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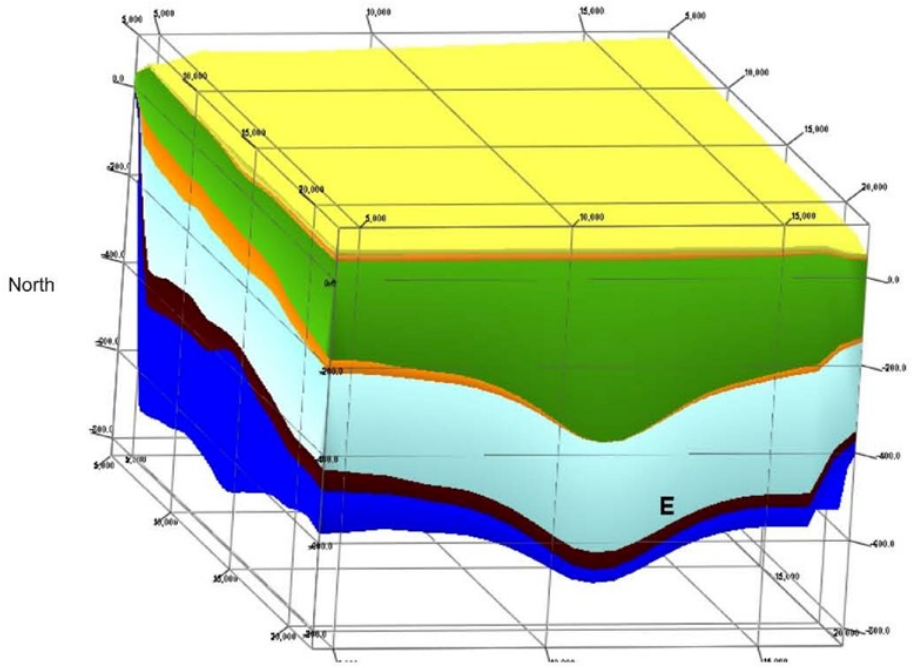
Manual On Aquifer Mapping



Central Ground Water Board
Ministry of Water Resources
Govt. of India
December 2012

Manual on Aquifer Mapping

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1 BACKGROUND

The 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.

The main objective of the National Water Mission, under National Action Plan for Climate Change is conservation of water, minimizing wastage and ensuring its more equitable distribution across the whole country through integrated water resources development and management. As India is the largest user of ground water in the world, there is an urgent need for an accurate and comprehensive picture of ground water resources available in different hydro-geological settings through aquifer mapping which will enable preparation of robust groundwater management plans for this common pool resource.

Aquifer mapping at the appropriate scale has to be devised and sustainable management plan to be prepared and implemented for this common-pool resource. This will help achieve drinking water security, improved irrigation facility and sustainability in water resources development in large parts of rural India and many parts of urban India. It will *also* result in better management of vulnerable areas. In the present scenario, the ground water assessment and management is broadly based on administrative boundaries. In some of the states, surface watershed boundaries are used to collate the information on regional geology, hydrogeology, aquifer characteristics and ground water geochemistry. These facts underscore the need for 3-D picture of demarcated aquifer systems of the country. It is therefore proposed to take up aquifer mapping to delineate the local aquifers of an extent of 50 to 100sq.km, as a unit for water management in the country. The experience gained from the use of various geophysical techniques in pilot aquifer mapping projects at five states under Hydrology project and its effectiveness in getting depth information will be used for replication in the national project of aquifer mapping.

The scheme needs to be implemented countrywide for aquifer mapping and management project by promoting the participatory ground water management involving the state agencies , community and stakeholders and by deploying grass root functionaries/ para-hydrogeologist /Jalrakshak/support staff for ground water related data collection and dissemination.

The activities of Long term Ground Water monitoring, Ground Water Resource Assessment, Publication of technical reports, Procurement of latest equipments and technological Upgradation, Information, Education, Dissemination, conducting Workshops, Seminars & ground water Congress, ground water Regulation, Technical assistance to State and Central Organizations, demonstrative artificial recharge and ground water exploration in drought, water scarcity and vulnerable areas are part of on-going activities of Central Ground Water Board. These activities which will be very useful for sustainable development of ground water resources will be also integrated in the aquifer mapping project. The major activities proposed under the Ground water Management scheme are:

- Aquifer Mapping for Delineation of Aquifer disposition in 3-D along with their characterization in 1:50,000 scale and further detailing up to 1:10,000 scale in the identified over-exploited and critical areas.
- Quantification of ground water availability and assessing its water quality to formulate Aquifer management plan for facilitating sustainable management of ground water resources at Regional and local level through participatory management approach with involvement of community and stakeholders.
- Regulation and control the development of ground water resources.
- Upgradation of technological capabilities and infrastructure of the Central Ground Water Board to meet the upcoming challenges in ground water field with best international practices.
- Capacity building in all aspects of ground water development and management through information, education and communication (IEC activities), information dissemination, education, awareness and training.
- Enhancement of coordination with concerned central / state govt. organizations and academic/research institutions for sustainable ground water management.
- Periodic long term monitoring of ground water regime for creation of time series data base and ground water resource estimation.

To achieve the envisaged objectives there are four major components namely Technical, Implementation mechanism, Capacity building and Manpower requirement. This manual deals with the technical component and capacity building of the para-hydrogeologist/ Jalrakshak/support staff only and is being prepared with a view to provide outline of the technical work to be undertaken under the aquifer mapping program. Details of manpower requirements, implementation mechanism including procedures and protocols for field activities is not part of this document and will be dealt separately.

This manual has been arranged in four parts namely, Protocol for Collection & Compilation of data, Data Gap Analysis, Aquifer Map Preparation and Training for Para hydrogeologist/ Jalrakshak/support staff under Participatory Ground Water Management.

2 PROTOCOL FOR COLLECTION & COMPILATION OF DATA

2.1 BACKGROUND

As subject of water is being dealt by several ministries and departments at central as well as state level, the country wide collection / compilations of all the ground water related data is a gigantic task and needs concerted effort by the nodal Agency.

Hydrogeological investigations are being carried out by Central Ground Water Board, State Groundwater Departments, State Drinking Water Supply Departments, State & Central Remote Sensing Agencies and in select research projects by Research Institutions, viz., National Institute of Hydrology, National Geophysical Research Institute etc. In addition, water conservation structures have also been constructed by State Forest Departments, State water shed development departments and State Agricultural Engineering Departments. The data generated by all these departments need to be brought on a common GIS platform for taking realistic and implementable management decisions.

Central Ground Water Board has also compiled National Atlas on Aquifer Systems of India 1:250,000 scale, which has been compiled from the data generated by Regional Offices of the Board. 14 principal Aquifers have been identified, which have been further segregated into 42 major aquifers as given below and presented in Fig 1 & 2:

Sl.No	Principal Aquifer Systems		Major Aquifers	Name	Age
	Code	Name	Code		
1	AL	Alluvium (945753 sq km) (29.82 %)	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quarternary
2			AL02	Pebble / Gravel/ Bazada/ Kandi	Quarternary
3			AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quarternary
4			AL04	Aeolian Alluvium (Silt/ Sand)	Quarternary
5			AL05	Coastal Alluvium (Sand/Silt/Clay)	Quarternary
6			AL06	Valley Fills	Quarternary
7			AL07	Glacial Deposits	Quarternary

Sl.No	Principal Aquifer Systems		Major Aquifers	Name	Age
	Code	Name	Code		
8	LT	Laterite (40925 sq km) (1.29 %)	LT01	Laterite / Ferruginous concretions	Quarternary
9	BS	Basalt (512302 sq km) (16.15 %)	BS01	Basic Rocks (Basalt)	Mesozoic to Cenozoic
10			BS02	Ultra Basic	Mesozoic to Cenozoic
11	ST	Sandstone (260415 sq km) (8.21 %)	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic
12			ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic
13			ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic
14			ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic
15			ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic
16			ST06	Sandstone with Shale	Proterozoic to Cenozoic
17	SH	Shale (225397 sq km) (7.11 %)	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic
18			SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic
19			SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic
20			SH04	Shale	Upper Palaeozoic to Cenozoic
21			SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic
22			SH06	Shale with Limestone	Proterozoic to Cenozoic
23	LS	Limestone (62898 sq km) (1.98 %)	LS01	Miliolitic Limestone	Quarternary
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	QZ01	Quartzite	Proterozoic to Cenozoic
34			QZ02	Quartzite	Azoic to Proterozoic

Sl.No	Principal Aquifer Systems		Major Aquifers	Name	Age
	Code	Name	Code		
		km) (1.48%)			
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 (Dolerite, Anorthosite etc.)	Proterozoic to Cenozoic
42			IN02	Ulrta Basics (Epidiorite, Granophyre etc.)	Proterozoic to Cenozoic

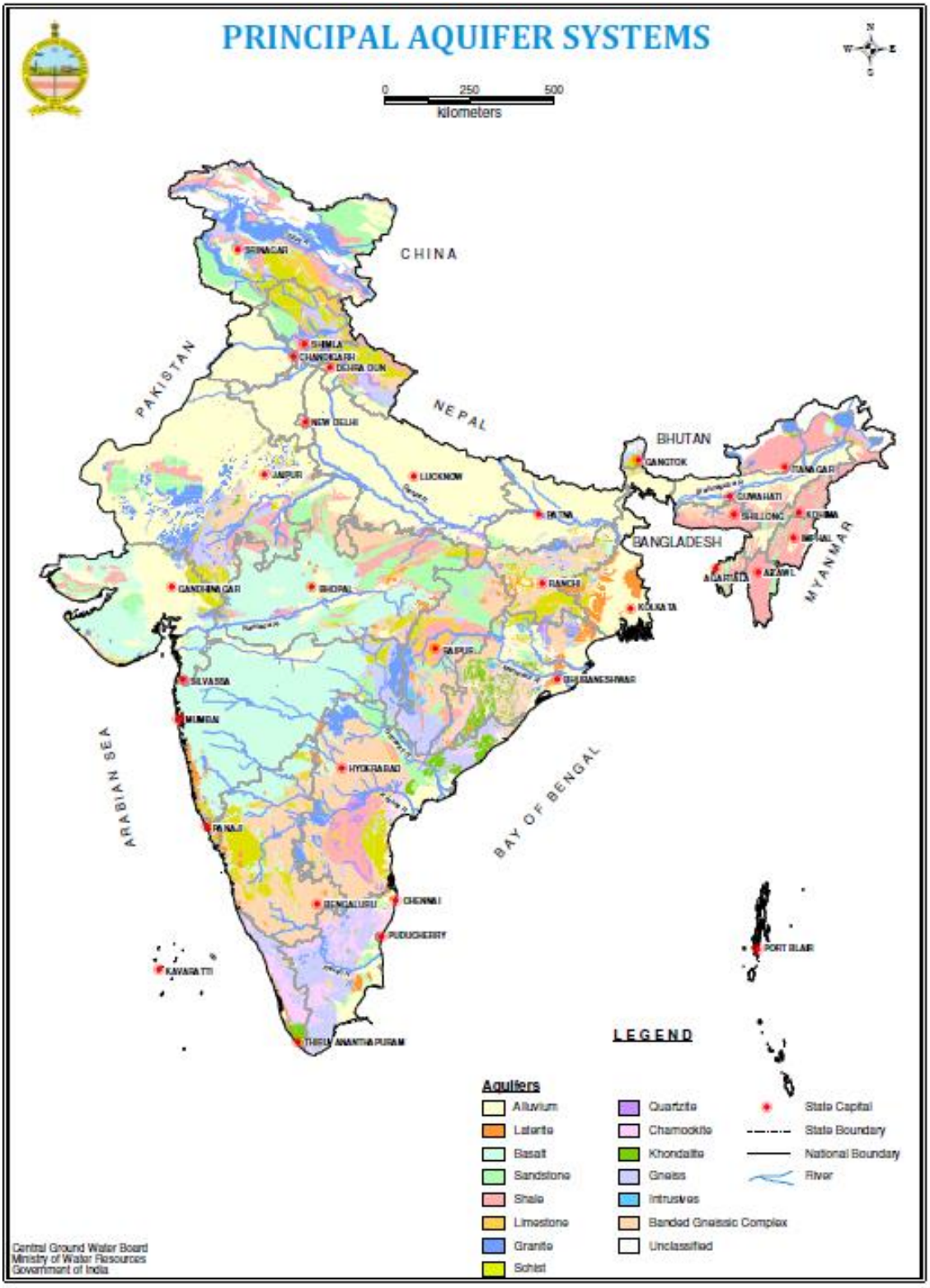

PRINCIPAL AQUIFER SYSTEMS
0 250 500
kilometers
CHINA
PAKISTAN
NEPAL
BHUTAN
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
SRINAGAR
SHIMLA
CHANDIGARH
DEHRA DUN
NEW DELHI
JAIPUR
LUCKNOW
PATNA
GANGTOK
ITANAGAR
GUWAHATI
SHILLONG
KOHIMA
IMPHAL
AIZAWL
AGARTALA
GANDHINAGAR
BHOPAL
RANCHI
KOLKATA
RAIPUR
BHUBANESHWAR
SILVASSA
MUMBAI
HYDERABAD
PANAJI
BENGALURU
CHENNAI
PUDUCHERRY
KAVARATTI
PORT BLAIR
THIRUVANANTHAPURAM
LEGEND
Aquifers
Alluvium
Laterite
Basalt
Sandstone
Shale
Limestone
Granite
Schist
Quartzite
Charnockite
Khondalite
Gneiss
Intrusives
Banded Gneissic Complex
Unclassified
State Capital
State Boundary
National Boundary
River
Central Ground Water Board
Ministry of Water Resources
Government of India

Fig 1

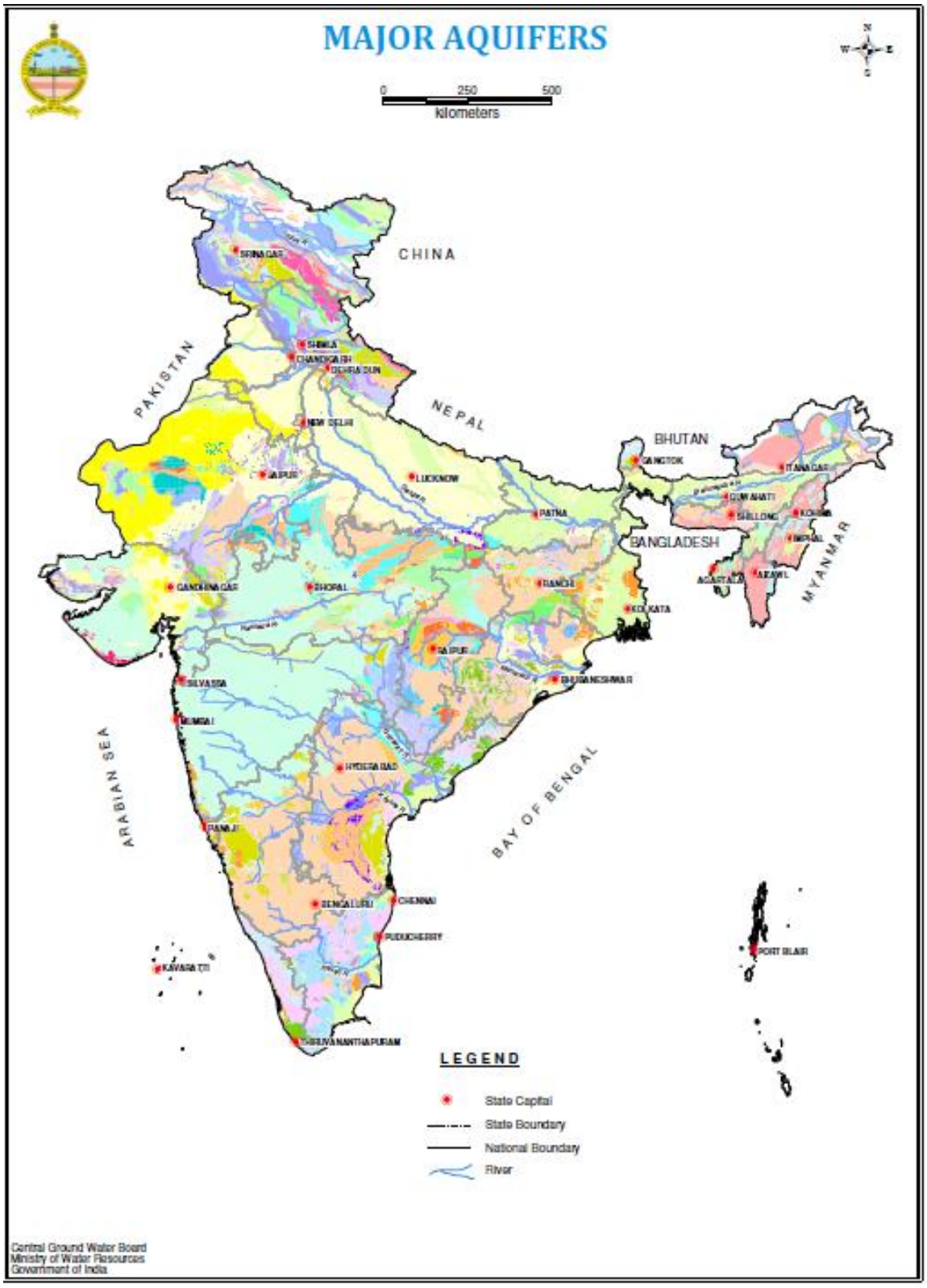

MAJOR AQUIFERS
0 250 500
kilometers
CHINA
PAKISTAN
NEPAL
BHUTAN
BANGLADESH
MYANMAR
ARABIAN SEA
BAY OF BENGAL
SRINAGAR
SHIMLA
CHANDIGARH
DEHRA DUN
NEW DELHI
JAIPUR
LUCKNOW
PATNA
GANDHINAGAR
BHOPAL
RANCHI
KOLKATA
RAIPUR
SILVASSA
MUMBAI
HYDERABAD
PANAJI
BENGALURU
CHENNAI
PUDUCHERRY
KAVARATTI
THIRUVANANTHAPURAM
GANGTOK
ITANAGAR
GUWAHATI
SHILLONG
KOHIMA
IMPHAL
AIZAWL
AGARTALA
PORT BLAIR
LEGEND
State Capital
State Boundary
National Boundary
River
Central Ground Water Board
Ministry of Water Resources
Government of India

Fig 2

It is proposed to undertake the aquifer mapping in an area of 9.25 Lakhs Sq Km in the XII plan at 1:50,000 scale in the areas as given in Fig 3. Based on preliminary aquifer map generation on 1:50 000 scale specific problematic areas will be identified and mapped on 1:10,000 scale. This exercise shall result in the identification of several smaller mapable aquifer units within the identified Principal/Major Aquifer Systems. It is envisaged to name the aquifers with local names for easier identity and understanding by the local stake holders.

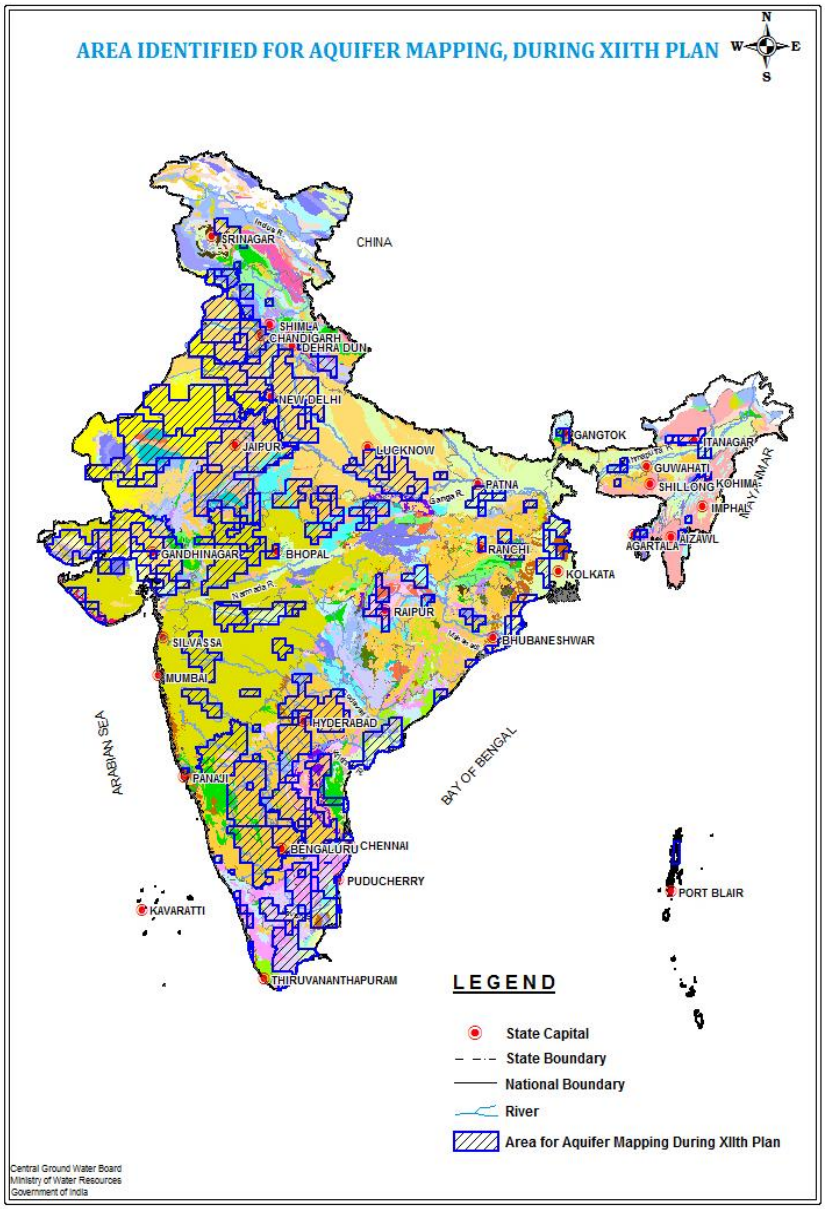


Fig 3

An implementation approach has been devised with steps and activities involving nationwide data collection and compilation is represented in the flow diagram (Fig . 4) and 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.

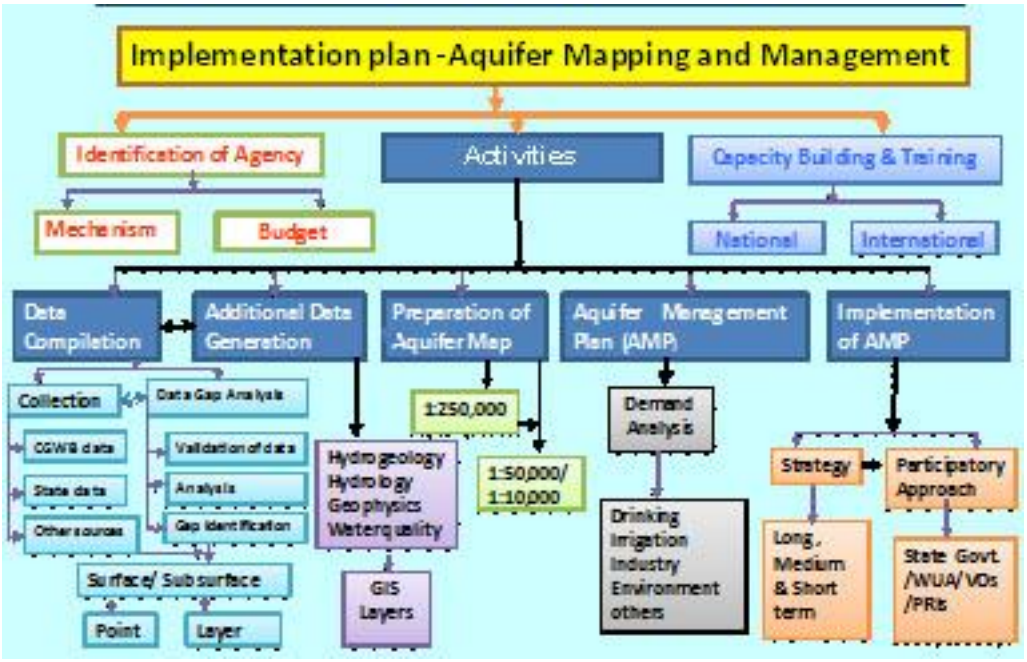


Fig 4. : Implementation Approach

2.1 PRESENT STATUS OF DATA AVAILABILITY:

The working group on "Water data base development and Management" constituted by Planning Commission for the preparation of XII plan headed by Prof A. Vaidyanathan, Ex Member, Planning Commission has deliberated in detail on the availability of water related data and submitted the final

report (http://planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_data.pdf), which brings out the present status of data availability in water sector and the wish list including groundwater.

The ground water resources chapter of the report includes status of availability of ground water related data and data gap analysis. The table on current status of data availability from the report is also presented in table below for ready reference.

Sl. No	**Items**	**Present Status of Data Generation**
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 states.
2	Groundwater 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

Sl. No	Items	Present Status of Data Generation
		measurements. ▪ A limited number of DWLR is 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 of rainfall-recharge relationship	▪ 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 structures	▪ Three type values of canal seepage factors have also been recommended based on soil types and lining of canals. ▪ 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

Sl. No	Items	Present Status of Data Generation
		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.

Source: Report of the Working Group on "Water Data Base Development and Management" constituted by Planning Commission for XII plan preparation)

(http://planningcommission.nic.in/aboutus/committee/wrkgrp12/wr/wg_data.pdf)

Some of the important compilations listed below needs to be consulted before starting the present exercise of data compilation.

2.1.1 CGWB

- Hydrogeological map of India on 1: 5 million scale (1984)
- Hydrogeological map of India on 1: 2 million scale (2002)
- Demarcation of Principal and Major Aquifer systems on 1:250,000 scale (2012)

2.1.2 NRSC

- Ground Water Prospect Map of NRSC

The maps available in different scale in respect of aquifers are presented in Fig. 2 to Fig 5. The Data Gap Analysis shall follow the major activity grouped under Data collection and data compilation. The data collection also includes data procurement from agencies like Survey of India, National Remote Sensing Agency, Geological Survey of India etc. The policy for data sharing in digital form is an important issue and needs to be addressed for speedy implementation of the project. A broad methodology for data compilation can be represented as given in subsequent sections.

2.2 ROLE OF THE STATE GW AGENCIES AND OTHER INSTITUTIONS (E.G. NRSC/ RRSC/STATE RSAC ETC)

The data collection 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 SCC will also comprise representative from Special purpose Vehicle (SPV), Technical Service Agency (TSA), State Implementation Partners (SIPs) and Collectors/ Members of Zila Panchayat on rotation basis. Concerned Regional Director, CGWB shall be the Member Secretary of SCC.

The SCC shall be responsible for

- Implementation of the Project in the State.
- State level NGOs called State Implementation Partners (SIPs) who would participate in the Project will be identified by the TSA and approved by SCC.

- SCC shall also be responsible for implementation of the Project through Line departments of the State and will associate with SPV and chalk out a Working Plan for the
- collection of data ,
- data gap Identification and
- Preparation of Aquifer Maps,
- Preparation of Aquifer Management Plans
- Implementation of Participatory ground water management through SIPs.

IMMEDIATE ROLE OF THE SCC

- To organize a Kickoff workshop by CGWB / State Agencies to mobilize the participating agencies
- Finalization of Base Map of the area taken up for aquifer mapping prepared by CGWB using toposheet of SOI on the scale of 1:50,000. The base map should also indicate:-
    - Administrative Boundary (State/District/Taluk/Block) Important Locations (District HQ, Block HQ) to be marked in the base map
    - Hills/Forests and water bodies
    - Elevation contours
- CGWB to procure SOI toposheets (hard copy and Digital GIS format) on 1:50, 000 scale.
- Preparation of essential thematic layers on GIS platform – Geomorphology, Soil, Land Use, Drainage etc. This Activity is to be taken up at CGWB Regional Offices in coordination with NRSC / RRSC/State Remote Sensing Agencies.

2.3 COMPILATION OF EXISTING DATA

The major data type identified for aquifer mapping along with proposed methodology is given below:

Sl No	Major Activities/Task	Methodology
1.	**Procurement of Maps/ Thematic Layers (Paper Map/GIS Data Sets)**	
	Topographical Maps	Shapes files of Villages, elevation contours, drainage, roads, water bodies, forest etc may be procured from SOI on the 1:50,000 scale. In addition hard copy maps on the 1:50,000 scale will also be procured. For identified areas, SOI is taking up 1:10,000 scale map preparation which will be also used and efforts will be made to generate more coverage under this project also

Sl No	Major Activities/Task	Methodology
	Geological Maps	Shape files of Geology may be procured from GSI. In addition hard copy maps on the 1:50,000 scale will also be procured.
	Geomorphological Maps	To be generated from CARTOSTAT, LISS –III, LISS IV resource set data by processing through suitable image processing remote sensing software.(ERDAS Imagine) The NRIS codes developed by NRSC may be followed in classification of the features class. Also, the available GIS layers from NRSC in 1:50,000 scale will be used as base for updating with more field data
	Soil	NBSS is the nodal agency and publish the map of soil on 1:500,000 scale. The maps are available with NDC Faridabad for whole India.
	Land use Land Cover	To be generated from LISS –III resource set data by processing through suitable image processing remote sensing software. The NRIS codes developed by NRSC may be followed in classification of the features class.
	Forest Cover	The data created by FSI need to be procured using Local Shopping procedures.
2	**Data Collection**	
	GW Observation Network	
	Network location map & details	Presently CGWB, State GW departments and other agencies are maintaining separate GW monitoring network for water level and water quality monitoring. At few places the observation network is common. There is need to bring this data on a single map to identify density of the available network. The maps depicting location of the network may be prepared using the standard methodology as described in the coming chapters.
	RL Survey of Monitoring Wells	The reduced level of the monitoring well required for preparing ground Water flow directions which are required for identifying the recharge and discharge areas. The RL survey of all the monitoring well of CGWB and State may be collected from these agencies and wherever it is not available same may be got using the State of Art equipments such as DGPS or through the level surveys.
	Water Level	Water level data from the various agencies

Sl No	Major Activities/Task	Methodology
		collecting data may be obtained and collated with the CGWB data.
	Water Quality	Water Quality data from the various agencies collecting data may be obtained and collated with the CGWB data
	Exploratory Drilling Data/Map	
	Well location map & details	CGWB construct tubewell and borewells under its exploratory drilling program. The location of well, their type and other related data as specified in the GEMS formats may be collected.
	RL Survey of Exploratory Wells	The reduced level of the exploratory well required for preparing 3 dimensional conceptual model, resources estimation and suggesting optimal scenario using digital GW modelling software etc. The RL survey of all the exploratory well of CGWB and State may be collected from these agencies and wherever it is not available same may be got using the State of Art equipments such as DGPS or through the level surveys.
	Lithologs	CGWB and State departments are drilling wells in the various geological formations. The information on drill cuttings is collected at every 3 meters in alluvial areas and every meter in hard rock areas. The information on lithology is recorded without following standard protocols and nomenclatures. There is urgent need to reclassify the whole lot of lithologs to standard classification and prepare the logs depicting lithologies.
	VES & Electric logs	The data from the State and CGWB may be collected and logs may be prepared wherever logs are not in pictorial forms. The data may be interpreted into lithologies.
	Aquifer parameters (pumping test) T/K/S/Sy	GW agencies carryout pumping test on the exploratory wells to estimate aquifer parameters such as Hydraulic Conductivity, Transmissivity, Stoprativity/Storage and Specific Yield. These may be collected and compiled to prepare distribution of aquifer parameters over the area.
	Aquifer Wise/Zone Wise Water Quality Data	As special studies GW agencies carry out zone test to understand the water quality of specific zones. The zones are isolated to avoid mixing from overlying and underlying zone using specific technology and samples are collected.

Sl No	Major Activities/Task	Methodology
		The data on zone wise water quality may be collated in the specific formats as defined under GEMS software.
	Other Data	
	Rainfall Data & Other Meteorological Data/IMD	Rainfall and other meteorological data is generated by IMD and State Revenue department. This data is required for estimation of resources and management of the aquifers. The data may be collected and collated in the specific formats as defined under GEMS software.
	River Gauge & WQ data	River Gauging and water quality data is important for integrated water resources management. The data may be collected in the standard formats from surface water organisation.
	Spring discharge	Springs are major sources of drinking water in hilly terrains. Their management ensuring the sustainability is priority in the hilly states. Also they account for major part of the base flow going out of the system. The data from the spring may be collected using the standard formats as designed in GEMS software.
	Canal Network & Irrigation Command Area	Information on canal Network & irrigation command Area is required for managing GW resources in canal command areas. There is need to collect maps of canal network and command areas from the CADA /CWC/State Irrigation/IPH etc departments along with data on quantum & schedule of water release, dimensions of canal networks, data on lining of canal systems etc
	Water Bodies/Tanks/Ponds	Water bodies /tanks/ponds are major source of water in water scarce areas and contribute to GW during the post-monsoon period is required for managing GW. The data on capacity, water availability days, size of water bodies may be collected from State departments.
	Location of major industries	Data on location of major industries and the details of products/effluents to be collected
	Location of mining/sand mining areas	Available data on mining/sand mining locations, abandoned quarries etc can be collected
	Cropping pattern and source-wise irrigation	Data on cropping pattern and source-wise irrigation
	Socio-Economic Data	

Sl No	Major Activities/Task	Methodology
	Villages wise Census	Population census data of villages from revenue department may be collected for GW management.
	Minor Irrigation data	The GW draft from the various GW sources is the outflow from the GW regime. The data on the well census (GW sources) may be collected along water use. The cropping pattern, crop water requirement may also be collected to cross check the draft from the system.
	Water Supply Schemes	Data on drinking and irrigation scheme may be collected from Irrigation and Public Health Departments
3	**Data Compilation, Processing and Interpretation**	
	Data Compilation and validation	
	Data Validation in Space and Time	The data collected from the central and state agencies need to validated using the standard protocols as prepared under HP-II and provisioned in GEMS software.
	Preparation of composite lithologs	Lithological logs, drill time logs, geophysical information and other relevant details need to be plotted in form of composite logs. This will give the complete overview of the hydrological information at the well site. The composite log can be prepared using the template as given in GEMS software.
	Preparation of sections from lithologs and Geophysical data	Sections along a line may be prepared from strip logs of lithology and geophysical data. This will give the complete overview of the hydrological information at the well site. The section may be prepared using the standard template of GEMS.
	Time series analysis of Water Level	Statistical analysis of the time series and water quality data is to be carried out for identifying trends in times series data. The methodology as adopted in GEMS may be used for WQ data analysis.
	WQ Data Analysis	
	Aquifer wise draft estimation	The aquifer wise draft estimation is the output of the analysis of the minor irrigation data, population data and cropping details along with aquifer map of the area.
	Aquifer-wise recharge estimation	Aquifer-wise recharge estimation incorporating input from various sources such as rainfall, applied irrigation, surface water sources.
	Data Processing and Map Preparation	

Sl No	Major Activities/Task	Methodology
	Digitization of Base Map	The base map may be prepared depicting location of towns, block boundaries, major drainage and transport network. The map can be prepared using the methodology as indicated in the aquifer map preparation section.
	Preparation and digitization Combined Network Map of WL /WQ of CGWB and Others	Maps may be digitised using the methodology, coordinate system etc as described in the aquifer map preparation section.
	Preparation and digitization Combined Exploration Map of CGWB and State	
	Preparation and digitization Combined VES location Map of CGWB and State	
	Value Addition to Geological map	The geological map collected on 1:50,000 scale may be used to identify surface geology and reinterpret and regroup them into suitable hydrogeological units.
	Value Addition to Geomorphological map	In case geomorphological maps are collected form the others agencies, the may have to be reinterpret and regroup them suitable into hydrogeomorphological units using Natural Resources Information System (NRIS) codes.
	Digitisation of Land use Land Cover Map	Land use and Land cover map may be prepared using NRIS coding scheme and using the methodology as described in the aquifer map preparation section.
	Aquifer Parameter T/K/S/Sy map	Aquifer wise map depicting the distribution of the aquifer parameters may be prepared adopting methodology as described in the aquifer map preparation section. The intervals of the parameters may be taken specific to state and range of data.
	Depth to Water Map	Interpolation of the Depth to water data may be used to prepare depth to water map having contour intervals as standardized in the GEMS software. While preparing these maps care should be taken to avoid continuous contours over hills and water bodies. The geomorphological controls along with geology should also be taken into consideration while preparation of these maps.
	WQ parameters map	Interpolation of the Water Quality parameters may be used to prepare WQ parameters maps having contour intervals as standardized in the GEMS software and depicting permissible limits

Sl No	Major Activities/Task	Methodology
		as per BIS and WHO standards . While preparing these maps care should be taken to avoid continuous contours over hills and water bodies. As land use has bearing on the water quality parameters it should be considered while preparation of these maps.
	Digitization of Command Area Map	Maps may be digitised using the methodology, coordinate system etc as described in the aquifer map preparation section depicting command and non-command areas.
	Digitization of Canal network Map	Maps may be digitised using the methodology, coordinate system etc as described in the aquifer map preparation section depicting major and minor canal network.
	Generation of Isohyetal Map	Maps may be digitised using the methodology, coordinate system etc as described in the aquifer map preparation section depicting rainfall distribution over the area under study.
	Digitisation of Location of River Gauge Map	Maps may be digitised using the methodology, coordinate system etc as described in the aquifer map preparation section depicting point data on the rivers.
	Digitisation of WQ of River Gauge Map	Maps may be digitised using the methodology, coordinate system etc as described in the aquifer map preparation section depicting point data on the rivers.
	Digitisation of Spring Locations	Maps may be digitised using the methodology, coordinate system etc as described in the aquifer map preparation section depicting point data as spring locations.
	Digitisation of of GW recharge and draft	Preparation of maps depicting distribution of gw recharge and draft for each aquifer
	Data Interpretation	
	Preparation of Hydrogeological map	Hydrogeological map is the overlay of several layers depicting hydrogeology, aquifer parameters such as yield prospects, ground

Sl No	Major Activities/Task	Methodology
		water elevation and water quality etc. These maps may be prepared using the protocols as described in the coming chapters.
	Demarcation of Principal Aquifer in 2D with Isopachs	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.
	3 D Visualization of the aquifers	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.

2.4 APPROACH AND METHODOLOGY:

The data collection includes collection of all data relevant to aquifer wise information from various agencies like CGWB, State Groundwater Department, State Water Supply Departments & other institutions like SOI, NGRI, NRSC, GSI, CWC & other research/academic institutions.

The data need to be compiled in reference to Geometry, potential, water quality, ground water draft etc of each aquifer units along with the geo-referencing information. On compilation, drilling data, 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 overall approach and methodology of the entire aquifer mapping and management program for major activities has been presented in the flow diagrams given in Fig 5 and 6 respectively.

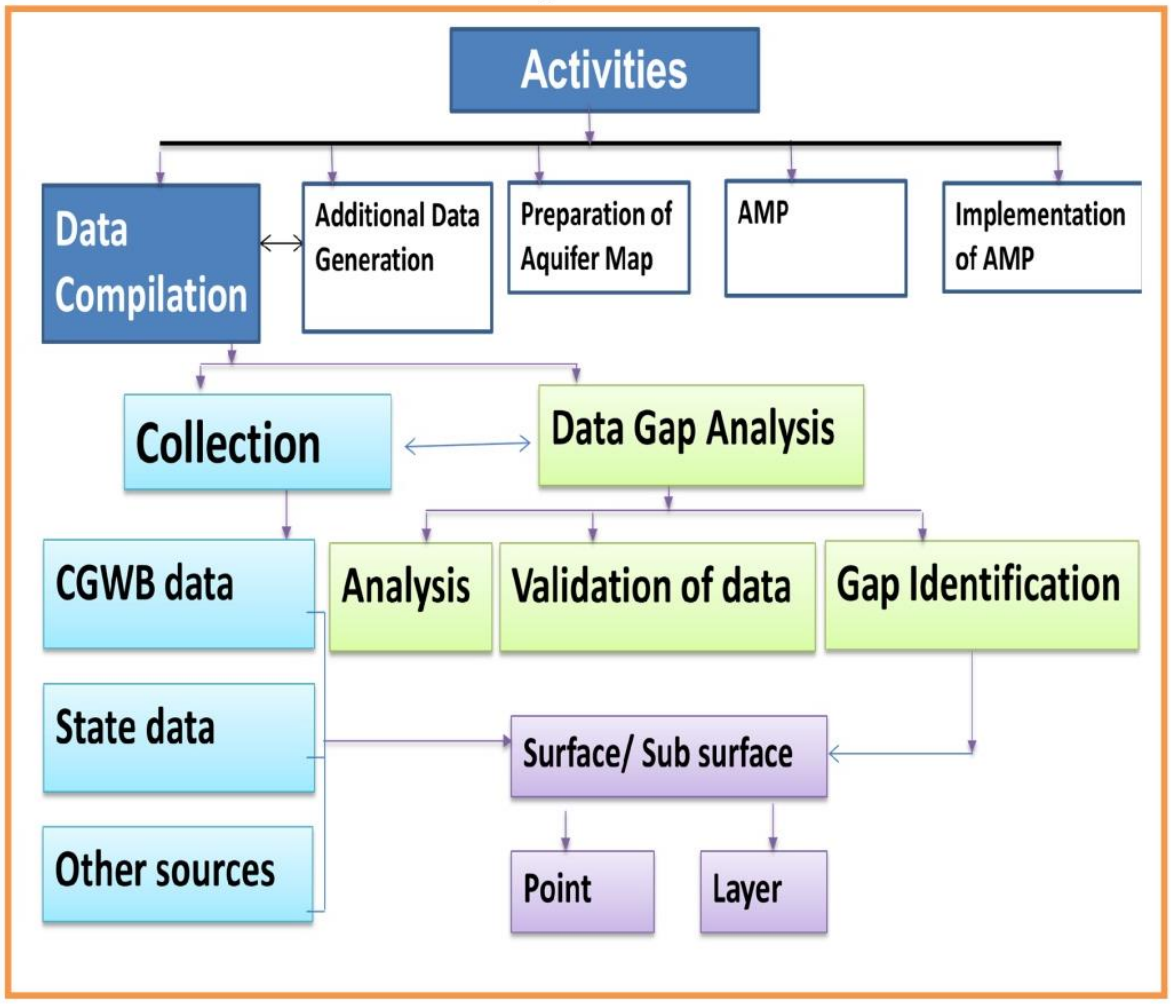


Fig 5 Activities Under Aquifer Mapping

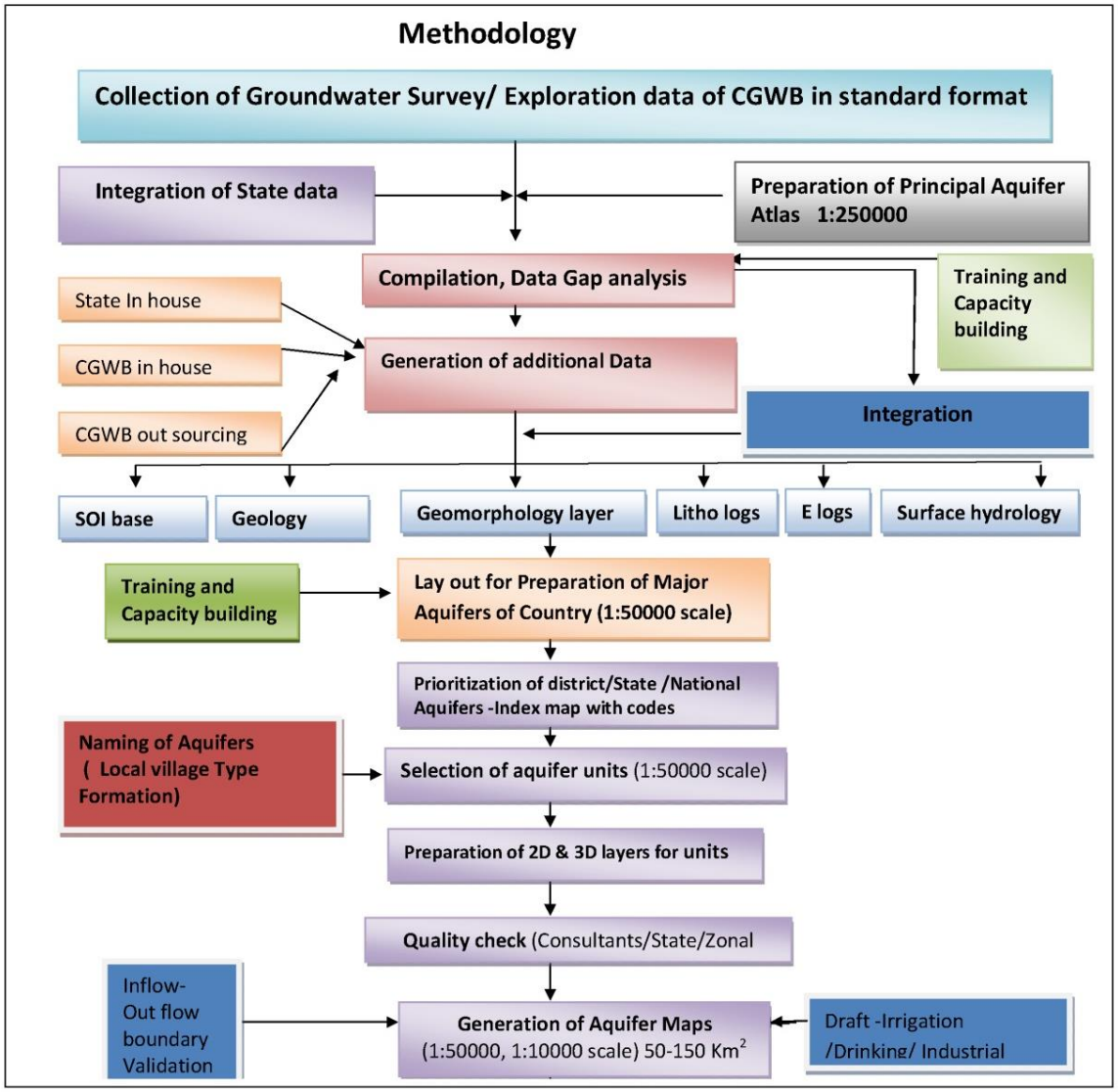


Fig 6: Methodology for Aquifer Mapping

2.5 SUB ACTIVITIES AND TASKS :

2.5.1 COLLECTION OF EXISTING DATA

Sl. No	Tasks	Activities / Source	Outputs	Remarks
1	Base map procurement / Creation	▪ Procurement of SOI paper map/ digital data and Preparation of Base map Based on SOI toposheets (paper / Digital data) indicating ▪ Administrative Boundary (State/District/Taluk/Block) ▪ Important Locations (District HQ, Block HQ) to be marked in the base map ▪ Hills/Forests and water bodies ▪ Elevation contours	Base map on paper / GIS layer	Standardised database
2	Collection of data pertaining to soil	▪ Procurement of Soil types and their characteristics.	Soil Maps	Standardised database
3	Land use particulars, cropping pattern	▪ Procurement/inhouse generation of Landuse maps	Landuse /land cover maps	Standardised database
4	Irrigation data	▪ Collection of Canal command/canal	Command and network	Standardised database

Sl. No	Tasks	Activities / Source	Outputs	Remarks
		network map data	map	
5	Data collection in respect of Geology / Structure	▪ Procurement of GSI paper map / Digital data / DRM maps in case the geological maps are not available	Geological Layer with regrouping	Standardised database
6	Data collection in respect of Geophysics	▪ All the surface and subsurface geophysical data to be collected (eg. VES, Logging, Seismic survey points, Imaging etc) and numbered for easy storage & retrieval from database. ▪ All the points should be located on the base map with proper geo-referencing. Source : CGWB, State Agency, GSI, NGRI, Other Institutions	Computerized data base preferably in GEMS format or in excel format	Standardised database
7	Data collection in respect of Hydrogeology	▪ Includes collection of all the data generated during Systematic Surveys, Reappraisal surveys and GW management studies (CGWB) and state Agencies pertaining to the area including Well Inventory details, water level monitoring,		Information regarding AR structures constructed by various agencies including CGWB are to be collected

Sl. No	Tasks	Activities / Source	Outputs	Remarks
		pumping tests, draft data, statistical data, Infiltration tests, specific yield determination etc. Source : CGWB/ State Agency		
8	Data collection in respect of Hydrometeorology	▪ Rainfall monthly and other climatic data including Evapotranspiration and temperature Sources: IMD, State Revenue Depart.		Standardised database
9	Data collection in respect of Geochemical	▪ Data related to ground water quality analysis in space and time with location of wells sampled (regular WQ monitoring wells, EWs, Key wells) ▪ WQ Data related to Surface water sources. Sources : CGWB, State Agency,		Premier academic institution can be included.
10	Data collection in respect of Hydrology	▪ Data related to rivers / stream morphology including length, cross section, slope and Gauge & discharge data. ▪ Canal Details, water Bodies, (as per the		Non-committed surplus rain runoff data. Data related to springs (location with discharge)

Sl. No	Tasks	Activities / Source	Outputs	Remarks
		data requirement of GEC) Sources : CWC, State Agency, NIH, CADA		
11	Data collection in respect of Ground water Exploration for Subsurface Aquifer Disposition	▪ All parameters to be collected as per existing GEMS formats. Sources : CGWB, State Agency,	Aquifer geometry frame work	Standardised database
12	Data collection in respect of Aquifer Properties	▪ All parameters collected as per in GEMS formats Sources : CGWB, State Agency,	Base level information of aquifer characteristics	Standardised database
13	Data collection in respect of Aquifer wise Draft Data	▪ Ground water withdrawal data, MI census, preferably with the depth of wells to identify aquifers	Base level information of aquifer characteristics	Industrial draft can be taken from CGWA data bank.

Note:

a. The format for data collection should be same as used in GEMS, minor changes may be taken up centrally as and when necessary.
b. The outcome of the data collection would be a database and maps in hard and soft copies which would be input to the aquifer mapping program

2.5.2 COMPILATION OF DATA

Tasks	Activities	Modalities / Source	Outputs	Deliverables / Outcome
1	Soil	▪ Grouping of soil on 1:50,000 to suit the requirements of hydrogeological studies	Regrouped soil map	Major soil group as per the requirements of hydrogeological studies
2	Landuse	▪ Classification of the remote sensing data into Landuse	Landuse map	Classes of landuse for water utilisation/pollution studies
3	Irrigation data	▪ Canal command area demarcation, marking of canal network along with water bodies	surface water sources map	Surface water sources Mapping
4	Geology / Structure	▪ Grouping of geology on 1:50,000 in line with Principal aquifer / major aquifers identified on 1:250, 000 scale to delineate Aquifer management Units	Maps showing Principal aquifers / major aquifers and further subdivisions	Principal /Major Aquifer Map
5	Geophysics	▪ All the surface and subsurface geophysical data to be compiled to present the subsurface disposition of aquifers. ▪ Preparation of Iso-resistivity contours ▪ Preparation of subsurface cross sections /fence diagram	2D/3D presentations of geophysical data for correlation with geological data	Demarcation of various layers (3D) giving lateral and vertical extents.

Tasks	Activities	Modalities / Source	Outputs	Deliverables / Outcome
		▪ 2D / 3D presentations of geophysical data to help in preparation of conceptual 3D aquifer model.		
6	Hydrogeology	▪ Linking of all the data pertaining to Well Inventory details, water level monitoring, pumping tests, draft data, statistical data, Infiltration tests, specific yield determination etc to aquifer polygons / AMUs (Aquifer Management Units) delineated for the area. ▪ Subsequent to establishing the layers / aquifers in 3D conceptual model the water level / piezometric heads to be linked with the aquifers.	Demarcation of aquifer units 2D/3D disposition of Aquifer Units Spatial variation of Aquifer Parameters for various Aquifer Units Spatial & temporal variation of Water level/piezometric surface for each aquifer units	3D Disposition of Aquifer Units Water level/Piezometric surface variation Aquifer parameters for making management strategy

Tasks	Activities	Modalities / Source	Outputs	Deliverables / Outcome
7	Hydrometeorology	▪ Plotting the locations of Observatories on the Base map ▪ Compilation of monthly rainfall and other climatic data including Evapotranspiration and temperature in GEMS format , -	Variability of Rainfall incidence	Drought Prone areas
8	Geochemical	▪ Plotting of location of wells sampled (regular WQ monitoring wells, EWs, Key wells) ▪ Linking the ground water quality data (Dynamic data) with aquifer polygons ▪ Linking of WQ Data related to Surface water sources with corresponding aquifers	Aquifer wise water quality information	Composite database for map preparation in 2D and 3D.
9	Hydrology	▪ Plotting the rivers / streams, Canal, water Bodies on the base map with aquifer management units so as to use these features as model boundaries, wherever possible. ▪ Linking all the parameters with these hydrological features from the compiled data.	Baseline information on Aquifer wise resources estimation	Rivers/Springs and other water bodies location and discharge

Tasks	Activities	Modalities / Source	Outputs	Deliverables / Outcome
10	Ground water Exploration for Subsurface Aquifer Disposition	▪ The lithologs collected should be used to group the lithology to make aquifers / aquitards and aquicludes by combing with geophysical logging data. ▪ Preparation of cross sections/ fence diagrams ▪ Preparation of isopachs, depth of basement rocks contours etc. ▪ Presentation of lateral and vertical extent/disposition of aquifers into 2D / 3D conceptual aquifer models.	Detailed 3 D configuration of the Aquifer systems	Improved aquifer wise estimation and management of ground water resources.
11	Aquifer Properties	▪ Linking of aquifer parameter to the identified aquifers / layers		Improved aquifer wise estimation and management of ground water resources.
12	Aquifer wise Draft Data	▪ Linking of ground water draft with the identified aquifers / layers		Improved aquifer wise estimation and management of ground water resources.

3 DATA GAP ANALYSIS

Data Gaps are often identified major bottlenecks to achieve effective and complete information on groundwater resources. These gaps, whether real or perceived, come in the form of information, technology, understanding etc. To achieve the objective of the aquifer mapping and accurate ground water resources management it is pertinent to fill these gaps.

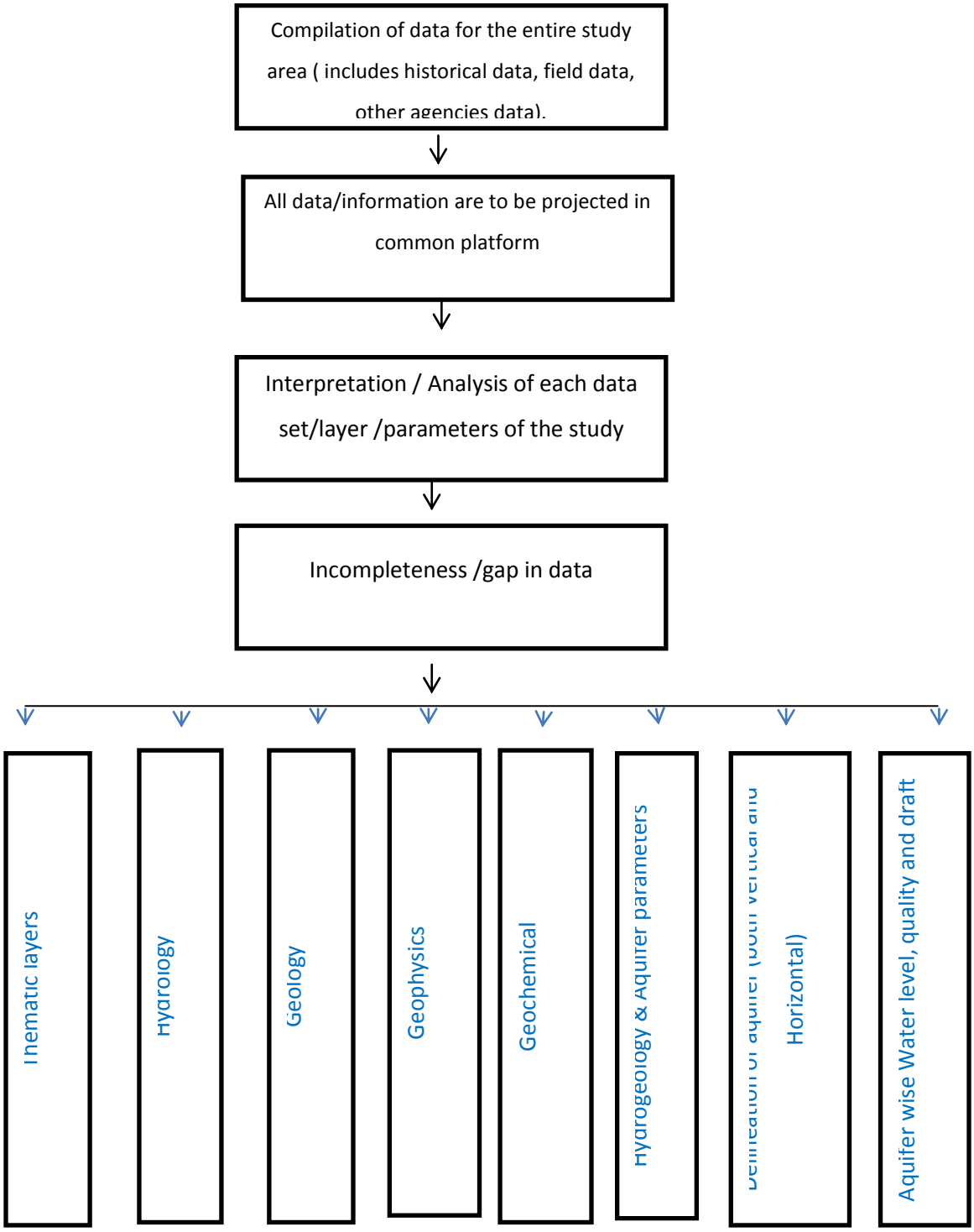
3.1 OBJECTIVE AND SCOPE

The objective of preparing this protocol is to:

- Provide methodology to identifying incompleteness in existing data for improved understanding of the aquifer systems and groundwater management
- Ensure focused groundwater investigations on filling the gaps.

3.2 METHODOLOGY

Compilation of all existing data and Integration of all the data in common platform have been discussed in the previous chapters.



Analysis of existing data for data gap identification

The data compiled will be analysed for achieving the various tasks of identifying the data gaps in thematic maps, geology, hydrogeology, hydrochemical, hydrology aspects, delineation of aquifers (laterally and vertically).

3.2.1 DATA GAP IN THEMATIC LAYER:

After collection of the layers on various themes from different sources the data need to collate at common platform for its scrutiny in respect of correctness and completeness. Since, aquifer mapping is proposed to be taken up on 1:50,000 scale in all areas and 1:10, 000 in specific areas, all the thematic maps such geomorphology, soils, land use, drainage etc are to be prepared on 1:50,000 scale. Wherever maps are not available in the designated scales, same needs to be generated.

3.2.2 DATA GAP IN SUB-SURFACE INFORMATION:

The data of all the wells drilled in the area is to be plotted on the map of 1:50,000 scale with 5 min by 5 min grid (9 x 9 km). Further, principal aquifer layer of the area needs to overlayed on this grid to visually inspect the density of the wells aquifer wise. Care has to be taken for proper representation of the varying geology / hydrogeology within the grid,. The grids/formations devoid of well may be identified as data gaps.

Once the above data gap is fulfilled, the data of the lithology and information of the geophysical logs collected /generated are interpreted manually as well as using suitable software. The shallow well having depth < 300 m in alluvium and < 200m in hard rock terrain may be considered as data gaps and should be used for characterisation of the shallow aquifers. Several cross-sections (2D) in different directions/fence diagrams/3D disposition are to be made to understand/visualise the subsurface aquifer system. Care should be taken so as to have information about the swelling and pinching/termination of layer including structures (fault/fold etc) by preparation of cross-sections/fence diagrams in different directions. After visual interpretation statistical tools may be used to arrive at a suitable spacing of wells in different aquifers so as to reach a level of confidence in interpolation between two observation points.

The aquifer characteristics may be compiled and aquifer parameters of individual aquifer may be considered for the purposes. The cumulative aquifer parameter values may be used for reference purpose only for apportioning on logical and scientific principles. Wherever the representation of the parameter is sparse the same may be marked as data gap and various geophysical resistivity methods or hydrograph analysis methods may be used for estimation of aquifer parameters.

3.2.3 DATA GAP IN INFORMATION ON WATER LEVEL:

The data of all the information on spatial distribution of observation wells in the area is plotted in the map of 1:50, 000 scale with 5 min by 5 min grid (9 x 9 km). Further, principal aquifer layer of the area needs to be overlain on this grid to visually understand the distribution of the observation wells. If the area has varying geology within the grid and has wide variation of water levels, suitable care has to be taken to represent all formation. In case of multi aquifer systems, individual aquifer to be treated separately and density is to be evaluated. The grids/formations/multi layer aquifers devoid of observation well may be identified as data gaps.

After visual inspection the water level data may be subjected to statistical methods to find out the optimal numbers of wells and their locations along with frequency of measurement such as krigging.

3.2.4 DATA GAP IN INFORMATION ON WATER QUALITY:

The data of all the information on spatial distribution of sampling wells in the area is plotted in the map of 1:50000 scale with 5 min by 5 min grid (9 x 9 km). Further, principal aquifers of the area needs to overlayed on this grid to identify the nature of the distribution of water quality parameters. The area with varying geology within the grid should have proper representation of observation points. The grids/formations devoid of sampling well may be identified as data gaps.

3.2.5 DATA GAP IN AQUIFER WISE DRAFT DATA :

Aquifer wise pumping wells data used for Agricultural, Water Supply, Domestic and Industrial are to be collected and compiled for estimation of the ground water usage from all sources. The data need to be collected on the standard formats used by the Minor Irrigation Census. Also, data on recharge to ground water need to be collected.

Following the summary of the items and methodology where the data gap analysis is to be carried out:

Sl nO	**Data Gap Analysis**	**Methodology**
1		
a	Additional Nos of Observation Network (WL/WQ)	Optimal density and frequency of the measurement to be arrived on visual/ statistical tools.
b	Additional Nos of Exploratory Well Locations	Optimal density of the exploratory well to be arrived on visual interpretation keeping in view

		the aquifer type/geomorphological setup etc. well having depth of 300 m in alluvium and 200 m in Hard rock may be considered as available data.
c	Aquifer Parameter and logs	At many well location aquifer parameters are not available due to various reasons. Data gaps may be identified for pumping test analysis on additional wells.
d	Additional VES Locations	Based on the existing and proposed wells, gaps may be identified wherein only VES data can supplement the information.
2	**Data Generation**	
a	Water Level Data	Establishment of improved network of water level observation wells/piezometer.
b	Water Quality Data	Establishment of improved network of water Quality observation wells/piezometer.
c	Subsurface Lithological data	Drilling of the wells at recommended sites following the standard protocols.
d	Aquifer Parameter	Determination of the K, T, S or SY of the aquifer using the standard methodologies of Aquifer Performance Test.
e	Aquifer Information from VES	VES surveys at recommended site using standard methodologies.
f	Total Well Inventory	One time well census on irrigation, drinking/domestic, industrial and other uses has to be generated in line of population census of India using standard and simplified formats.
g	2D Imaging	Demarcation of the aquifer system using standard geophysical practices of the 2D imaging. The technique to be used at select places.
h	Advance Geophysical Methods	Demarcation of the aquifer system using advanced geophysical practices. To be used at select places.
i	Soil Infiltration Studies	Estimate soil infiltration parameters at suitable places using standard methodologies.

4 AQUIFER MAP PREPARATION

Geographic Information System technology enables bringing data and maps developed separately from various sources on a common platform. The process of multiple overlays enables to place one map over the other. It also helps in building an interrelationship between features to reveal the characteristics of geographically located common areas. The essential requirement of the present project is to build the aquifer map into GIS environment for developing interrelationship between various parameter which controls occurrence and movement of the ground water. Under this endeavor, GIS datasets are proposed to be created for the entire India at a scale of 1:50,000 scale and 1:10,000 scale for specific problem areas. Survey of India toposheets having scale 1:50,000 would form the base of all the maps on LCC projection. The data already available with the different State Ground Water Agencies created on 1:50,000 scale would be utilized for the project after validation checks. For better understanding of the hydrological/hydrogeological system and for refining the water resource estimations, additional spatial data on surface drainage, land-use, geomorphology, slope, soils, geology and structures, sub surface data and man-made (anthropogenic) features are required. The field measurements, when analysed in combination with the spatial data, vastly enhance the understanding of the hydrological system. The GIS tool enables to visualise the real world through integration of the different layers of spatial information and point data in 3 Dimension. Digital maps, generated from the toposheets and the thematic data interpreted from satellite imageries, when linked to attribute data stored in the database, provide a new understanding of the water resource systems. The present protocol is an effort to standardize the processes and methodology of development of GIS datasets and Maps creations using standards adopted though out the World.

4.1 OBJECTIVE

The objective of preparing this protocol is to:

- Develop GIS database on aquifers of India for the benefit of Users and professional on desktop or on internet environment.
- Develop a methodology for designing and printing maps for public use**.**

4.2 SCOPE

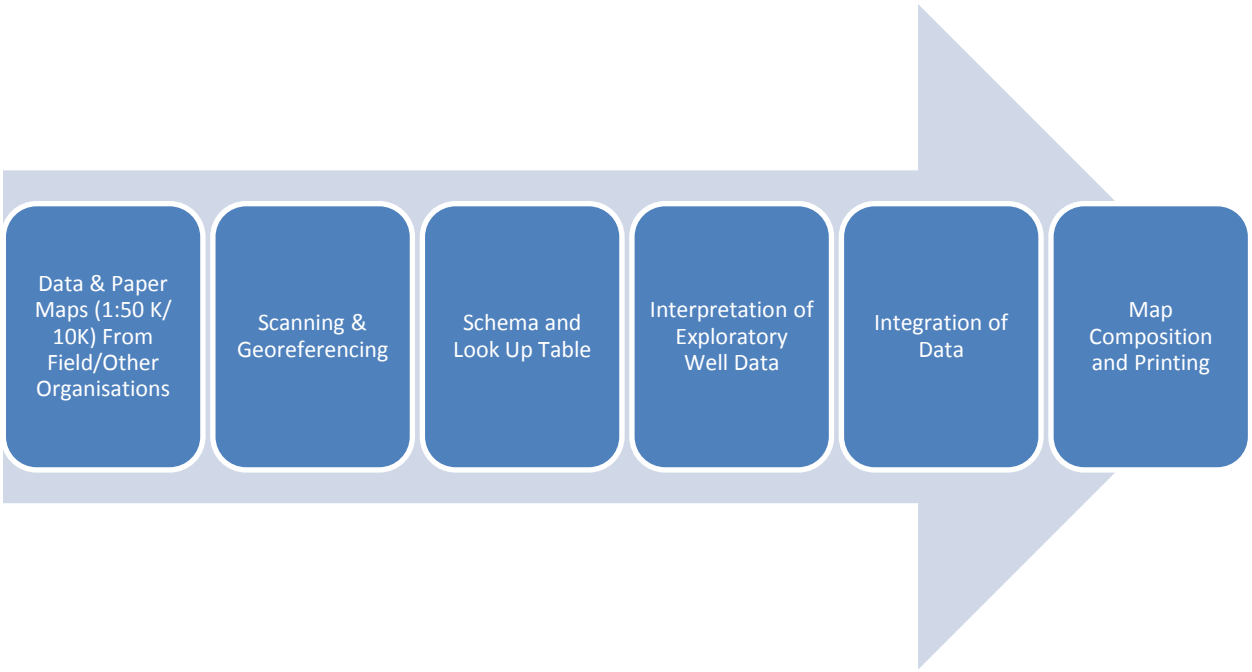
Preparation of the Aquifer Map includes

- Digitisation of aquifer map and preparing aquifer GIS Data sets .

- Preparing GIS datasets on aquifer thickness, depth of occurrences of water bearing zones, their water bearing and transmission properties, etc
- Digitisation of the Maps and preparing GIS Datasets depicting geophysical parameters.
- Digitisation of the Maps and preparing GIS Datasets depicting water quality parameter.
- Preparation of conceptual model of the area and visualization of the aquifer units in three dimension including fence and cross section preparation.
- Aquifer wise groundwater resource estimation

4.3 METHODOLOGY

The processes of digitisation, preparing GIS dataset and finally printing involve various steps. These have been elucidated in the following flow diagram:-



4.4 SCANNING AND 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 and each map tile will be assigned a unique number. Thematic coverage of any specific hydrologic or administrative unit will be generated by digitally mosaicing 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 manmade 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 LCC 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 associate 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. It is proposed to digitize/ procure the following GIS data:

S.No	Theme	Type	Source
Primary Layers			
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**		
3	GW-SW interaction	Polygon	In house Data analysis
4	Demand Supply Map	Polygon	In house Data analysis
5	Environmental Protection Area Map	Polygon	In house Data analysis
6	Drinking Water Supply Source Map	Polygon	In house Data analysis
7	Industrial Zone map	Polygon	In house Data analysis
8	Water Market & Others Map	Polygon	In house Data analysis

S.No	Theme	Type	Source
C	**Management options support maps**		
9	Population	Points	Census
10	Land Use/ Cover	Polygon	NRSC
11	Soil	Polygon	NBSS
12	Geology – lithology	Polygon	GSI
13	Geology - structure	Line	GSI
14	Geomorphology	Polygon	NRSC/ In house Data Analysis
15	Hydrologic boundary	Polygon	In house
16	Drainage	Line	SOI/ DEM In house Data Analysis
17	Transport network Road/ Rail Line	Line	SOI
18	Contours	Line	SOI/ DEM In house Data Analysis
19	Spot heights	Point	SOI
20	Administrative boundary	Polygon	SOI
21	Block Boundary	Polygon	SOI
22	Village Boundary	Polygon	SOI
23	Towns	Point	SOI
24	Isohyte Map	Line	In house Data analysis of IMD Data
25	Groundwater quality	Polygon	In house Data analysis
26	Isotope study results	Point/polygon	In house Data analysis
27	C 14 Study results	point	In house Data analysis
28	GW Pollution	Polygon	In house Data analysis

S.No	Theme	Type	Source
	Industrial/Agriculture/ Domestic		
D Management 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

After paper map is ready same shall be scanned and digitized using an appropriate scanner following standard procedure. The geo-database (ESRI) shall be created and edited to remove digitization errors, and the topology shall be built. The features shall be labelled 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.

4.5 SCHEMA AND LOOK UP TABLE

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

4.6 INTERPRETATION OF EXPLORATORY WELL DATA

CGWB and States Departments have vast repository of the data pertaining to wells drilled for exploratory purposes, drinking water supply and irrigation purposes. This data can provide rich

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 program of CGWB and the other State Govt. programs 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 reclassifying the whole lot of lithological data following the standard international nomenclature system preferably adopting the same lithologies 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 the area can be developed using off the self suitable litho-modelling software. The output of these model 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 the bigger area. These diagrams will further give a general layout of the aquifers in the area depicting smaller units also. These output can be used as input to the local models for managing local aquifers. However, lithological models have their limitation and are rarely useful for regional level models interpolation. The smaller aquifer need to be bunched/grouped under major aquifer systems. These re-grouped systems are the major aquifer systems occurring a large areas and can be further used for regional level aquifer management.

The lithological and stratigraphic model of the areas will provide three dimensions configuration, aquifer top, aquifer bottom and their thickness over the area of occurrence. The major constraint of such interpolation modeling software is non-availability of the Reduce Level 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 map to be presented in 2D and modeling software for development of optimal water resources utilization plans.

4.7 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 map. This map would provide area and location specific information to the user in friendly manner. These maps can grouped in three

categories namely, the aquifer maps, aquifer properties & vulnerability maps and aquifer management option maps.

- The aquifer maps may depict the aquifer extent, bed rock configuration 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 stress and quality affected 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 give out suitable management options for areas under consideration. The major input to 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 for the specific area.

4.8 LAYOUT AND DESIGN

As discussed in the previous paragraphs the map data will be generated in GIS environment. Since, these data are either point, line or polygon features and hence difficult to be understood by simply observing. These features required to be color coded and annotated with standard labels for their easy under stability. All the maps need to labeled and color coded using the standards available worldwide.

Since, these maps will be used for implementation of various GW management plans, they are required to be presented on a large working scale preferable 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 covers an area of approximately 720 sq. km corresponding to one Survey of India (SOI) toposheet on 1:50, 000 scale and consists 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 for locating the user in their area of interest.

The map title, fonts, styles, color scheme, annotation styles etc should be adopted from the Survey of India toposheets. The color coding scheme and symbology for aquifer systems on 1:50,000 scale should

be distinct and standardized for an area and should be uniformly used throughout India. The map title should occupy the center position and north aero should be on the top right. The map should also bear a logo of department along with copy right information on the lower left corner.

4.9 LEGEND OF THE MAP

Legend is the key to the map and help in reading the map information. The number of themes, their colour schemes and font give richness to the map and help in understanding it in user friendly way. The international legend style will be used in preparation of the 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 present the information from various sources generated by the other departments they need to be acknowledged suitably. The sources of the data shall be mentioned in each map in the bottom left outside of the map frame to acknowledge the work of peer agencies. The map should have following elements:

Sl no	Map Contents
1.	Title of the Map
2.	Method followed for preparing the Map
3.	Scale of the Map
4.	Map number - Survey of India 1:50,000 scale toposheet index number
5.	Administrative area covered by the map
6.	Geographical directions of the map area
7.	Organization which has copy right on the map
8.	Input data used for preparing the map
9.	Organization which has prepared the map
10.	Index for Aquifer Map - Fixed part of the legend
11.	Index for hydrological Information - Fixed part of the legend
12.	Index for base map Information - Fixed part of the legend
13.	Body of the map
14.	Main Legend of the map – Dynamic part of the legend describes body of the map taking
15.	Location map – index

4.10 DATA BACKUP AND STORAGE

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

5 PARTICIPATORY GROUND WATER MANAGEMENT

5.1 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 water regime.
- Capacity building of groundwater using farmers for increasing water use efficiency
- Efficient management of groundwater and informed decision making on cropping pattern and application 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 cropping pattern

5.2 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 be exclusively constituted as Ground Water Management Association (GWMAs). The formulation and 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 of groundwater. Awareness, capacity building and training of farmers for demand side management of ground water.
- Participatory Ground Water Monitoring – The farmers are equipped to record the ground water level and rainfall data, analyze the seasonal (and daily fluctuations) for understanding the ground 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 and seasonal 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 District level where all the data collected by Para-hydrogeologists may be compiled and sent to the State HQ.

5.3 PARTICIPATORY GROUND WATER MONITORING TRAINING MODULES

For awareness, capacity building and training of farmers for PGWM several training modules have been developed under APFAMGS. Based on the past experiences of various successful participatory ground water 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

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	▪ History of groundwater development. ▪ Understanding the present ground water situation. ▪ Participatory ground water Monitoring Institutions involved in water management. ▪ Crop water	▪ The farmers understand the ground water situation, the concept of PGWM, water balance estimation and preparation of crop plan according to the water audit.

		on groundwater development	budgeting	
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	▪ Need for PGWM ▪ Water cycle and distribution ▪ Handling of instruments ▪ Facilitating the	▪ PHGs/ Farmers understand the utility of measuring the rainfall, water level and

		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	data collection ▪ Recording the data ▪ Allocating responsibilities	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 period of time	▪ Data recording ▪ Data dissemination ▪ Data Interpretation ▪ Preparation source wise hydrographs ▪ Preparation of composite hydrograph	▪ PHGs Enter the data in record register ▪ Prepare hydrographs ▪ Disseminate data on display boards ▪ Understand the factors influencing ground water fluctuations
5	Water balance	▪ Water balance estimation of the	▪ Groundwater situation	▪ The participants are able to assess

	estimation	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	▪ Watershed delineation ▪ Data analysis	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	▪ Estimation of ground water recharge ▪ Estimation of ground water draft ▪ Estimation of groundwater	▪ Prepare graphs and tables summarizing crop plans, water budget, water balance, and cropping pattern

		▪ Plan for groundwater recharge ▪ In case of deficit balance, change the crops from high water requiring crops to low water requiring crops	balance ▪ Crop plans ▪ Crop water requirements ▪ Projected groundwater balance ▪ Change in cropping pattern	changes that may be required

Central Ground Water Board

MANUAL ON AQUIFER MAPPING

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