniform distribution.
iii. Site for OW‟s should be selected by Mise-a-la-Masse method to encounter the same aquifer and mapping the aquifer geometry.
iv. For the first aquifer 4-5 pumping test are be carried out in dug wells/ if possible in shallow bore wells.
v. Aquifer performance test shall be conducted at all the seven EW‟s tapping the various aquifers to estimate the aquifer hydraulic parameters and water quality.

Fig-C1

Sample- Data required for 2/3 Aquifer group system in Basaltic areas (for Ist, IInd or IIIrd Aquifers)

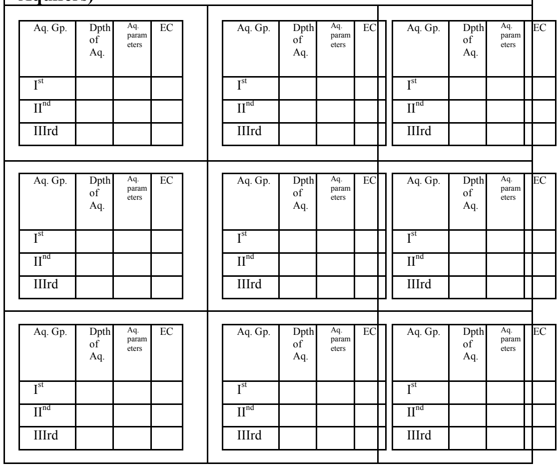
EW – 1 OW – 1 (second/Third aquifer)		EW – 1 OW – 1 (Second aquifer)
	Well Field EW – 2/3 OW – 2/3 (one in each aquifer)	
EW – 1 OW – 1 (Second aquifer)		EW – 1 OW – 1 (second/Third aquifer)

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy (Adequacy of available sub-surface information for deciphering aquifer geometry at the desired vertical & horizontal scale) is to be done based on recommended and available information.
ii. Aquifer wise parameters availability (T and S/Sy) *or non-availability* upto the desired depth should be presented in form of square diagram for each quadrant. (Fig-C2)
iii. Quadrant wise recommended and existing EW/OW/PZ/SH should be depicted using square diagram and the additional EW/OW/PZ/SH etc. required for aquifer geometry delineation should be assessed (Fig-C3).

Fig-C2

Sample- Data adequacy of exploratory data for 2/3 Aquifer group system in Basaltic areas (for Ist, IInd and IIIrd Aquifers)



Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

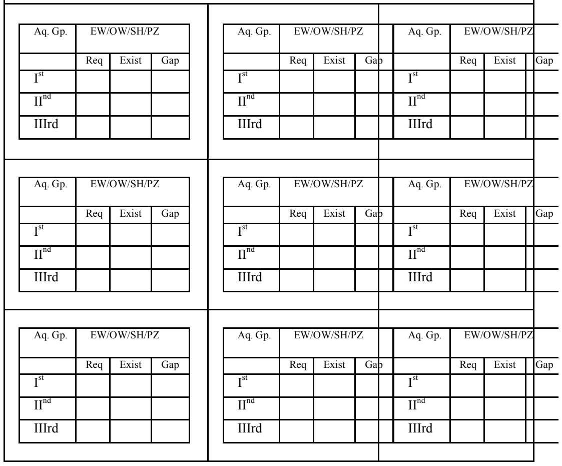
Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			
IInd			
IIIrd			

Fig-C3

Sample- Data gap analysis for exploratory data for 2/3 Aquifer group system in Basaltic areas (for Ist, IInd or IIIrd Aquifers)



Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			
IInd			
IIIrd			

b. Geophysical Data

- ***Data Required***

i. Desirable spatial scale should be 5'' x 5'' grids and 200 m depth.

ii. It is recommended that 2 to 3 Profiling/ VES/TEM soundings upto 200 meter interpretation depth should be carried out in each of the nine quadrants of the toposheet totaling to 18 to 27 nos. in each sheet to decipher aquifer geometry (Fig-C4).

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-C5)

ii. Quadrant wise recommended and existing Profiling/VES/TEM profiling data should be depicted using square diagram and the additional Profiling/VES/TEM required for aquifer geometry delineation should be assessed (Fig-C6).

Fig-C4

Sample- Geophysical Data required for 2/3 Aquifer group system in Basaltic areas

2 to 3 Profiling/ VES/TEM	2 to 3 Profiling/ VES/TEM	2 to 3 Profiling/ VES/TEM
2 to 3 Profiling/ VES/TEM	2 to 3 Profiling/ VES/TEM	2 to 3 Profiling/ VES/TEM
2 to 3 Profiling/ VES/TEM	2 to 3 Profiling/ VES/TEM	2 to 3 Profiling/ VES/TEM

Fig-C5

Sample- Data adequacy of Geophysical data for 2/3 Aquifer group system in Basaltic areas (quadrant wise)

<table>
<tr>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
</tr>
<tr>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
</tr>
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<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr><tr><td>IInd</td><td>Y/N</td></tr><tr><td>IIIrd</td><td></td></tr></table></td>
</tr>
</table>

Fig-C6

Sample- Data gap analysis for geophysical data of 2/3 Aquifer group system in Basaltic areas (quadrant wise)

<table>
<tr>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
</tr>
<tr>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
</tr>
<tr>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr><tr><td>IInd</td><td></td><td></td><td></td></tr><tr><td>IIIrd</td><td></td><td></td><td></td></tr></table></td>
</tr>
</table>

c. Ground Water Monitoring Data

- ***Data Required***

i. Desirable spatial scale should be 5'' x 5'' grids and 200 m depth.

ii. For 1st aquifer (un-confined/Phreatic) one open/dug wells are recommended for each quadrant of a toposheet. (Fig-C7). In addition EW/OW constructed should be used for monitoring.

iii. For 2nd or 3rd aquifer the EW/OW constructed should be used as piezometers for GW monitoring. (Fig-C7)

iv. Minimum four times monitoring annually is recommended as per the state specific schedule of monitoring.

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-10)

ii. Quadrant wise recommended and existing DW/PZ should be depicted using square diagram and the additional DW/PZ required for ground water monitoring should be assessed (Fig-11).

Fig-C7

Sample- GW Monitoring Data required for 2/3 Aquifer group system in Basaltic areas

I Aq - 1 II/III Aq - 1	I Aq - 1	I Aq - 1 II Aq - 1
I Aq - 1	I Aq - 1 II/III Aq – 1	I Aq - 1
I Aq - 1 II Aq - 1	I Aq - 1	I Aq - 1 II/III Aq - 1

Fig-C8

Sample- Data adequacy of GW Monitoring data for 2/3 Aquifer group system in Basaltic areas (quadrant wise)

Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N
Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N
Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ	Aq. Gp.	DW/PZ
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N

Fig-C9

Sample- Data gap analysis for GW Monitoring data of 2/3 Aquifer group system in Basaltic areas (quadrant wise)

Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			
Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			
Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ			Aq. Gp.	DW/PZ		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			

d. Ground Water Quality Data

- ***Data Required***

i. Desirable spatial scale should be 5‟ x 5‟ grids and 200 m depth.
ii. For 1st aquifer (un-confined/Phreatic) one sample from open/dug wells is recommended for each quadrant of a toposheet. (Fig-C10)
iii. For 2nd or 3rd aquifer the water sample may be collected from EW constructed for GW quality monitoring. (Fig-12)
iv. Minimum two times monitoring initially is recommended for quality monitoring.

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information and depicted as in Fig-C11.
ii. Quadrant wise recommended and existing quality monitoring stations should be depicted using square diagram and the additional quality monitoring stations required should be assessed (Fig-C12)

Fig-C10

Sample- GW Quality Data required for 2/3 Aquifer group system in Basaltic rock areas

I Aq - 1 III Aq -1	I Aq - 1	I Aq - 1 II Aq – 1
I Aq - 1	I Aq - 1 II Aq – 1 III Aq -1	I Aq - 1
I Aq - 1 II Aq – 1	I Aq - 1	I Aq - 1 III Aq -1

Fig-C11

Sample- Data adequacy of GW Quality data for 2/3 Aquifer group system in Basaltic areas (quadrant wise)

Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N
Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N
Aq. Gp.	Sample point	Aq. Gp.	Sample point	Aq. Gp.	Sample point
Ist	Y/N	Ist	Y/N	Ist	Y/N
IInd	Y/N	IInd	Y/N	IInd	Y/N
III	Y/N	III	Y/N	III	Y/N

Fig-C12

Sample- Data gap analysis for GW Quality data of 2/3 Aquifer group system in Basaltic areas (quadrant wise)

Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			
Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			
Aq. Gp.	Sample point			Aq. Gp.	Sample point			Aq. Gp.	Sample point		
	Req	Exist	Gap		Req	Exist	Gap		Req	Exist	Gap
Ist				Ist				Ist			
IInd				IInd				IInd			
III				III				III			

D. FOR HILLY AREAS

a. Exploratory Data

- ***Data Required***

i. Desirable spatial scale should be 5‟ x 5‟ grids and 100 m depth depending upon the area attributes.

ii. In hilly areas 10 EW‟s and 10 OW‟s should be constructed (wherever possible) at suitable locations, preferably one in central quadrant and one each in the four corner quadrants for establishing aquifer geometry and determining aquifer parameters. (Fig-D1)

iii. For the first aquifer 3-4 pumping test are be carried out in dug wells/ if possible in shallow bore wells.

iv. Aquifer performance test shall be conducted at all the ten EWs tapping different aquifers to estimate the aquifer parameters/ hydraulic characteristics and water quality.

Fig-D1

Sample- Data required for the Aquifer in Hilly areas

EW – 2 OW – 2		EW – 2 OW – 2
	EW – 2 OW – 2	
EW – 2 OW – 2		EW – 2 OW – 2

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy (Adequacy of available sub-surface information for deciphering aquifer geometry at the desired vertical & horizontal scale) is to be done based on recommended and available information.

ii. Aquifer parameter availability upto the desired depth should be presented in form of square diagram for each quadrant. (Fig-D2)

iii. Quadrant wise recommended and existing EW/OW/PZ/SH should be depicted using square diagram and the additional EW/OW/PZ/SH etc. required for aquifer geometry delineation should be assessed (Fig-D3).

Fig-D2

Sample- Data adequacy of exploratory data for Aquifer in Hilly areas (quadrant wise)

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Aq. Gp.	Dpth of Aq.	Aq. parameters	EC
Ist			

Fig-D3

Sample- Data gap analysis for exploratory data of Aquifer in hilly areas (quadrant wise)

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

Aq. Gp.	EW/OW/SH/PZ		
	Req	Exist	Gap
Ist			

b. Geophysical Data

- ***Data Required***

i. Desirable spatial scale should be 5‟ x 5‟ grids and 100 m depth depending upon the site attributes.(wherever possible)

ii. It is recommended that 2 Profiling/VES/TEM soundings having 100 meter interpretation depth should be carried out in each of the nine quadrants of the toposheet totaling to 18 nos. in each sheet to decipher aquifer geometry (Fig-D4).

iii. It is recommended that all the Exploratory Wells should be e-logged and the data should be tabulated.

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-D5)

ii. Quadrant wise recommended and existing VES/TEM profiling data should be depicted using square diagram and the additional Profiling/ VES/TEM required for aquifer geometry delineation should be assessed (Fig-D6).

<table>
<tr><td colspan="3">Fig-D4
Sample- Geophysical Data required for Aquifer in Hilly Areas (Quadrant wise)</td></tr>
<tr><td>2 Profiling/ VES/TEM</td><td>2 Profiling/ VES/TEM</td><td>2 Profiling/ VES/TEM</td></tr>
<tr><td>2 Profiling/ VES/TEM</td><td>2 Profiling/ VES/TEM</td><td>2 Profiling/ VES/TEM</td></tr>
<tr><td>2 Profiling/ VES/TEM</td><td>2 Profiling/ VES/TEM</td><td>2 Profiling/ VES/TEM</td></tr>
</table>

<table>
<tr><td colspan="3">Fig-D5
Sample- Data adequacy of Geophysical data for Aquifer in Hilly Areas (quadrant wise)</td></tr>
<tr>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr></table></td>
<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr></table></td>
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<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr></table></td>
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<td><table><tr><td>Aq. Gp.</td><td>VEM/ TEM</td></tr><tr><td>Ist</td><td>Y/N</td></tr></table></td>
</tr>
</table>

<table>
<tr><td colspan="3">Fig-D6
Sample- Data gap analysis for Geophysical data of Aquifer in Hilly Areas (quadrant wise)</td></tr>
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<td><table><tr><td>Aq. Gp.</td><td colspan="3">Profiling/ VES/TEM</td></tr><tr><td></td><td>Req</td><td>Exist</td><td>Gap</td></tr><tr><td>Ist</td><td></td><td></td><td></td></tr></table></td>
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c. Ground Water Monitoring Data

- ***Data Required***

i. Desirable spatial scale should be 5‟ x 5‟ grids and 100 m depth.

ii. One open/dug well is recommended for each quadrant of a toposheet. (Fig-12)

iii. All the spring sheds in a toposheet should be demarcated and only sustainable spring sheds are to be taken for discharge and quality monitoring.

iv. Minimum four times monitoring annually is recommended as per the state specific schedule of monitoring.

<table>
<tr><td colspan="3">Fig-D7
Sample- GW Monitoring Data required for the Aquifer in hilly areas</td></tr>
<tr><td>Ist Aq – 1</td><td>Ist Aq - 1</td><td>Ist Aq - 1</td></tr>
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- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information.(Fig-D8)

ii. Quadrant wise recommended and existing DW/PZ should be depicted using square diagram and the additional DW/PZ required for ground water monitoring should be assessed (Fig-D9).

Fig-D8

Sample- Data Adequacy of GW Monitoring Data for the Aquifer in hilly areas

Aq. Gp. DW/PZ Ist Y/N	Aq. Gp. DW/PZ Ist Y/N	Aq. Gp. DW/PZ Ist Y/N
Aq. Gp. DW/PZ Ist Y/N	Aq. Gp. DW/PZ Ist Y/N	Aq. Gp. DW/PZ Ist Y/N
Aq. Gp. DW/PZ Ist Y/N	Aq. Gp. DW/PZ Ist Y/N	Aq. Gp. DW/PZ Ist Y/N

Fig-D9

Sample- Data Gap Analysis for GW Monitoring Data for the Aquifer in hilly areas

Aq. Gp. DW/PZ Req Exist Gap Ist	Aq. Gp. DW/PZ Req Exist Gap Ist	Aq. Gp. DW/PZ Req Exist Gap Ist
Aq. Gp. DW/PZ Req Exist Gap Ist	Aq. Gp. DW/PZ Req Exist Gap Ist	Aq. Gp. DW/PZ Req Exist Gap Ist
Aq. Gp. DW/PZ Req Exist Gap Ist	Aq. Gp. DW/PZ Req Exist Gap Ist	Aq. Gp. DW/PZ Req Exist Gap Ist

d. Ground Water Quality Data

- ***Data Required***

i. Desirable spatial scale should be 5" x 5" grids and 200 m depth.
ii. For 1st aquifer (un-confined/Phreatic) one sample from open/dug wells is recommended for each quadrant of a toposheet. (Fig-D10)
iii. Quality of available springs should be monitored.
iv. Minimum two times monitoring initially is recommended for quality monitoring.

- ***Data adequacy and Data gap analysis***

i. Assessment of Data Adequacy is to be done based on recommended and available information and depicted as in Fig-D11.
ii. Quadrant wise recommended and existing quality monitoring stations should be depicted using square diagram and the additional quality monitoring stations required should be assessed (Fig-D12)

Fig-D10

Sample- GW Quality Data required for the Aquifer in hilly areas

Ist Aq - 1	Ist Aq - 1	Ist Aq - 1
Ist Aq - 1	Ist Aq - 1	Ist Aq - 1
Ist Aq - 1	Ist Aq - 1	Ist Aq - 1

Fig-D11

Sample- Data Adequacy for GW Quality Data for the Aquifer in hilly areas

Aq. Gp. Sample point Ist Y/N	Aq. Gp. Sample point Ist Y/N	Aq. Gp. Sample point Ist Y/N
Aq. Gp. Sample point Ist Y/N	Aq. Gp. Sample point Ist Y/N	Aq. Gp. Sample point Ist Y/N
Aq. Gp. Sample point Ist Y/N	Aq. Gp. Sample point Ist Y/N	Aq. Gp. Sample point Ist Y/N

Fig-D12

Sample- Data Gap analysis for GW Quality4 Data for the Aquifer in hilly areas

Aq. Gp. Sample point Req Exist Gap Ist	Aq. Gp. Sample point Req Exist Gap Ist	Aq. Gp. Sample point Req Exist Gap Ist
Aq. Gp. Sample point Req Exist Gap Ist	Aq. Gp. Sample point Req Exist Gap Ist	Aq. Gp. Sample point Req Exist Gap Ist
Aq. Gp. Sample point Req Exist Gap Ist	Aq. Gp. Sample point Req Exist Gap Ist	Aq. Gp. Sample point Req Exist Gap Ist

4.2.5 Data Gap in Ground Water Recharge and Draft components

Recharge and discharge parameters are vital in assessing the status of ground water resources in the aquifers. Rainfall, recharge from canals, surface water bodies and tanks and recharge from applied irrigation constitute the major sources of recharge, whereas ground water draft for various uses, base flow into streams and evapotranspiration in shallow water table areas constitute the major components of ground water draft.

4.2.5.1 Data gap in ground water recharge components

As per the guidelines of the Ground Water Estimation Committee of Government of India, data pertaining to aquifer geometry (vertical & lateral), rainfall, ground water levels/piezometric heads, canal command area, cropping pattern, surface water bodies, aquifer parameters (specific yield / storativity) and ground water quality are required for realistic assessment of ground water recharge. Modalities of collection, compilation and processing of data pertaining to all these components have already been elaborated in the previous chapter of this manual. The data gap analysis in respect of recharge components will consist mainly of assessment of inadequacy of data in respect of the components and plans to generate/collect additional data in the data generation phase of the project.

4.2.5.2 Data gap in ground water draft components

Ground water draft from the aquifers is generally for irrigation, domestic and industrial uses. Irrigation sector is the major user of ground water from aquifers in the major part of the country. Season-wise unit draft and the number of ground water abstraction structures in each aquifer zone used for irrigation are vital for realistic assessment of ground water draft. Data pertaining to crop-water requirements and prevailing cropping pattern in the area are often used to cross check the estimated ground water draft. Data pertaining to population, per-capita water requirement, number of industrial units, their water requirements and the number and types of abstraction structures used for ground water extraction are required to assess the domestic and industrial ground water draft. As mentioned in the case of recharge components, the data gap analysis in ground water draft components will also consist mainly of assessing the inadequacy of the components mentioned and plans for additional data generation to facilitate realistic ground water draft assessment.

5. DATA GENERATION

5.1 Introduction

In the context of National Aquifer Mapping and Management Program, data generation consists of generation/collection of additional data to fill up the identified data gaps in respect of thematic layers, subsurface data and ground water recharge/draft components. Data generation may often require tailor-made field investigations aimed at generating data pertaining to one or more aquifer zones in standard formats developed for the purpose.

The activities for data generation can broadly be classified into the following groups:

- Hydrological and hydrogeological investigations
- Exploratory drilling
- Geophysical investigations
- Ground water levels and water quality monitoring
- Hydrochemical investigations and analyses
- Isotope studies / Carbon dating
- Techno-economic studies.

Details of data to be generated from these activities are summarized in **Table 5.1**

Table 5.1: Activities for data generation for Aquifer Mapping.

Sl.No	Activity/study	Sub-activity	Data to be generated
1	Hydrological	Soil infiltration studies	Soil infiltration rates Rainfall infiltration factor
		Determination of Recharge / Draft Parameters (Through sample surveys)	Recharge parameters (Recharge through canals, surface water/ground water irrigation, water bodies etc.) Draft parameters (Season-wise unit draft)
2	Hydrogeological	Well inventory	Subsurface geological information Thickness of weathered zone Fracture density Basement topography
		Pumping tests/Slug tests	Aquifer parameters (Sy,K,T,S)
		Ground water draft estimation	Unit drafts of ground water abstraction structures for various uses.
		Determination of Specific yield	Specific yields of various litho-units in

		through dry season water balance studies	the phreatic zone
		Ground water level/piezometric heads monitoring	Depth to water levels/Piezometric heads, Seasonal fluctuations, Ground water flow direction.
3	Exploratory drilling & Pump tests.	Exploratory drilling Slug tests Aquifer performance tests	Sub-surface lithology Aquifer parameters
3	Geophysical	Vertical Electrical sounding	Sub-surface hydrogeologic information to supplement data collected from exploratory drilling and to provide sub-surface data in areas not feasible for exploratory drilling.
		Borehole logging	
		Profiling	
		Resistivity imaging	
		Ground/Heli-borne TEM	
		Seismic/Gravity/Magnetic surveys	
4	Hydrochemical	Collection of water samples (both surface & ground water)	Spatial and temporal variations in ground water quality Ground water contamination issues
5	Isotope studies / carbon dating	Stable & environmental isotope studies Carbon dating of ground water/ sub-surface lithological samples	Information on ground water recharge and discharge parameters, residence time of ground water in aquifers etc. Age of ground water & sub-surface formations
6	Techno-economic studies	Sample survey of investments & returns in ground water irrigation	Economic aspects of ground water use in the aquifer.

6. AQUIFER MAP PREPARATION

6.1 Introduction:

Once the collection, compilation, data gap analysis and additional data generation to fill the identified data gap are completed, the final and most important step is the preparation of the aquifer map, which brings together various aspects of the aquifers and their ground water resources in the form of a map, which can then be used by the stakeholders to plan their sustainable development and management. Aquifer map preparation essentially involves the following activities

- Digitization of aquifer map and preparing aquifer GIS Data sets.
- Preparation of GIS datasets of aquifer thickness, depth of occurrences of water bearing zones, their water bearing and transmission properties, etc.
- Digitization of the Maps and preparing GISDatasets depicting geophysical parameters.
- Digitization of the Maps and preparing GIS Datasets depicting water quality parameters
- Digitization of the Maps and preparing GIS Datasets depicting status of ground water resources.
- Preparation of conceptual model of the area and visualization of the aquifer units in threedimension including fence and cross section preparation.

6.2 Methodology

The processes of digitisation, preparing GIS dataset and finally printing involve various steps. These have been elucidated in the following flow diagram (**Fig.6.1**)

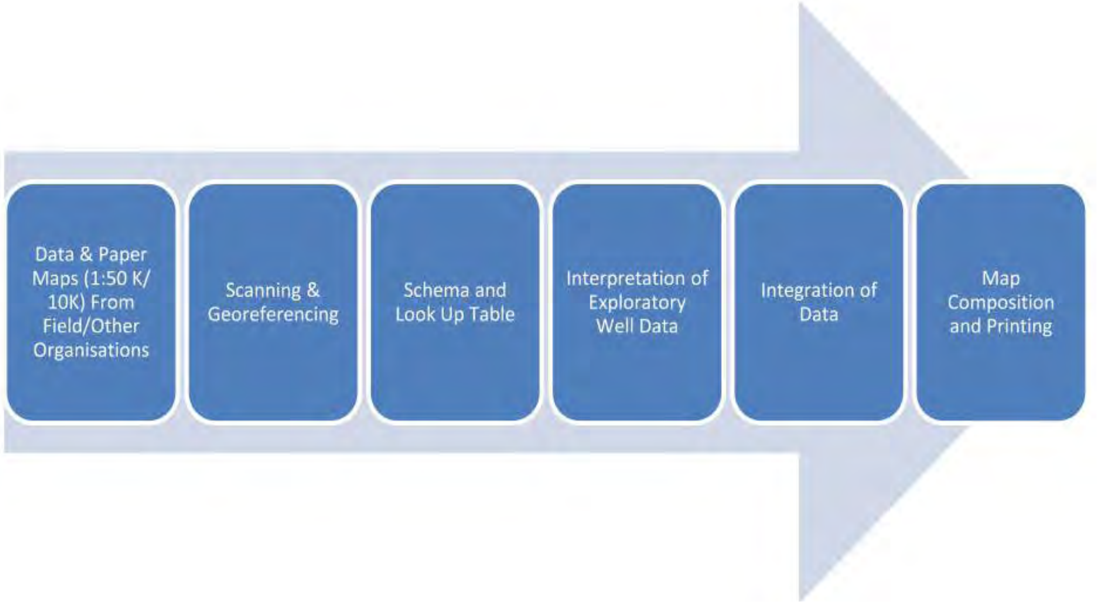

Fig.6.1: Flow diagram showing the preparation of aquifer maps

6.2.1 Scanning & Geo-referencing

The spatial database for each layer will be organized in a grid of 15 minutes by 15 minutes geographic area, corresponding to a SOI 1:50000 scale map sheet. Each map tile will then be assigned a unique number. Thematic coverage of any specific hydrologic or administrative unit will be generated by digitally mosaicking the map tiles. Standard and unique "TIC Ids" will be created for each cross-section of latitude and longitude at 15 minutes interval. All maps will be digitized by taking TIC points at four corners of each 15-minute tile, and the appropriate Id will be assigned. Additional registration points (permanent man-made features) will be digitized to enable co-registration of scanned maps without lat- long details. The registration point Id will be the map tile number followed by a serial number. All the map sheets (of each theme) in each State will be transformed to the Lambert Conformal Conic (LCC) projection using the central latitude and longitude of projection origin of the State. The code for each primary theme as also the data structure of the Look Up Table (LUT) need to be finalized before starting digitization of the theme. Each primary data coverage will be named as for example Landuse54K06 representing the theme and SOI map sheet number, and all associated files will have this identification as the prefix. The metadata of each of the layers would be prepared, having information on the source, scale, age etc. of the data. The details of data proposed to be digitized/ procuredare furnished in **Table.6.1**.

Table 6.1: GIS data proposed to be digitized / procured for National Aquifer Mapping

S.No	Theme	Type	Source
A	**Aquifer Maps**		
1	Aquifer Map	Polygon	In house Data analysis
2	Isopach (aquifers thickness) Map & Aquifer top and bottoms, Bed Rock topography		In house Data analysis
B	**Derivative Maps**		
1	GW-SW interaction	Polygon	In house Data analysis
2	Demand Supply Map	Polygon	In house Data analysis
3	Environmental Protection Area Map	Polygon	In house Data analysis
4	Drinking Water Supply Source Map	Polygon	In house Data analysis
5	Industrial Zone map	Polygon	In house Data analysis
6	Water Market & Others Map	Polygon	In house Data analysis
C	**Management options support maps**		
1	Population	Points	Census
2	Land Use/ Cover	Polygon	NRSC
3	Soil	Polygon	NBSS
4	Geology - lithology	Polygon	GSI
5	Geology - structure	Line	GSI
6	Geomorphology	Polygon	NRSC/ In house Data Analysis
7	Hydrologic boundary	Polygon	In house
8	Drainage	Line	SOI/ DEM In house Data Analysis
9	Transport network Road/ Rail Line	Line	SOI
10	Contours	Line	SOI/ DEM In house Data Analysis

11	Spot heights	Point	SOI
12	Administrative boundary	Polygon	SOI
13	Block Boundary	Polygon	SOI
14	Village Boundary	Polygon	SOI
15	Towns	Point	SOI
16	Isohyetal Map	Line	In house Data analysis of IMD Data
17	Groundwater quality	Polygon	In house Data analysis
18	Isotope study results	Point/polygon	In house Data analysis
19	C 14 Study results	point	In house Data analysis
20	GW Pollution (Domestic / Agricultural / Industrial)	Polygon	In house Data analysis
DManagement Option Maps			
29	Suitable Area for Artificial Recharge	Polygon	In house Data analysis
30	Water Quality Amelioration Maps	Polygon	In house Data analysis
31	Suitable Area for GW Development	Polygon	In house Data analysis

Once the paper mapsare ready, the same shall be scanned and digitized using an appropriate scanner following standard procedures. The geo-database (ESRI) shall be created and edited to remove digitization errors, and the topology shall be built. The features shall be labeled and coded as defined in the attribute table of the each layer. The features shall then be transformed into on LCC projection. The transformation process shall involve geometric rectification through Ground Control Points (GCPs) identified on the input features and corresponding SOI map.

6.2.2 Schema and Look-up Table

For geospatial analysis between layers, each of the layers needs to have a schema (structure) and be attached with attributes (data). The schema for each layer will be prepared and standards defining the attributes shall be prepared. The attributes defined for a layer will be attached with each entity in the respective layer. The National Resource Information System (NRIS) coding scheme for creating structures of the attribute tables and attaching attributes to the features classes may be adopted as is being done by various Government agencies such as NSDI, NIC, NRSCetc.

6.2.3 Interpretation of exploratory well data

Central Ground Water Board and many States Ground Water Departments have vast repository of data pertaining to wells drilled for exploratory purposes, drinking water supply and irrigation purposes. This data can provide valuable information on the third dimension of the aquifer systems and their configuration over the area along with hydraulic properties.

Presently, the lithological data collected from the drilling programsof CGWB and the other State Governments do not follow standard protocols and nomenclature of the litho-units. Hence, the data cannot be used directly as input to any standard interpolation and modeling software in the present form. There is a need to reclassify the available lithological data following the standard international nomenclature system, preferably adopting the same lithology‟s as accepted for Aquifer Atlas of India or having further subdivision as proposed for the Aquifer Systems to be demarcated on 1:50, 000 scale.

Using this reinterpreted data, lithological model of an area can be developed using suitable litho-modeling software available in the market. The output of these models will be in form of 2D strip-logs, cross sections and 3D modeled fence diagrams. These diagrams will help in establishing the linkages between the smaller (children) units of the aquifers forming a major (Parent) aquifer unit over a bigger area. These diagrams will further give a general layout of the aquifers in the area depicting smaller units also. These can be used as input to the local models for managing local aquifers. However, lithological models have their limitations and are rarely useful for regional level model interpolation. The smaller aquifer need to be bunched/grouped under major aquifer systems. These re-grouped systems are the major aquifer systems covering large areas and can be further used for regional level aquifer management.

The lithological and stratigraphic models of the aquifers will provide three-dimensional configurations, aquifer tops, aquifer bottoms and their thicknesses over the area of occurrence. The major constraint of such interpolation modeling software is non-availability of the Reduce Level data of the data points and lesser density of the available data points. Hence, the RL survey will be the first data requirement for building such models. The output of these models can be exported to GIS files for using as input for preparing aquifer maps to be presented in 2D and modeling software for development of optimal water resources utilization plans.

6.2.4 Integration of data

The GIS data created and data obtained from various statistical analyses would be integrated in GIS environment with the derived aquifer information to generate composite maps in respect of aquifers. These maps would provide area and location specific information for judicious management of ground water resources in them in a user friendly manner. These maps can grouped in three categories namely, aquifer maps, aquifer properties & vulnerability maps and aquifer management option maps.

- The aquifer maps may depict the aquifer extents, bed rock configuration etc. along with the locational features. 2D and 3D diagrams can be presented on the aquifer map as insets.
- Derivative maps depict aquifer properties such as hydraulic properties, water quality, water resources availability, water stressed and contaminated area.
- The management options depends on several factors such as terrain characteristics, aquifer media, depth to water, hydraulic conductivity, net recharge, impact of vadose zone etc. All these factors when used in combination will facilitate suitable management options for areas under consideration. The major inputs into such maps are the socio-economic data and data collected from other related departments. These maps will be simpler, depicting the target area along with management options recommended.

6.2.5 Map Composition and Printing

6.2.5.1 Lay-out and design

As discussed in the previous paragraphs,all map data for the maps will be generated in GIS environment. Since these data will consist of point, line or polygon features and hence difficult to be clearly understood by the stakeholders, they will have to be color coded and annotated with standard labels for easy understanding.

Since these maps will be used as the base for formulation and implementation of various scientific interventions for the management of ground water resources, they have to be presented on a suitable scale, preferably on 1:50,000 scale having standard 15 minutes by 15 minutes coverage. The hard copy format will be available in the form of A0 size map (1 / 1.2 meter paper print). Each map will cover an area of approximately 720 sq. km corresponding to one Survey of India (SOI) toposheet on 1:50, 000 scale and will also consist of an exhaustive self-explanatory legend. The aquifer map will also be made available as soft copy in PDF format also so that it can be viewed using a normal computer system with appropriate software. However, to view the map along with latitude - longitude information (map in Geo-PDF format), Adobe Acrobat Reader software 9.3.1 or higher version will be required. Maps will have important geographical features such as village locations, roads, railway lines, administrative boundaries etc.to help the users locate their areas of interest.

The map title, fonts, styles, color scheme, annotation styles etc. should be the same as used in Survey of India toposheets. The color coding scheme and symbology for aquifer systems on 1:50,000 scale maps shouldbe distinct and standardized for an area and should be uniformly used throughout India. The map title should occupy the center position and north arrow should be on the top right. The map should also bear a logo of Central Ground Water Board, along with copyright information at the lower left corner.

6.2.5.2 Map legend

Legend is the key to the map and help in reading the map information. The number of themes, their color schemes and font give richness to the map and help in understanding it in a user friendly manner. The international legend style will be used in preparation of aquifer maps. The fonts, styles, color scheme, annotation styles etc. of the legends should be adopted from the Survey of India toposheets and aquifer Atlas of India. The legend should occupy preferably the lower right part of the map frame. The final output maps may present the information generated by the various organizationswhich need to be acknowledged suitably. The sources of the data shall be mentioned in each map outside bottom left of the map frame to acknowledge the work of peer agencies. The map should preferably have the following information:

- Map Title
- Method followed in preparing the Map
- Map Scale
- Map number - Survey of India 1:50,000 scale toposheet index number
- Administrative area covered by the map
- Geographical directions of the map area
- Copyright information
- Input data used for preparing the map
- Organization which has prepared the map
- Index for Aquifer Map - Fixed part of the legend
- Index for hydrological Information - Fixed part of the legend
- Index for base map Information - Fixed part of the legend
- Body of the map
- Main Legend of the map - Dynamic part of the legend describes body of the map taking
- Location map - index

6.3 Data back-up and storage

The backup of GIS data and printed maps would be stored in portable hard disk drives. The GIS data prepared under the project shall be stored in such a way as to provide direct access to users without use of proprietary software through a suitably designed web-based system for easy dissemination of the information.

7. PARTICIPATORY GROUND WATER MANAGEMENT

7.1 Objectives of Participatory Ground Water Management(PGWM)

The objectives of PGWM are:

- Capacity Building of farmers and ground water users for efficient monitoring of ground waterregime.
- Capacity building of groundwater using farmers for increasing water use efficiency
- Efficient management of groundwater and informed decision making on cropping pattern andapplication of water at a collective level so as to benefit all groundwater user farmers.

The outputs that are expected to accrue from PGWM are as follows:

- Enhanced capacity of the farmers in utilizing groundwater efficiently
- Increased groundwater use efficiency in irrigation
- Sustainable exploitation and stabilization of the groundwater by adopting a suitable croppingpattern

7.2 Activities Envisaged Under the PGWM

The activities to be implemented under PGWM are:

- Water User Associations (WUAs) can be strengthened to include ground water users or may beexclusively constituted as Ground Water Management Association (GWMAs). The formulationand capacity building of GWMAs is an integral part of PGWM. The Para-Hydrogeologists (PHGs)or Jal Surakshaks to be responsible for primary data collection and for collective management ofgroundwater. Awareness, capacity building and training of farmers for demand sidemanagement of ground water.
- Participatory Ground Water Monitoring – The farmers are equipped to record the ground waterlevel and rainfall data, analyze the seasonal (and daily fluctuations) for understanding theground water behaviour. Rationale for monitoring of ground water data by PHGs:
- Local People understand the groundwater system they are operating within
- The users can understand the changes in the groundwater systems on an annual basis
- The users can regulate the use of groundwater on an annual basis
- Crop Water Budgeting – Once the farmers are able to understand the water availability andseasonal water balance, the crops to be sown can be identified as per water budget(GWMAs/WUAs need to play a vital role in this exercise).
- A Ground Water Monitoring Cell with adequately trained staff needs to be constitutes at Districtlevel where all the data collected by Para-hydrogeologists may be compiled and sent to theState HQ.

7.3 Participatory Ground Water Monitoring Training Modules

For awareness, capacity building and training of farmers for PGWM several training modules have beendeveloped under APFAMGS. Based on the past experiences of various successful participatory groundwater management projects across the world, and particularly India, following modules are proposed:

- Orientation on PGWM

- Formation of PGWM groups (Monitoring)
- Water balance estimation
- Participatory ground water level monitoring
- PHM data recording and analysis
- Crop water budgeting

Table – 7.1 Participatory Ground Water Monitoring Training Modules

S.No.	Module	Objectives	Contents	Outputs
1	Orientation on PGWM	▪ Balancing groundwater draft with recharge ▪ Improving water productivity with efficient irrigation. Sustainable agriculture by increasing land productivity ▪ Equity in groundwater usage ▪ Social regulation on groundwater development	▪ History of groundwater development. ▪ Understanding the present ground water situation. ▪ Participatory ground water Monitoring Institutions involved in water management. ▪ Crop water budgeting	▪ The farmers understand the ground water situation, the concept of PGWM, water balance estimation and preparation of crop plan according to the water audit.
2	Formation of PGWM groups (Monitoring)	▪ Creating awareness on ground water availability ▪ Establishing the local micro-catchments/Aquifer level rainfall and its relationship with recharge ▪ Develop appropriate water use plans matching with the utilizable ground water reserves ▪ Establish need for conservation of groundwater and increased recharge	▪ Need for PGWM Water cycle and distribution ▪ Handling of instruments ▪ Facilitating the data collection ▪ Recording the data ▪ Allocating responsibilities	▪ Farmers understand the utility of measuring the rainfall, water level and discharge measurement at least for comparing the performance of wells – location and season wise. Farmer volunteers will be able to describe the importance of hydrological cycle and acquire the knowledge of operating the instruments.
3	Participatory Ground Water Monitoring	▪ Creating awareness on groundwater availability ▪ Establishing the local micro-catchments level rainfall and its relationship with recharge ▪ Develop appropriate water use plans matching with the utilizable groundwater reserves ▪ Establish need for conservation of groundwater and increased recharge	▪ Need for PGWM ▪ Water cycle and distribution ▪ Handling of instruments ▪ Facilitating the data collection ▪ Recording the data ▪ Allocating responsibilities	▪ PHGs/ Farmers understand the utility of measuring the rainfall, water level and discharge measurement at least for comparing the performance of wells – location and season wise Farmer volunteers will be able to describe the importance of hydrological cycle and acquire the knowledge of operating the instruments.
4	Ground WL analysis	▪ To calculate the rainfall vs recharge relationship over a	▪ Data recording ▪ Data dissemination	▪ PHGs Enter the data in record register

S.No.	Module	Objectives	Contents	Outputs
		period of time	▪ Data Interpretation ▪ Preparation source wise hydrographs ▪ Preparation of composite hydrograph	▪ Prepare hydrographs ▪ Disseminate data on display boards ▪ Understand the factors influencing ground water fluctuations
5	Water balance estimation	▪ Water balance estimation of the unit ▪ Focus on demand side rather than supply side management ▪ Promotion of low water requiring crops ▪ Improve irrigation water efficiency and productivity ▪ Sensitize the community on ground water situation ▪ Involving Institutions towards water equity, productivity and sustainability ▪ Planning for village level participatory water resources	▪ Groundwater situation ▪ Watershed delineation ▪ Data analysis	▪ The participants are able to assess the existing draft, gross and net annual groundwater availability of the watershed. ▪ The participants know the percentage of groundwater resource assessment
6	Crop water budgeting	▪ Preparation of crop plans ▪ Calculation and estimation of water requirement for all the planned crops ▪ Plan for groundwater recharge ▪ In case of deficit balance, change the crops from high water requiring crops to low water requiring crops	▪ Estimation of ground water recharge ▪ Estimation of ground water draft ▪ Estimation of groundwater balance ▪ Crop plans ▪ Crop water requirements ▪ Projected groundwater balance ▪ Change in cropping pattern	▪ Prepare graphs and tables summarizing crop plans, water budget, water balance, and cropping pattern changes that may be required

Uniform Formats for Data Compilation and Computerization for NAQUIM

Technical Support Group (TSG) has finalized the uniform formats to be adopted for data compilation and computerization. The formats as per the following list are given below.

Contents of Format of Data Compilation & Computerisation	
Sl no	**Item**
1	Litholog
2	Aquifer Parameters
3	Aquifer Wise/Zone wise Water Quality Data
4	Minor Irrigation Data
5	Major, Medium and Bigger Minor Irrigation Data
6	Water Conservation structures
7	Soil Conservation structures
8	Cropping Pattern Data
9	Hydrogeoogical Data
10	WaterLevel Monitoring Data
11	Rainfall Data
12	Geophysical Data

1. FORMAT FOR LITHOLOG

Unique ID	
Village	
Taluka/Block	
District	
Toposheet No.	
Lat	
Long	
RL (m amsl)	
Drilled Depth	
Casing	
SWL (m bgl)	
Discharge (lps)	
Date/Year	

Depth range (m bgl)		**Thickness (m)**	**Litholog**
From	**To**		

2. FORMAT FOR AQUIFER PARAMETERS

Unique ID	Village/ Location	Taluka/ Block	District	Topo-sheet No.	Lat	Long	Type of Well (DW/BW/TW)	Depth	Dia	Date of pumping Test	SWL (mbgl)	Discharge (lps)	Drawdown (m)	Transmissivity (m2/day)	Storativity/S.Yield	Specific Capcity (lpm/m of dd)	Source/Agency

Any other relevant data if available

3. FORMAT FOR AQUIFER WISE/ZONE WISE WATER QUALITY DATA

Unique ID	Village/ Location	Taluka/ Block	District	Lat	Long	Year	Depth (mbgl)	Aquifer Type	pH	EC (µS/cm)	TA	TDS	TH	Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4	NO_3	F
											(mg/L)												

Any other relevant parameter such as Heavy Metals, BOD, COD, Colliform, e-Colli, etc. if available

4.FORMAT FOR MINOR IRRIGATION DATA

Note: The georeferenced map showing locations of MI structures should also be collected

Uique ID	Name	Toposheet	Lat	Long	Taluka/Block	Watershed No.	District	Storage Capacity (MCM)		Command area (Ha)		Quantity of water utilized for irrigation (MCM)
								Gross	Live	Gross	Irrigated	

Any other relevant data if available

5.FORMAT FOR MAJOR, MEDIUM AND BIGGER MINOR IRRIGATION DATA

Note: The georeferenced map showing locations of Major, Medium & Bigger minor structures and their command areas with canal network should also be collected

Unique Id	Name	Topo-sheet No.	Lat	Long	Taluka /Block	District	Storage Capacity (MCM)		Canal			Command area (Ha)		Quantity of water utilized for (MCM)		
							Gross	Live	Length (Km.)	Width (m)	Discharge (Cumec)	Gross	By Latest Date	Irrigation	Domestic	Industrial

Any other relevant data if available

6.FORMAT FOR WATER CONSERVATION STRUCTURES (KT WEIRS, GULLY PLUGS/CHECK DAMS/NALA BUNDS/PERCOLATION TANKS ETC.)

Note: The georeferenced map showing locations of WC structures should also be collected

Unique ID	Name	Toposheet	Lat	Long	Taluka/Block	Watershed No.	District	Storage Capacity (TCM)	
								Gross	Live

Any other relevant data if available

7.FORMAT FOR SOIL CONSERVATION STRUCTURES

Note: The georeferenced map showing locations of soil conservation structures should also be collected

Unique ID	District	Taluka/Block	Live Graded bunding	Graded Brush Wooden Bunding	Paddy Bunding	Compartment Bunding	Continuous contour trench	Earthen structure	loose Boulder Structure	Earthen Bandhara	Cement Plugs	Gabian Structure	Under ground Bandhara	Diversion Bandhara	Form ponds	Trench Deepening
			(Nos)	(Nos)	(Nos)	(Nos)	(Kms)	(Nos)	(Nos)	(Nos)	(Nos)	(Nos)	(Nos)	(Nos)	(Nos)	(Nos)

Any other relevant data if available

8. FORMAT FOR CROPPING PATTERN DATA

Note: The georeferenced cropping pattern map should also be collected

Area in Ha/Sq.Km.

S. No.	Year	District	Taluka/ Block	Geographical area	Paddy	Wheat	Jowar	Bajra	Total Cereals	Total Pulses	Total Food Grians	Sugar-cane	Spices	Fruit+ Vegetables	Total Food Crops	Cotton	Oil-seeds

Any other relevant data if available

9.FORMAT FOR HYDROLOGICAL DATA

Monthly Discharge Data of Stream Gauging Stations in MCM/Month

Unique ID	Name	Toposheet	Lat	Long	Taluka /Block	Watershed No.	Year	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov.	Dec.

10. WATER LEVEL MONITORING DATA COMPILATION

Unique ID	Name of Village/ site	Latitude in degrees decimal	Longitude in degrees decimal	Establishment date (dd/mm/yyyy)	RL (mamsl)	Total Depth of Pz/ Dw (mbgl)	Type (DW/PZ/Spring)	Aquifer group	Measuring point (magl)	Source/ Agency	Any other information

Dynamic data

Unique ID	Date of Measurement (dd/mm/yyyy)	Depth to water level in mbgl	Remarks

11. FORMAT FOR RAINFALL DATA

Monthly Rainfall data in mm

Unique ID	Name	Topo-sheet	Lat	Long	District	Taluka /Block	Source	Year	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov.	Dec.

Any other relevant data if available

12. GEOPHYSICAL DATA COMPILATION

VES/TEM Data

Unique ID	
Village	
Taluka/Block	
District	
Toposheet No.	
Lat	
Long	
RL (m amsl)	
Date/Year	
Nearby DW/DCBW/BW depth	
Yield / discharge	
Whether borehole was drilled at this point? If Yes,	
Depth Drilled	
Dischareg (lps)	
Transmissivity (m2/day)	
Storativity	

Logging Data

Unique ID	
Village	
Taluka/Block	
District	
Toposheet No.	
Lat	
Long	
RL (m amsl)	
Date/Year	
Depth Logged (m bgl)	
Mud Resistivity	
Shale Line	

Unique id

Depth range (m bgl)		**Thickness (m)**	**Resistivity (ohm-m)**	**Inferred Lithology**
From	**To**			

Unique id

Depth range (m bgl)		**Thickness (m)**	**SP**	**Long Normal**	**Short Normal**	**Natural Gamma**	**Lithology**
From	**To**						

Scanned copy of Log to be attached as jpg file