



Ground Water Prospects Maps

Prepared Under

Rajiv Gandhi National Drinking Water Mission Project

User Manual



Ministry of Drinking Water and Sanitation

Government of India,
New Delhi - 110003

National Remote Sensing Centre

Indian Space Research Organization
Dept. of Space, Govt. of India, Hyderabad - 500625

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Foreword

There are about 45 lakh informed public drinking water sources in the rural areas of the country of which about 80 percent are based on ground water sources. The ground water development is highly dynamic and widely varying amongst different agro-climatic zones in the country. While the total drinking water requirement is only about 8 percent of the total water usage in the country, sustainability of these drinking water sources is largely impacted in some places due to other activities like agriculture, industry etc.

As a part of achieving sustainability of drinking water sources through artificial water recharge, surface impoundment/percolation, rain-water harvesting etc., it is essential to prepare Hydro Geo-Morphological (HGM) Maps using satellite data for facilitating the State Governments to identify correct locations of siting sustainability structures and also to locate high yielding/sustainable borewell/tubewell locations.

In this attempt, the Ministry has engaged the services of National Remote Sensing Centre, ISRO, Hyderabad for preparation of ground water prospect maps/HGM Maps. As of now, HGM Maps have been completed for 19 States. Similar maps preparation is under process for the remaining States and UTs and these are expected to be completed before the end of year 2013.

In order to facilitate the field engineers/hydro-geologists for using these maps effectively, a User Manual has been prepared. I expect that this Manual will be of use to all field level implementing agencies, planners, researchers and monitoring agencies in managing ground water based drinking water sources effectively.

(Vilasini Ramachandran)

New Delhi
October 18, 2011



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Preface

Ground water is the major source of drinking water in India. In order to make ground water sustainable, there is a need to understand the aquifer characteristics as well as its geological setting. This understanding not only helps in designing regulated withdrawal of ground water but also for planning suitable mechanism for ground water recharge. It is estimated that there are large number of habitations yet either Not-Covered (NC) or Partially Covered (PC) with potable water supply schemes mainly because the potential locations for the occurrence of potable ground water could not be identified in the immediate vicinity of such habitations. In recent years, even the covered habitations are also slipping back to NC and PC categories due to drying up of existing wells. It is now felt that to address and overcome these problems the drinking water supply schemes have to be developed considering the hydrogeological information and maps. At the request of the Ministry of Drinking Water and Sanitation, Government of India, National Remote Sensing Centre / ISRO is preparing Ground water prospects maps containing comprehensive data on ground water using Remote Sensing technology and Geographic Information System (GIS). The maps are serving as a reference database for identifying potential locations both for drilling wells and constructing recharge structures specific to the site.

However, since the ground water is a hidden resource, a number of parameters that are manifested on the ground had to be considered and analyzed based on deductive techniques involving complex processes to prepare the maps. Both input and derivative data along with the processes are depicted on the maps to make them self explanatory. However, it is understood that the map users, particularly the non-hydrogeologists, find it not very easy to read the maps. It is in this context that a user manual has been prepared explaining the contents of the maps. I hope that the document will help the users especially the hydrogeologists and engineers to make use of these maps effectively on the ground for siting wells and for constructing recharge structures.

I complement the efforts of NRSC/ISRO and Ministry of Drinking Water and Sanitation for bringing out such a user friendly - easy to follow manual for the benefit of field level officials who are implementing the drinking water supply schemes in the States.

Vkdadhwal
(V. K. Dadhwal)



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1. Map Description

1.1 Background for preparation of ground water prospects maps

Identification of potable ground water sources which are sustainable for longer periods is a critical issue in the supply of drinking water to the rural habitations in the country. To address this issue, the erstwhile Department of Drinking Water and Sanitation (DDWS), Ministry of Rural Development (MoRD), Govt. of India which is the apex organization for drinking water supply in the country has requested National Remote Sensing Centre (NRSC), ISRO / Dept. of Space, Govt. of India to prepare ground water prospects maps (technically Hydro Geo Morphological-HGM maps) on 1:50,000 scale using remote sensing and GIS technology. The Ministry wants these maps to be used by the engineers and hydro geologists of the line departments in respective states for identifying ground water sources, particularly for Not Covered (NC) and Partially Covered (PC) habitations. NRSC has taken up the work in phased manner under Rajiv Gandhi National Drinking Water Mission (RGNDWM) project. The maps have already been prepared for major part of the country and handed over to the line departments in respective states. Preparation of maps for remaining part of the country has been taken up recently and is expected to be completed by 2013.

The states for which the maps are already prepared and the line departments in the respective states with whom the maps are available are furnished in Table-1.1.

Table-1.1: States covered by ground water prospects mapping as on 2010 and respective state line departments with whom the maps are available

Phase	States for which maps are prepared	Line departments with whom maps are available
Phase-I (1999-2002)	Andhra Pradesh (Eastern part)	Rural Water Supply & Sanitation
	Chhattisgarh	Public Health & Engineering Dept.
	Karnataka	Mines & Geology
	Kerala	Public Health & Engineering Dept.
	Madhya Pradesh	Public Health & Engineering Dept.
	Rajasthan	Public Health & Engineering Dept.
Phase-II (2003-2005)	Gujarat	Gujarat Water Supply & Sewerage Board
	Himachal Pradesh	Public Health & Engineering Dept.
	Jharkhand	Public Health & Engineering Dept.
	Orissa	Public Health & Engineering Dept.
Phase-III A (2008-2010)	Andhra Pradesh (Western part)	Rural Water Supply & Sanitation
	Assam	Public Health & Engineering Dept.
	Jammu & Kashmir	Public Health & Engineering Dept.
	Maharashtra	Ground water Supply & Development Agency
	Punjab	Minor Irrigation & Water Supply
	Uttarakhand	Public Health & Engineering Dept.

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Phase	States for which maps are prepared	Line departments with whom maps are available
Phase–IIIB (2009–2010)	Arunachal Pradesh	Public Health & Engineering Dept.
	Haryana	Public Health & Engineering Dept.
	Uttar Pradesh (Agra & Bundelkhand regions)	Jalnigam
	West Bengal (7 districts)	Public Health & Engineering Dept.

1.2 Format of the ground water prospects maps

The ground water prospects maps are available both in digital as well as in hard copy formats. The information content is same in both the formats.

The hard copy format is available in the form of A0 size map (1 / 1.2 meter paper print). Each map covers an area of approximately 700 sq. km corresponding to one Survey of India (SOI) toposheet on 1:50, 000 scale and consists of an exhaustive self-explanatory legend. The same ground water prospects map is also available as soft copy in PDF format. It can be viewed using a normal computer system with Adobe Acrobat Reader 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 is required.

The digital ground water prospects maps are made using 19 independent layers, each layer containing information pertaining to a specific parameter. All these layers are available both in e00 and shape file formats. The final ground water prospects maps are available in mapcomposition or mxd. file format. In addition to this, five more thematic maps - 1) lithology map 2) Structural map 3) Geomorphology map 4) Hydrology map and 5) Base map are generated as intermediate products in the process. List of the input layers used for map making and the sequence of ground water prospects maps generation is explained schematically in Fig-1.1.

The digital ground water prospects maps can be viewed on Workstations with Arc GIS software 9.5.1 or higher version. They are amenable for user specific modifications. The maps can be enlarged to larger scales, subjected to analysis for deriving user specific solutions, updated by incorporating dynamic data, etc.

1.3 Relevance of the user manual

Since the ground water is a hidden resource, a number of parameters have been studied and analyzed to know its occurrence and distribution. The resource has been mapped based on derivative techniques involving complex processes. Both input and derivative data along with the processes have been illustrated and depicted on the map to make the same self-explanatory and to facilitate the users to draw their own conclusions about the resource. Therefore, it is a pre-requisite of the users to read the data in right perspective and understand the information content properly in order to put the ground water prospects map to effective use. Thus the envisaged objective of Rajiv Gandhi National Drinking Water Mission project can be achieved.

In fact, the ground water prospects maps are meant for usage by the field geologists / hydrogeologists. It may not be that easy to read and understand the maps straight away like the other resource maps by all. A geological / hydrogeological knowledge is required for understanding

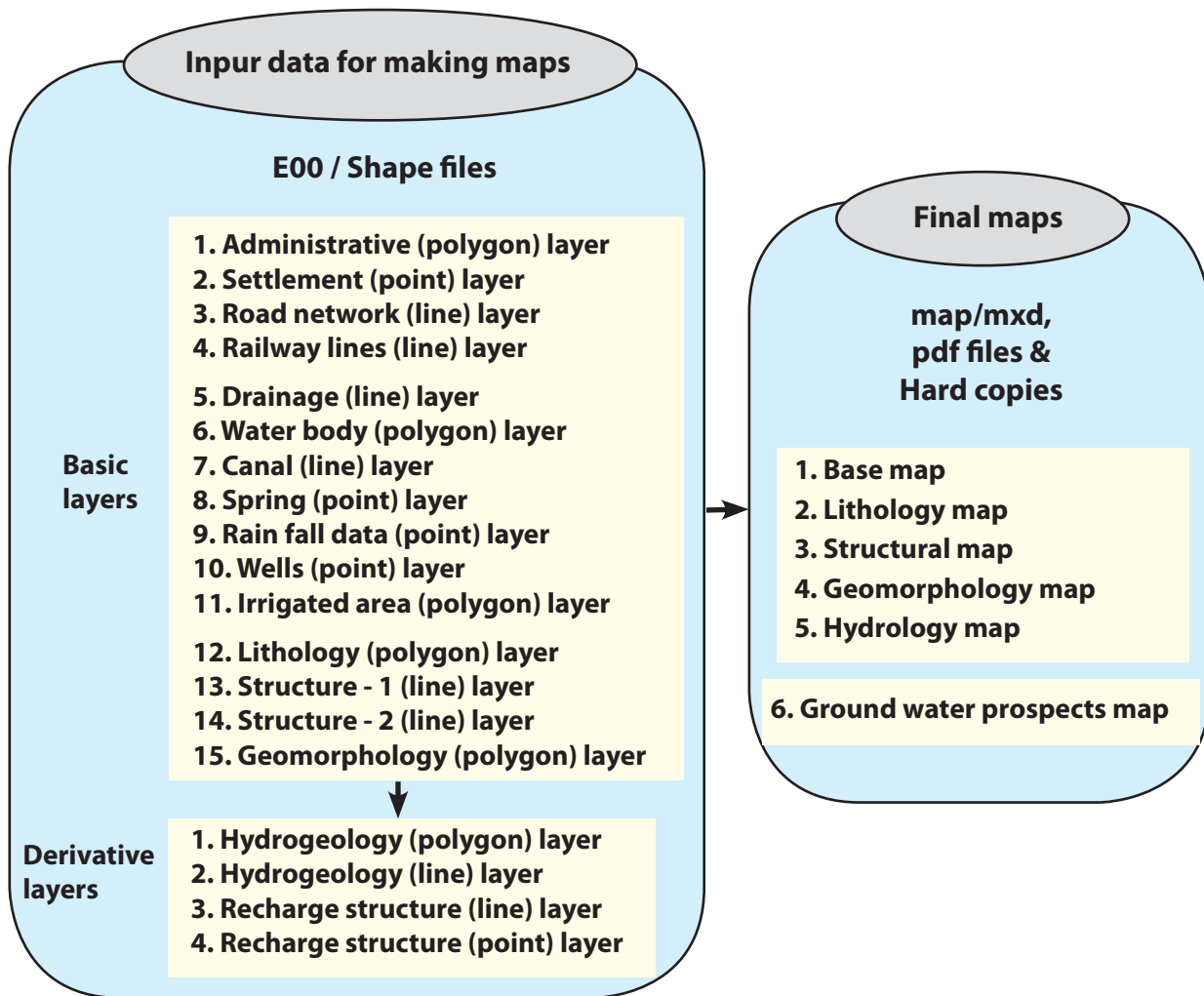


Fig-1.1: Components of digital ground water prospects map

the maps more meaningfully. However, in order to improve the map reading skills and build the capacity of all the technical people who are involved in rural drinking water supply programme in using the ground water prospects maps for ground water prospect area identification and site selection for constructing ground water recharge structures, this manual is being brought out.

There are three major aspects that are to be looked into by the user while using the maps in the field. i) The amount of information content depicted in the form of different symbols and codes, ii) The scientific rationale behind the process of generation of information content and iii) Referencing of map features in terms of x, y and z coordinates with the corresponding ground objects in order to a) identify ground water sources for supplying drinking water to the problematic villages and b) to locate sites for constructing site-specific recharge structures to improve the sustainability of the ground water sources.

An attempt is made in this document to address these issues under five chapters. In the first chapter, the background in which the preparation of the ground water prospects maps have been taken up, the format of the map and status of the availability of the maps are discussed. In the second

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chapter, the information content that is available in the map has been furnished. In the third chapter, the scientific rationale behind the process of generation of information content has been explained. In the fourth chapter, the procedure to identify the locations in terms of x, y and z coordinates for drilling wells as well for constructing recharge structures besides the other map features on the ground. In the fifth chapter, different applications of the map, including its use for developing drinking water security plans has been highlighted. It is expected that the document will enable the users – a hydro geologist or an engineer - to use the map more effectively.

2. Map Contents

The ground water prospects map contains mainly three categories of information – i) Reference information ii) spatial data on ground water prospects and sustainability including relevant hydrological and cultural features and iii) legend / index giving explanation about the map contents. All this information is organized and depicted on the map in the form of 21 components. A sample ground water prospects map pertaining to part of Bangalore district of Karnataka state showing all the 21 components in circles is provided in fig-2.1 on a reduced scale for ready reference.

Same map on 1:50,000 scale which gives better clarity and facilitates easy reading is provided separately in the pouch of the manual. Each component in terms of its information content is described below.

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 designed and developed the map layout
10	Organization which has prepared the map
11	Organization which has provided technical guidance for preparing map
12	Organizations which have participated in the preparation of the map
13	Organization which has provided methodology for preparation of the map
14	Organization which has sponsored the mapping work
15	Index for ground water prospect information - Fixed part of the legend
16	Index for hydrological Information - Fixed part of the legend
17	Index for structural Information - Fixed part of the legend
18	Index for base map Information - Fixed part of the legend
19	Body of the map
20	Main Legend of the map – Dynamic part of the legend describes body of the map taking symbols from the fixed part of the legend as well.
21	Location map - index

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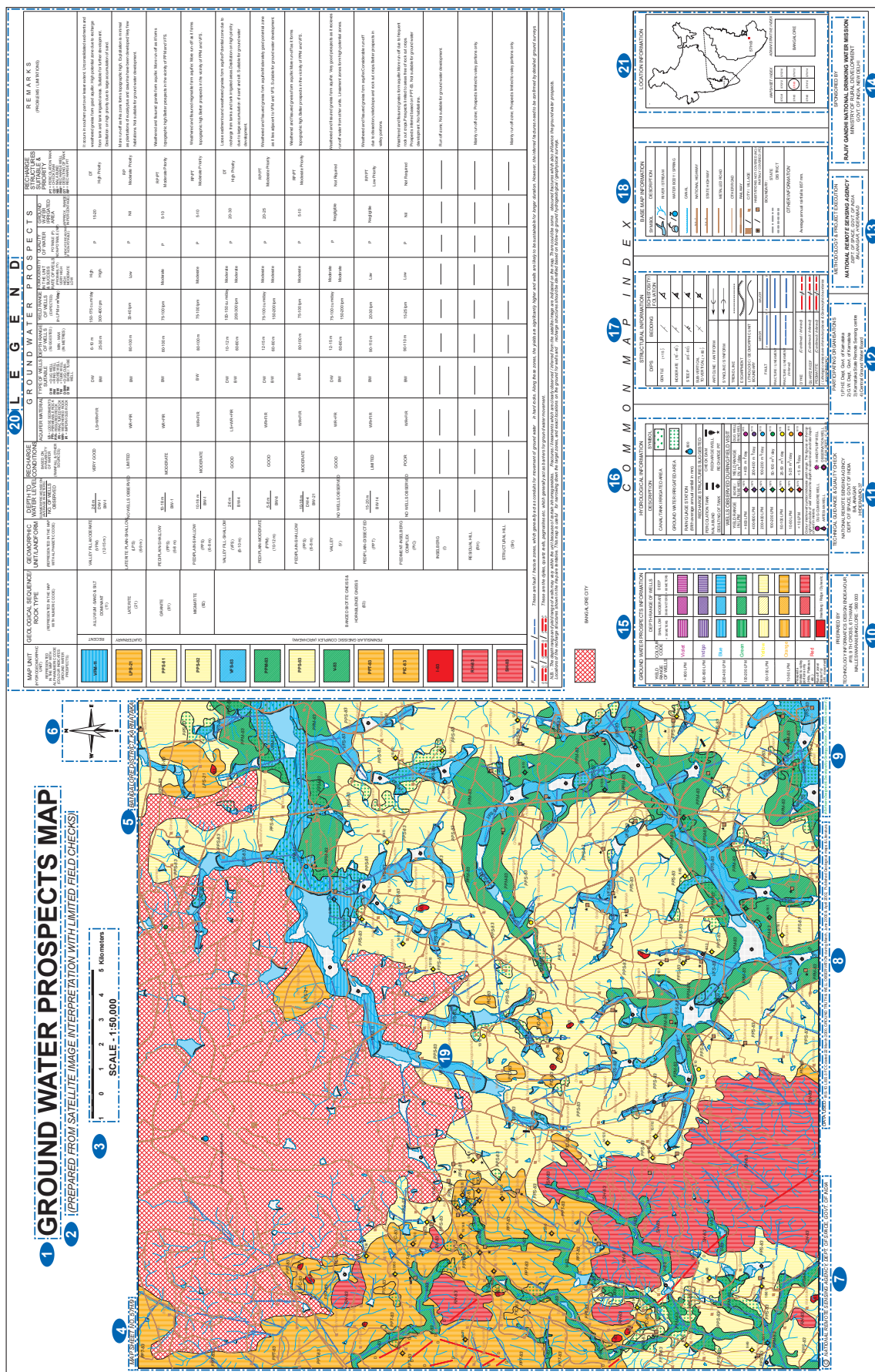


Fig-2.1: A sample ground water prospects map pertaining to part of Bangalore district of Karnataka showing map components
 Note: Please see the full size map pasted inside the back cover

2.1 Reference information

The map is titled as "Ground water prospects map" **1**. The title is given so, because the map not only provides information on the potentiality of the aquifer for the occurrence of ground water but also on the ground water prospects and availability of ground water at a given location.

The map is prepared based on the interpretation of satellite data with limited field checks **2**. The input data required for preparing the map is extracted from satellite data using image interpretation techniques in conjunction with ground truth data collected at few representative locations. The input data in turn is integrated using GIS and derived ground water information based on correlation study with existing well observation data.

The ground water prospects map (hard copy) is produced on 1:50,000 scale. It is shown on the map in the form of bar scale **3**.

It helps in measuring the distances between two points. One centimeter on the map is equivalent to 50,000 centimeters i.e. 500 meters / ½ kilometer on the ground.

The map is prepared in such a way that it corresponds to Survey of India toposheet on 1:50,000 scale in terms of sizes, shapes and distances of objects. The map can be used in conjunction with the toposheet. Hence the map is provided with the toposheet number **4** (for example, Map sheet no. 57 H/9) to which the map corresponds. The number changes from map to map.

The ground area covered by each map is approximately 700 sq km. Administrative point of view, the map area belongs to one or more than one district of one or more than one state. The name of



SCALE - 1:50,000

the district (s) and state (s) to which the map area belongs is given (for example, part of Bangalore District, Karnataka State) at **5**.

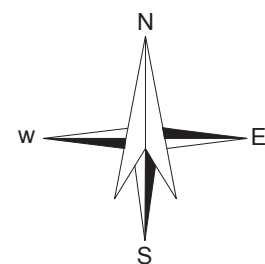
The location of the area in terms of its toposheet number and administrative coverage is shown as an Index map at **21**.

Geographical directions of the area covered by mapping is given in terms of 4-directions, North, South, West and East using a symbol **6**.

The map needs to be oriented accordingly for referencing the spatial features on the map with corresponding ground objects.

Capability of the Remote Sensing and GIS technologies for ground water study is unique. The methodology used for preparing the ground water prospects map is innovative. They are developed by National Remote Sensing Centre (NRSC) / Indian Space Research Organization (ISRO), Department of Space, Government of India. Hence the map is under copy right of the organization **7**.

Satellite data is the main input for preparing the maps. Ground truth, Existing well observation data and already available maps & literature have also been used for updating and validation of the maps. The details of the satellite images, ground truth and well observation data used for preparing the maps is given at **8**.



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Hydrogeology Division of National Remote Sensing Centre (NRSC), ISRO has designed and developed the layout of the ground water prospects map **9**.

Preparation of ground water prospects maps for entire country is a voluminous task. Many activities are involved in the mapping work. Hence the maps are prepared under project mode by a group of organizations, each one taking the responsibility for specified project area. NRSC, State Remote Sensing Centers, State line departments, Universities, private entrepreneurs are involved in preparing the maps. The organization that has prepared the map is given at **10**.

National Remote Sensing Centre (NRSC) / Indian Space Research Organization (ISRO), Department of Space, Government of India, Hyderabad has provided technical guidance for preparing all the maps **11**.

Different organizations in different states have contributed their data, expertise and manpower for preparing the maps. Organizations which have contributed are listed at **12**.

National Remote Sensing Centre (NRSC) / Indian Space Research Organization (ISRO), Department of Space, Government of India, Hyderabad has provided methodology for preparing all the maps. The same is mentioned at **13**.


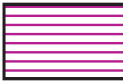



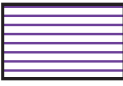

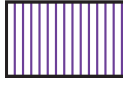



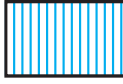



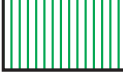









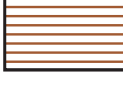







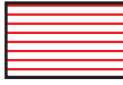



The ground water prospects maps are prepared under Rajiv Gandhi National Drinking Water Mission Project. The organization which has sponsored this project is erstwhile Department of Drinking Water and Sanitation, Ministry of Rural Development, Govt. of India, New Delhi given at **14**.

Ground water prospects Information 15: The depth and yield ranges of the wells recommended hydrogeomorphic unit - wise are represented with different colours and different hachuring patterns. The yield ranges that are possible belong to nine categories. Similarly the depth ranges that are possible belong to three categories. Any combination of these yield and depth ranges is possible to occur and the numbers of combinations are many. To represent each combination on the map a VIBGYOR colour scheme is used and is given at **15** as fixed part of the legend.

There are seven colours, i.e. violet to red, used for depicting different yield ranges. However, the orange colour used for depicting 10-30 lpm yield range is further divided into three ranges i.e 10-20, 20-30 and 30-50 and depicted with pink, brown, orange colours respectively on the maps prepared under phase III A, B and IV of the project. Within each yield range, 3 hachuring patterns are used for depicting the depth range of wells. Thus, a hydrogeomorphic unit showing one of the three hachuring patterns in a particular colour (from violet to red) indicates the expected yield range and suggested depth range of the wells. For example, a unit with horizontal hachuring in blue colour indicates that the expected yield range in that unit is 200-400 lpm and the depth range of the well is <30 m. The inselbergs, linear ridges, dykes, etc which act as run-off zones/ barriers for ground water movement, are indicated with solid red colour, and the hills (SH, DH and RH) and dissected plateaus where the prospects are limited to valley portions only are indicated with red hachuring.

However, the depth and yield information of the wells pertaining to the fracture controlled hydrogeomorphic units is given in the form of foot note of the legend (dynamic part) as it is not possible to represent with colour-hachuring codes. It is considered that the yield of wells in fracture controlled hydrogeomorphic units is one range high of the wells in surrounding lithology-landform controlled hydrogeomorphic unit. However, the depth of the wells is same as the depth of the wells in surrounding lithology-landform controlled hydrogeomorphic unit. As far as the ground water prospects pertaining to the fracture controlled hydro geomorphic units filled with dykes, they are

15 GROUND WATER PROSPECTS INFORMATION

COLOUR	YIELD RANGE OF WELLS	DEPTH RANGE OF WELLS		
		SHALLOW < 30 M	MODERATE 30-80 M	DEEP > 80 M
	> 800 LPM			
	400 – 800 LPM			
	200 – 400 LPM			
	100 – 200 LPM			
	50 – 100 LPM			
	30 – 50 LPM			
	20 – 30 LPM			
	10 – 20 LPM			
	Prospects limited to valley portions only (Hills & Plateaus)			
	Run off zones / Barriers (Linear ridges / Dyke ridges / Inselbergs)			




























treated as barriers of ground water and are represented on the map with red colour. However, upstream side of the unit forms as potential locales for ground water occurrence.

Hydrological Information 16 : There are two types of hydrological parameters on which information is provided in the map. First type of parameters includes rainfall, streams, rivers, water bodies, canals, irrigated area, and springs. They indicate recharge condition prevailing in the given area and surface water available for harvesting. Information on these parameters is represented on the map using different symbols.

Information on rainfall is provided in terms of location of rain gauge station and average annual rain fall (in mm) at the station. The location is shown with symbol and rainfall as a value in the form of superscript to the symbol. Information on streams, rivers, water bodies and canals is provided in terms of their spatial occurrence. On the map, the streams are represented as cyan colour line

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16 HYDROLOGICAL INFORMATION

DESCRIPTION		SYMBOL	
CANAL/TANK IRRIGATED AREA			
GROUND WATER IRRIGATED AREA			
RAIN GAUGE STATION (With average annual rainfall in mm)			
RECHARGE STRUCTURES SUGGESTED			
PERCOLATION TANK		CHECK DAM	
NALA BUND		RECHARGE WELL	
DESILTING OF TANK		RECHARGE PIT	
WELLS OBSERVED DURING FIELD VISIT			
YIELD RANGE IN LPM	BORE / TUBE WELL	YIELD RANGE IN m ³ / day	DUG WELL/ RING WELL
> 800 LPM		> 400 m ³ / day	
400-800 LPM		200-400 m ³ / day	
200-400 LPM		100-200 m ³ / day	
100-200 LPM		50-100 m ³ / day	
50-100 LPM		25-50 m ³ / day	
10-50 LPM		5-25 m ³ / day	
< 10 LPM		< 5 m ³ / day	
<p><i>Colour inside well symbol indicates yield range. The figures on the top right hand side of well indicate the depth to water level and total depth of well in meters.</i></p>			
	DUG-CUM-BORE WELL		HAND PUMP WELL
	ARTESIAN WELL		OBSERVATION WELL OF G.W DEPT. / C.G.W.B

features where as the rivers and the water bodies as cyan color polygon features. However, the perennial part of the rivers and water bodies is shown with solid cyan colour and the ephemeral part is shown with black colour dots. Ordering of the streams into 1st, 2nd, 3rd, 4th, and 5th orders can be done by studying the network. When two 1st order streams join, the stream from confluence down is a 2nd order stream. Similarly two 2nd order streams meet to make the 3rd order stream from their confluence point downward. Thus similarly 4th, 5th and higher order streams are formed. Information on irrigated area is provided in terms of source water for irrigation i.e. canal/tank irrigated area and ground water irrigated area.

The presence of canal and the canal/tank irrigated area indicate that the given area is getting an additional recharge from the return flow whereas the presence of ground water irrigated area indicates the status of ground water utilization though a part of the irrigated water recharges the ground water. Information on springs is provided in terms of its location. Springs form where ground water table intersects with surface, hence indicates aquifer condition.

Existing wells, numbering about 80-100 in each map, considered for map preparation can be treated as second type of hydrological parameters. They indicate potentiality of the given aquifer for occurrence of ground water. Information on the sample wells is provided in terms of yield of the well, water level in the well and depth of the well. The sample wells are represented on the map hydrogeomorphic unit wise, using the symbols shown in 16.

In the symbol, the yield of the well is represented in the form of colour, whereas the water level and depth of the well is represented in the form of numerical values separated by “/” as a superscript to the symbol. The first value pertains to water level and the second value pertains to depth of the well. Both yield and water level values given in the map pertain to the period during which the map is prepared. The period in which the map is prepared is given in the bottom of the map under the heading “data used”.

The symbols used for representing different types of recharge structures are provided at 16 as part of fixed legend. Information on types of recharge structures that are suggested in every hydrogeomorphic unit is given in the form of abbreviations in the 13th column of the dynamic legend against the map units.

Structural information 17: The structural information is represented on the map using different symbols. The symbols are shown as fixed part of the legend given at 17. The main structural features that control the occurrence and movement of ground water are faults, fractures, joints, dykes, etc. Availability of ground water along fractures and faults is better as compared to its immediate surroundings. The dykes work as a barrier for the flow of ground water. Thus in up slope front of a dyke ground water availability is better as compared to the down slope side.

Base map Information 18: Base map information consists of information on cultural features - i) road network ii) rail connectivity iii) habitations and iv) administrative units. Information pertaining to all these features is provided and represented on the map using different colour symbols. The symbols that are used for indicating various cultural features are provided at 18 as part of fixed legend for ready reference.

Information on road network includes information on – National and State highways and all metalled roads in the area and approach roads to the habitations. Each category of roads is shown with different line symbols on the map. All the railway lines passing through the area are shown with distinct symbols. Information on habitations is provided in terms of their locations along with names, and the habitations’ status with respect to drinking water supply. Based on the drinking water supply status the habitations are classified into Not-Covered, Partially-Covered and Normal habitations. Accordingly the information is represented on the map using different symbols. Data pertaining to the status of the habitations with respect to drinking water supply is collected from the concerned state line departments at the time of preparing the maps. As the drinking water supply status of a habitation is a dynamic component, the information provided in the map may not be of permanent use. As far as the information on administrative units is concerned, only the state and district boundaries are shown on the map with line symbols.













17 STRUCTURAL INFORMATION

DIPS	BEDDING	SCHISTOSITY/ FOLIATION
GENTLE (< 15°)		
MODERATE (15° - 45°)		
STEEP (45° - 80°)		
SUB-VERTICAL TO VERTICAL (> 80°)		
ANTICLINE / ANTIFORM		
SYNCLINE / SYNFORM		
TREND LINE		
ESCARPMENT		
LITHOLOGIC / GEOMORPHIC UNIT BOUNDARY		
FAULT	MINOR	MAJOR
	F F	F F
FRACTURE / LINEAMENT		
FRACTURE / LINEAMENT (inferred)		
DYKE (Confirmed / Inferred)		
QUARTZ REEF (Confirmed / Inferred)		
PEGMATITE (Confirmed / Inferred)		
<i>(Lithologic contacts are inferred at places & Geomorphic boundaries are gradational)</i>		

2.2 Body of the map 19

One corner to another corner, the map covers 15 minutes' of latitudes / 15 minutes' of longitudes which is equivalent to approximately 700 sq km ground area. It contains spatial data pertaining to i) cultural features (Base map details), ii) hydrological features and iii) Hydrogeomorphic units occurring within the given 700 sq km area. Hydrogeomorphic units are nothing but aquifers.

18 BASE MAP INFORMATION

SYMBOL	DESCRIPTION
	RIVER / STREAM
	WATER BODY / SPRING
	CANAL
	NATIONAL HIGHWAY
	STATE HIGHWAY
	METALLED ROAD
	OTHER ROAD
	RAILWAY
	CITY / VILLAGE
	HABITATIONS: NOT-COVERED (NC)/ PARTIALLY COVERED (PC)
BOUNDARY :	
	STATE
	DISTRICT
OTHER INFORMATION	
Average annual rainfall is 857 mm.	

Cultural features that are required for the purpose of general reference and hydrological features that are relevant to ground water are only considered for the map making. All of them are represented on the map using different symbols. It has already been discussed in the preceding sections about these features and the symbols used for their representation.

Aquifers: There are two types of aquifers - i) Lithology-landform controlled aquifers and ii) Fault/Fracture controlled aquifers. Both the aquifers are shown on the map. The number of aquifers and the area they occupy depends on the hydrogeological heterogeneity existing in the map area.

i) Lithology-landform controlled aquifers: The lithology-landform controlled aquifers normally occupy large area extent. Hence they are represented on the map as polygon-units as shown in fig-2.2 of the sample map. Each aquifer is identified by an alpha-numerical code, for example VFS-532. In the alpha-numeric code, alpha-code stands for landform (Valley Fill Shallow) and numerical-code stands for lithology (Sandstone of Upper Gondwana Formation) which are controlling the ground water potential in the aquifer. There are 99 types of lithological units and 160 types of landforms in

the country (as per the classification system used for preparing the Ground Water Prospects maps), hence many combinations of lithology and landform types and corresponding number of aquifers are possible.

Each aquifer is estimated for the depth (as a range in meters) to which the well is to be drilled and the yield (as a range in lpm in case of bore wells and Cu.M/Day in case of dug wells) that can be expected from the drilled well. On the map, the depth is represented by hachuring and the yield is represented by colour.

Three depth range categories - i) < 30 m ii) 30-80 m and iii) > 80 m are considered. < 30 m range is represented with horizontal, 30-80 m with slant and > 80 m with vertical hachuring. Similarly, 9 categories of yield ranges - > 800 lpm, 400-800 lpm, 200-400 lpm, 100-200 lpm, 50-100 lpm, 30-50 lpm, 20-30 lpm, 10-20 lpm and <10 lpm are considered. > 800 lpm range is represented in violet, 400-800 lpm range in indigo, 200-400 lpm range in blue, 100-200 lpm range in green, 50-100 lpm range in yellow, 30-50 lpm range in orange, 20-30 lpm range in brown, 10-20 lpm range in pink and <10 lpm range in red colours, respectively.

In addition to this, the aquifers are classified in to five categories -

Aquifers where ground water recharge is required with high priority

Aquifers where ground water recharge is required with medium priority

Aquifers where ground water recharge is required with low priority

Aquifers where ground water recharge is not required

Aquifers where ground water recharge is not feasible

The aquifers where ground water recharge is not required and feasible are not considered for identification of site-specific recharge structures. No recharge structure is shown on the map in these aquifers. In the remaining aquifers as per the suitability, locations for seven types of recharge structures - Recharge Pit, Check Dam, Percolation Tank, Nala Bund, De-silting of Tank, Invert Well (Recharge Well), and Subsurface Dyke – are identified and marked on the map within the respective aquifer boundaries.

ii) Fault / Fracture controlled Aquifers: There are six types of fault / fracture controlled aquifers as listed in Table-2.1.

All these aquifers occupy narrow linear areas forming as a zone. It is not possible to represent such zones as polygons on 1:50,000 scale maps. Hence they are represented as line-units using different line symbols as shown in Table-2.1. The minor units are represented with thin blue lines, the major units are represented with thick blue lines and the units filled by dykes are represented with red lines. Further, the units inferred from satellite data are represented with dashed lines where as the units confirmed with field data are represented with continuous lines. A major fault / fracture controlled aquifer inferred from satellite data and a major confirmed fault/fracture controlled aquifer can be seen in the sample map as shown in fig-2.3.

The fault/fracture controlled aquifers act as potential zones for ground water occurrence. They also act as conduits for ground water movement. The depth to which the well is to be drilled and the yield that can be expected from the drilled well is not estimated exclusively for these aquifers and represented on the map. It is to be understood that the yields of the wells drilled in these aquifers are better than (one range up) the surrounding lithology-landform controlled aquifers. Accordingly, a note is given on the bottom of dynamic legend.

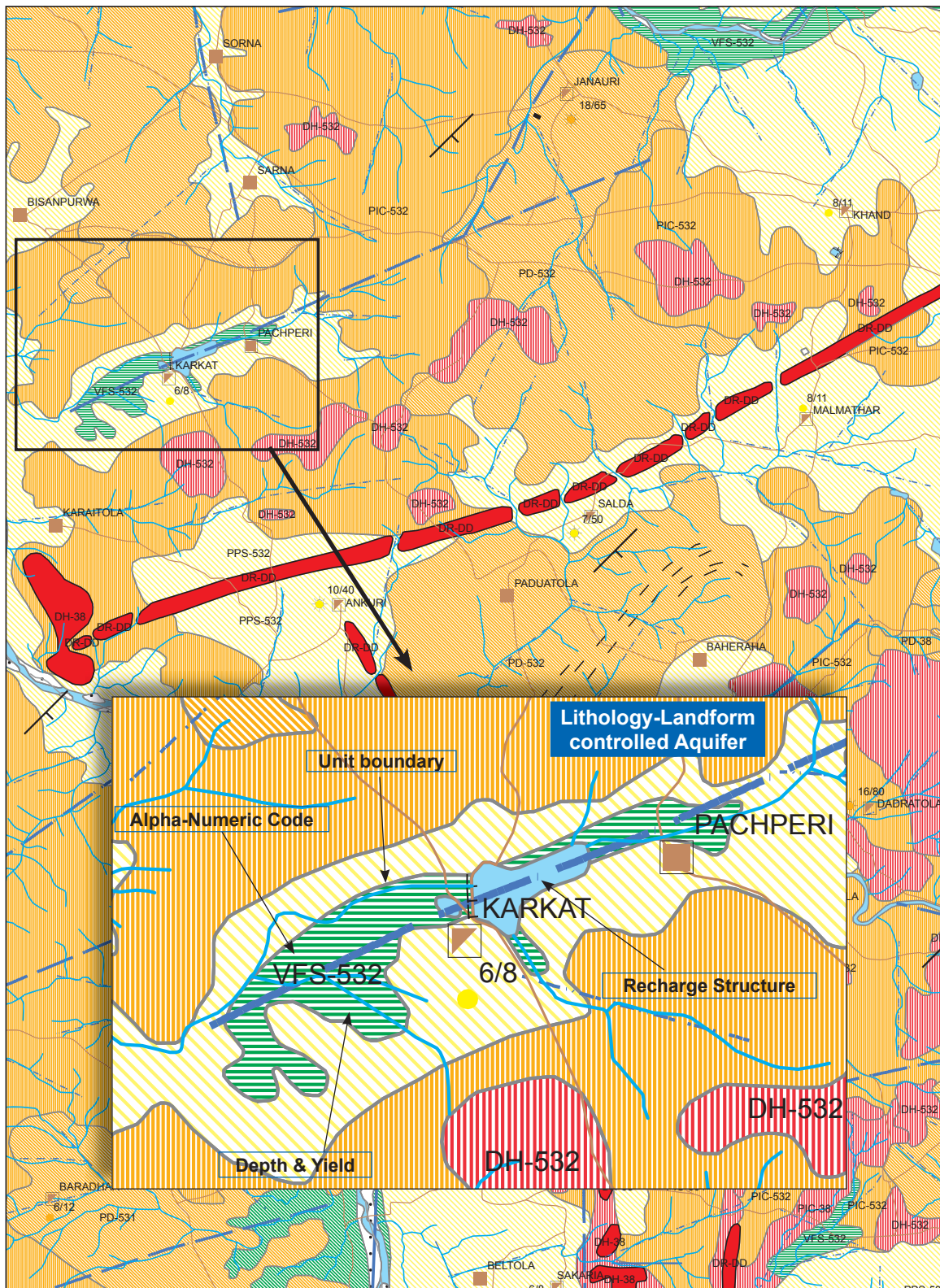


Fig. 2.2: Ground water prospects map of part of Umaria & Shahdol Dist., MP showing Lithology-Landform controlled aquifers and their ground water prospects. In the inset, one aquifer is shown in detail

Table-2.1: Types of fault / fracture controlled aquifers

Type of unit		Symbol
Fault / fracture controlled aquifers - Minor	Inferred from satellite data	
	Conformed from field data	
Fault / fracture controlled aquifers - Major	Inferred from satellite data	
	Conformed from field data	
Fault / fracture controlled aquifers - Filled by dykes / linear intrusives	Inferred from satellite data	
	Conformed from field data	

Similarly, the fault/fracture controlled aquifers filled with dykes, veins and other intrusives act as barriers for ground water movement. However, the contact zones with surrounding aquifer on upstream side forms as potential ground water locales.

Since all the fault/fracture controlled aquifers comprise porous and permeable geological material, they act as potential locations for constructing recharge structures, particularly the percolation tanks. Hence, suitable site-specific recharge structures are identified along all the fault/fracture controlled aquifers wherever adequate source water is available and their locations are marked on the map with symbols.

However, aquifer-wise information pertaining to rock type, landform, type of aquifer material, water level data of the existing wells, recharge condition, ground water prospects other than depth and yield i.e type of well suitable, success rate of the wells drilled, status of ground water exploitation and other related aspects which is generated during the process of map making could not be represented on the map as it is not possible. The same is provided in the form of a legend (dynamic part).

2.3 Legend of the Map - Dynamic part

The dynamic part of the legend is divided into rows and columns. Each row is dedicated for describing a hydrogeomorphic unit/aquifer. The number of rows depends on the number of aquifers occurring in the map area. However, there are 14 fixed columns in each row in which description about the aquifer is given. A dynamic legend of a ground water prospects map is provided in fig-2.4 as a sample for ready reference. The information that is provided in each column is discussed hereunder.

Column-1; Map Unit: In this column, the aquifers occurring in the map area are indicated in the form of boxes filled with colour hatching and alpha-numeric code. The alpha-numeric code indicates the type of aquifers, wherein the alphabetic code represents geomorphology and numeric code represents lithology. The colour represents the yield range of wells and hatching pattern indicates the depth range of wells.

Column-2; Geological sequence / Rock Type: In this column, the lithology / rock types are indicated following the geological sequence (stratigraphy). This column is sub-divided into 2 sub-columns. In the first sub-column, name of the Super group / Group has been given vertically (with geological age in the brackets). In the second column, rock type / lithology indicating the Formation / Type name has been given horizontally (e.g. Barakar sandstone, Peninsular Gneiss etc). The code no. appropriate to each is given in the brackets after the rock type. In case of Deccan Traps, in sub-

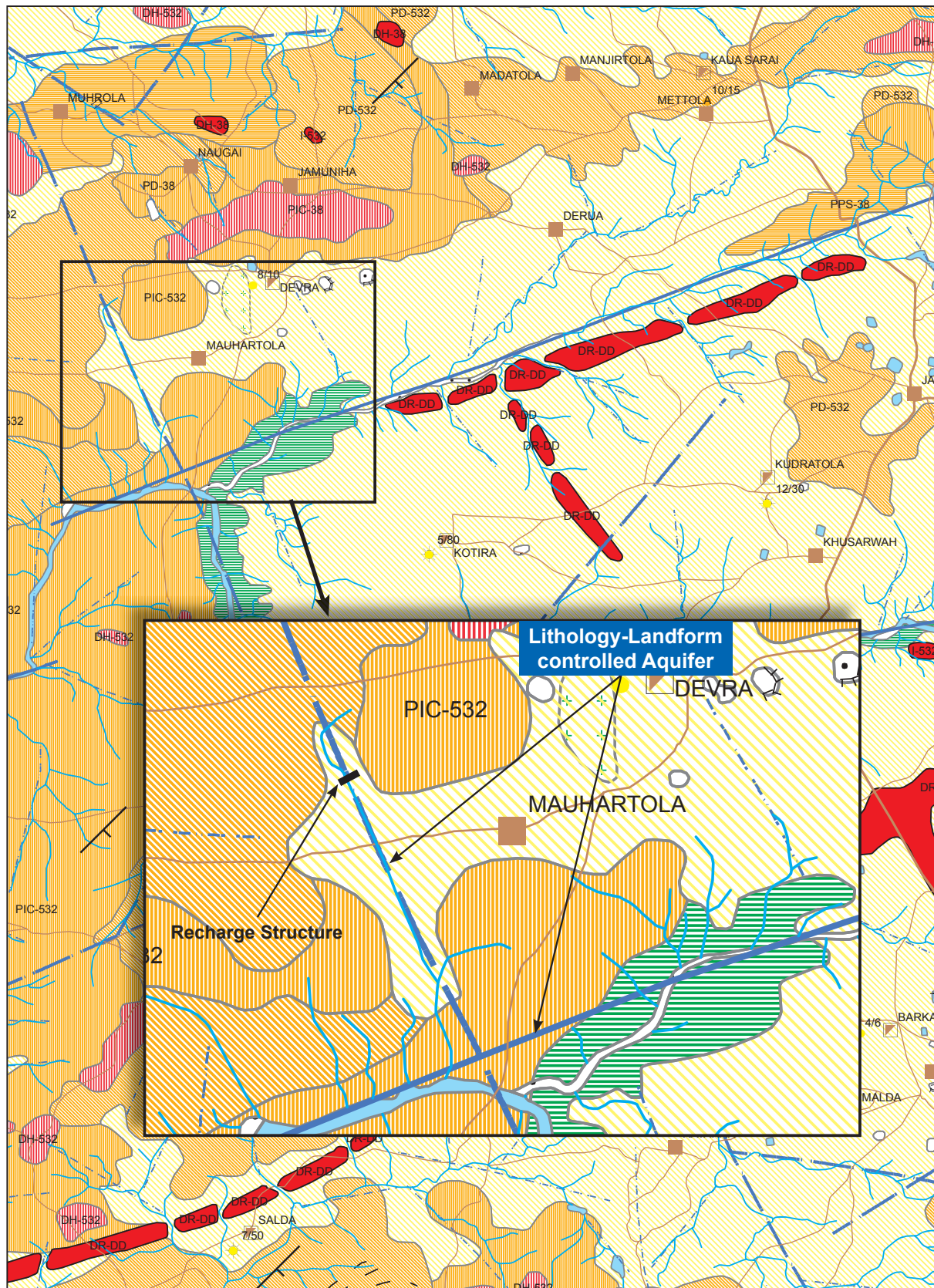


Fig. 2.3: Ground water prospects map of part of Umariya & Shahdol Dist., MP showing Fault/Fracture controlled aquifers and their ground water prospects. In the inset, a portion of the aquifer is shown in detail

LEGEND

MARUJIT (HYDROGEOLOGIC UNIT) (REPRESENTED IN THE MAP BY COLOUR INDICATES GROUND WATER PROSPECTS)		GEOLOGICAL SEQUENCE / ROCKTYPE (REPRESENTED IN THE MAP BY NUMERIC CODE)	GEO MORPHIC UNIT / LANDFORM (REPRESENTED IN THE MAP BY ALPHABETIC CODE)	DEPTH TO WATER TABLE (IN METERS) No. OF WELLS OBSERVED	RECHARGE CONDITIONS AVAILABILITY OF WATER TABLE (BASED ON OTHER AVAILABLE DATA)	AQUIFER MATERIAL (WEATHERED ROCK, UNWEATHERED ROCK, IMPERMEABLE ROCK, SEMI-IMPERMEABLE ROCK, IMPERVIOUS ROCK)	TYPES OF WELLS (DIA. & SUITABLE FOR WATER PRODUCTION) (SUITABLE FOR WATER PRODUCTION)	DEPTH RANGE OF WELLS (IN METERS)	YIELD RANGE OF WELLS (IN LPM OR CUM/DAY)	HOMOGENEITY IN THE AQUIFER (PROBABILITY OF WELLS TO INTERSECT) (VERY HIGH, HIGH, MODERATE, LOW)	QUALITY OF WATER (NON POTABLE)	GROUND WATER (IRREGULAR) (RANGE IN %)	RECHARGE SUITABLE PRIORITY (PT - PERCOLATION TANK, IW - INVERT WELL, PP - RECHARGE PT)	REMARKS (PROBLEMS/LIMITATIONS)	
PPS-38	BASIC ULTRYSYLVE	DOLERITE SILL/DYKE (38)	PEDIPLAIN WEATHERED SHALLOW (PPS)	---	Limited	WR	DW	10-15m	10-15 Cum/day	Low	---	---	CD/PT HIGH	Prospects restricted to sediment above dolerite sill.	
PD-38			PEDIMENT (PD)	---	Poor	FR	BW	80-90m	10-15 LPM	Poor	---	---	---	Prospects restricted to weathered & fractured zone.	
PIG-38			PEDIPLAIN INSELBERG COMPLEX (PIC)	---	Poor	FIR	BW	80-100m	<10 LPM	Poor	---	---	---	Prospects restricted to weathered & fractured zone.	
DH-38			DENUDATIONAL HILL (DH)	---	---	---	---	---	---	---	---	---	---	---	Generally forms run-off zone.
DR-D-D	UPPER GONDWANA	SANDSTONE (52)	DYKE RIDGE (DR P 5)	---	---	---	---	---	---	---	---	---	---	Forms run-off zone and act as barrier.	
VFS-52			VALLEY FILL SHALLOW (VFS)	---	Very Good	LS	DW	10-15m 20-30m	70-80 Cum/day 140-170 LPM	Very High	P	---	---	PT LOW	General casing required to cover loose sediments.
PPS-52			FLOOD PALIN SHALLOW (PPS)	---	Very Good	LS	DW	10-15m 30-50m	70-80 Cum/day 150-180 LPM	High	P	---	---	---	General casing required upto weathered zone.
PPS-52			PEDIPLAIN WEATHERED SHALLOW (PPS)	4-12 / 23 wells	Good	WR	BW/TW	60-70m	60-80 LPM	Moderate	P	1-2 %	---	---	Turbidity in water due to friable sandstone.
PD-52			PEDIMENT (PD)	6-18 / 10 wells	Limited	PR	BW	70-80m	30-50 LPM	Limited	P	---	---	---	Better prospects at greater depth.
PIG-52			PEDIMENT INSELBERG COMPLEX (PIC)	14 / 1 well	Limited	PR	BW	90-100m	20-40 LPM	Low	P	---	---	---	Better prospects at greater depth.
I-52			INSELBERG (I)	---	---	---	---	---	---	---	---	---	---	---	Forms run-off zone.
DH-52			DENUDATIONAL HILL (DH)	---	---	---	---	---	---	---	---	---	---	---	Generally forms run-off zone. Prospects limited to valley portion-prospects <10 LPM at >80m. Depth expected.
SH-52			STRUCTURAL HILL (SH)	---	---	---	---	---	---	---	---	---	---	---	Prospects limited to valley portion and fractured zone.
PPS-51			FLOOD PALIN SHALLOW (PPS)	---	Very Good	LS	TW	30-50m	150-200 LPM	Very High	P	---	---	---	General casing required upto weathered zone.
PPS-51	PEDIPLAIN WEATHERED SHALLOW (PPS)	6-8 / 4 wells	Good	WR	DW	10-15m 60-70m	30-50 Cum/day 60-100 LPM	High	P	---	---	---	PT/CD HIGH	Deeper range of borewell require to intersect more aquifer zone.	
PD-51	PEDIMENT (PD)	6-16 / 2 wells	Moderate	PR	BW	10-15m 60-90m	20-25 Cum/day 40-50 LPM	Moderate	P	---	---	---	CD/PT HIGH	Bore wells of deeper range require to intersect more aquifer zone.	
PIG-51	PEDIMENT INSELBERG COMPLEX (PIC)	---	Limited	PR	BW	80-90m	20-40 LPM	Low	P	---	---	---	CD LOW	Bore wells of deeper range require to intersect more aquifer zone.	
DH-51	DENUDATIONAL HILL (DH)	---	---	---	---	---	---	---	---	---	---	---	---	Generally forms run-off zone. Prospects <10 LPM at depth >80m. expected.	

These are fault/fracture zones, which generally act as conduits for movement of groundwater in hard rocks. Along these zones, the yields are significantly higher and wells are likely to be sustainable for longer duration. However, the altered fractures need to be confirmed by detailed ground surveys.

These are dykes, quartz reefs, pegmatites etc. which generally act as barriers for ground water movement.

M.B. The depth ranges and yield ranges of wells shown in the map are approximate. Groundwater prospects are shown in the map by colour. This map is useful for macro-level and detailed location of the recharge structures shown in the map are suitable.

Fig-2.4: Dynamic legend of ground water prospects map of part of Umaria & Shahdol Dist., MP showing hydro geomorphic unit/ aquifers-wise description

column 2, the list of flows with heading Basalt Flows is given. For each flow no., type of flow (e.g. massive, vesicular, unclassified group, etc) is written in 1st line and its elevation range (in m MSL) is given in 2nd line.

Column-3; Geomorphic Unit / Landform: In this column, the name of geomorphic unit / landform has been given followed by alphabetic codes in brackets, e.g. Valley Fill - Shallow (VFS), Bajada – Shallow (BJS). All the geomorphic units / landforms within a given rock type have been arranged as per the relief, i.e. starting from valleys and plains on the top and hills at the bottom. In case of Deccan Trap, the name of geomorphic unit / landform is given in the 1st line and the elevation range for each unit has been given in second line.

Column-4; Depth to Water Table and No. of Wells Observed: In this column, information collected during field work on depth to water level of summer season / pre-monsoon period (minimum to maximum range in metres) along with the number of wells observed are given. In the aquifers where no well is present, it is mentioned as “No Well”. Where, wells are not observed, it is mentioned as “Wells Not Observed”.

Column-5; Recharge conditions: In this column, the recharge conditions generalized for each aquifer unit have been given based on the water availability from rainfall and other sources, and hydrogeological conditions. The recharge conditions have been categorized as excellent, very good, good, moderate, limited, poor or nil.

Column-6; Aquifer material: In this column, the nature of aquifer material has been indicated for each aquifer unit. The aquifer material can be one of the 6 categories based on their material content. The abbreviation of the appropriate category is indicated. Where, more than one category is to be indicated, it is shown as LS + WR or WR + FIR as the case may be.

Column-7; Types of Wells Suitable: In this column, type of well suitable for that particular aquifer unit has been given. If in a particular aquifer unit, more than one type of wells is suitable, they are mentioned in this column in two separate lines giving depth range, yield range and other particulars separately for each type of well.

Column-8; Depth Range of wells (Suggested): In this column, the optimum depth range of wells in metres has been indicated. Though colour scheme-wise the depth range of wells is classified into 3 categories i.e. <30, 30-80 m, >80m, actual depth range of wells like 40-55 m, 70-80m, 90-110m is given depending on the situation.

Column-9; Yield Range of Wells (Expected): In this column, the tentative yield range of the wells has been given in liters per minute (lpm) for bore/tube wells or in cubic meters (cu m) per day for dug wells.

Note: In case of the aquifer units where two productive aquifers are encountered, in the first line the prospects of more productive aquifer are mentioned in the ‘type of wells suitable,’ ‘depth range of wells’ and yield range of wells’ columns, followed by that of less productive aquifer.

Column-10; Homogeneity in the Aquifer and Success Rate of Wells: In this column, the success rate of wells has been indicated in the form of very high, high, moderate, low or poor based on the homogeneity in the aquifer.

Column-11; Water Quality: In this column, the ground water quality, i.e. Potable (P) or Non-Potable (NP) has been mentioned for each unit. Wherever the water is non-potable, the reasons for

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non-potability (e.g. high TDS, high fluoride, high nitrate content, brackishness, etc) have been given in this column.

Column-12; Ground Water Irrigated area: In this column, for each aquifer unit, the extent of ground water irrigated area has been indicated in terms of percentage, as a range, for example as 5-10%, <5%, >30% etc.

Column-13; Recharge Structures Suitable / Priority: In this column, the type of recharge structure suitable and priority for taking up recharge structures has been indicated.

Column-14; Problems / Limitations / Remarks: In this column, the problems / limitations with reference to ground water prospects, e.g. caving and collapsing of wells, high failure rate, quality / potability etc. other relevant information have been given. In the sedimentary and volcanic formations where the ground water prospects are better in the underlying rock type, such things have also been indicated in this remarks column. Which particular zone / stratigraphic unit form the aquifer has also been indicated. In addition to the above, justification is given in this column wherever recharge structures are suggested with Very High, High Priority, No Priority or Not Suitable. For example-

- Very high priority for recharge structures, since ground water exploitation is very high / wells dry up during summer
- No priority for recharge structures, since mainly occupied by forest and no habitations
- Recharge structures not suitable, since mainly gullied / ravinous area, etc.

3. Scientific rationale

Occurrence and distribution of ground water is a function of the degree of porosity-permeability of the geological formation and the amount of recharge to the geological formation. Porosity-permeability is a variable parameter of space i.e. varies from place to place whereas the recharge is the variable parameter of time. Hence, mapping of these two variables in the given 700 sq kms of area covered by the map, amounts to mapping of the prospects of ground water resource.

The properties of porosity-permeability at a given area can be deciphered based on the study and analysis of geological parameters such as rock type, landform and geological structure. Similarly, the amount of recharge can be estimated based on the study and analysis of hydrological parameters such as drainage network, water bodies, canal system, rainfall data, springs, and irrigated area. In other words, all these parameters act as indicators of ground water prospect in the given area.

Therefore, as a first step of mapping the ground water prospects, all the parameters occurring in the map area along with relevant base map details required for map referencing are inventoried and mapped as independent layers. These layers form as basic input for the preparation of final ground water prospects map. The basic layers are subjected to overlay analysis and integration under GIS environment resulting in the derivation of hydrogeomorphology and recharge structure layers. Both basic and derivative layers are composed as ground water prospects map showing ground water prospect areas as well as locations for site-specific recharge structures. In the process of map composition, thematic maps such as base, lithology, structure, geomorphology and hydrology maps are also generated as intermediate products. The list of the basic and derivative layers and the sequence with which the final ground water prospect map is generated is given in Fig-3.1.

3.1 Basic layers

3.1.1 Base map layers

Administrative units, Settlements, Road net work, Railway lines are considered as relevant cultural features that can be used for map referencing. These base map details are derived mainly from SOI toposheets and field information. However, satellite images (Fig-3.2 a) are used as a supplement for updating dynamic aspects (Fig-3.2 b). The base map details thus derived are mapped as a layer (Fig-3.2 c) and represented them on the map with different line symbols shown at 18 as part of fixed legend in the sample map.

1. Administrative layer: International boundaries, State boundaries, district boundaries derived from SOI toposheets are shown on the layer in the form of polygon features. The block / taluq, village boundaries can be added as per the requirement.

2. Settlement layer: All the habitations marked on the Survey of India toposheet on 1:50, 000 scale are considered. They are classified into Not Covered (NC), Partially Covered (PC) and normal habitations based on the data provided by the line departments in respective states. However, this categorisation is dynamic and changes from time to time. The locations of the habitations are updated / rectified using satellite data. On the False Colour Composite satellite image, settlements appear in dark bluish green in the core built up area and bluish in the periphery. The size varies from small to big; irregular and discontinuous in appearance; can be seen in clusters, non-contiguous or scattered. However, the location of the habitation is marked as a point feature.

3. Road net work layer: The roads are considered in 4 categories - i) National Highways, ii) State Highways, iii) Metalled road and iv) Other roads. SOI toposheet together with satellite image help

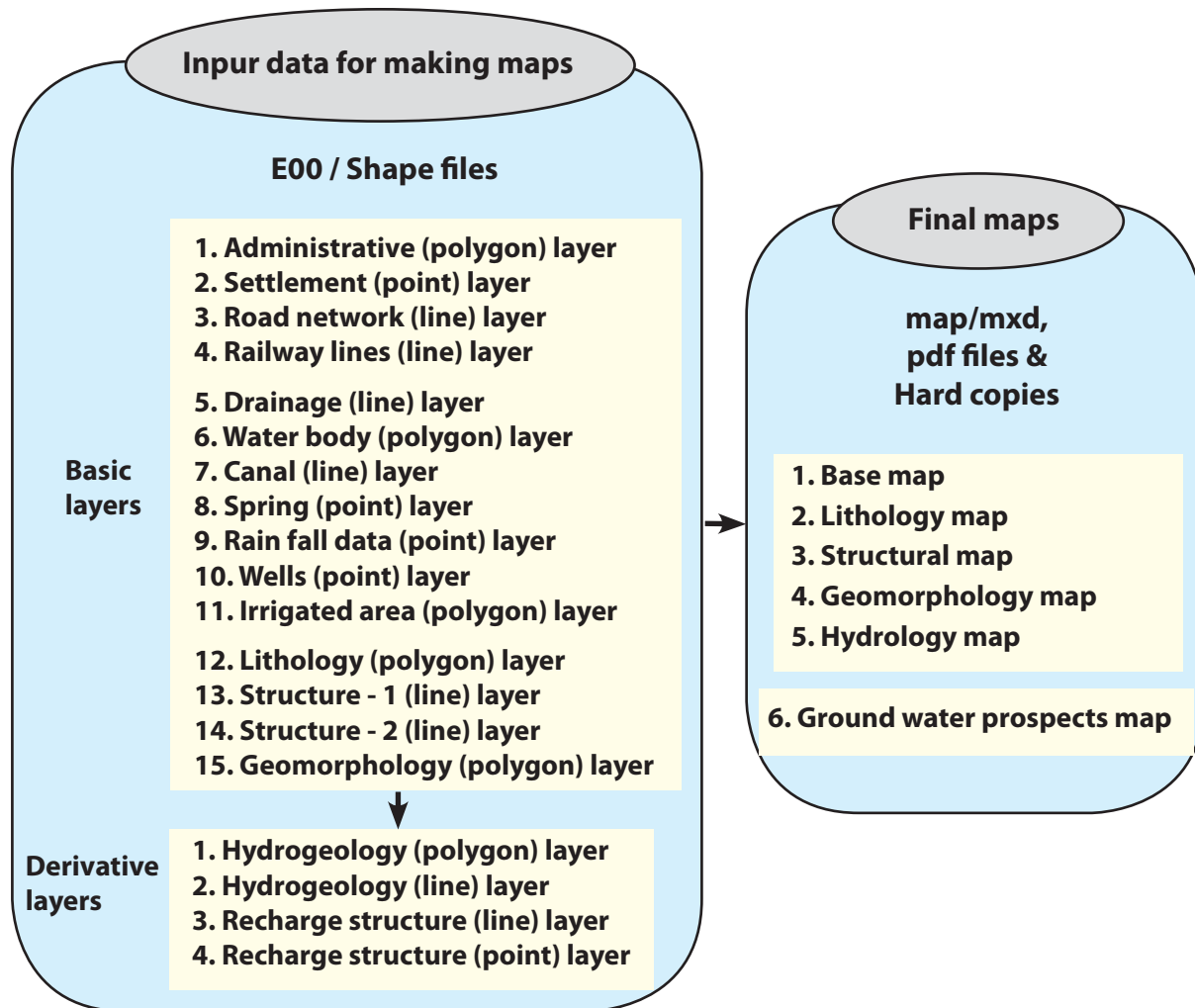


Fig-3.1: Input and output components of ground water prospects map

identifying the road network. Attribute information of the roads are invariably taken from SOI toposheet. However, on FCC satellite image, the black topped State and National highways appear in dark tone as linear features having sharp contact with the background. The remaining roads appear usually in white tone connecting to different settlements. The road network is mapped as line features with different thicknesses.

4. Railway line layer: All railway lines are considered as a single class. The railway lines also appear in dark tone but they are straight for quite a long distance on the FCC satellite image. The rail network also represented as line features in the layer. Main source of this information is SOI toposheet updated with high resolution satellite image interpretation.

3.1.2 Hydrological layers

Rainfall, water bodies (rivers, tanks, reservoirs, canals, etc.), return flow from the irrigation, etc. are the main sources of recharge. Satellite data (Fig-3.3 a and 3.4 a) provides information on all these features in terms of their location, distribution and the impact they create in the downstream side, except the rain fall. Therefore, all the hydrological features occurring in the area are extracted (Fig-3.3 b and 3.4 b) mapped as individual layers (Fig-3.3 c and 3.4 c). The hydrological features are represented on the map with symbols and colours shown at 17 of the fixed part of the legend.

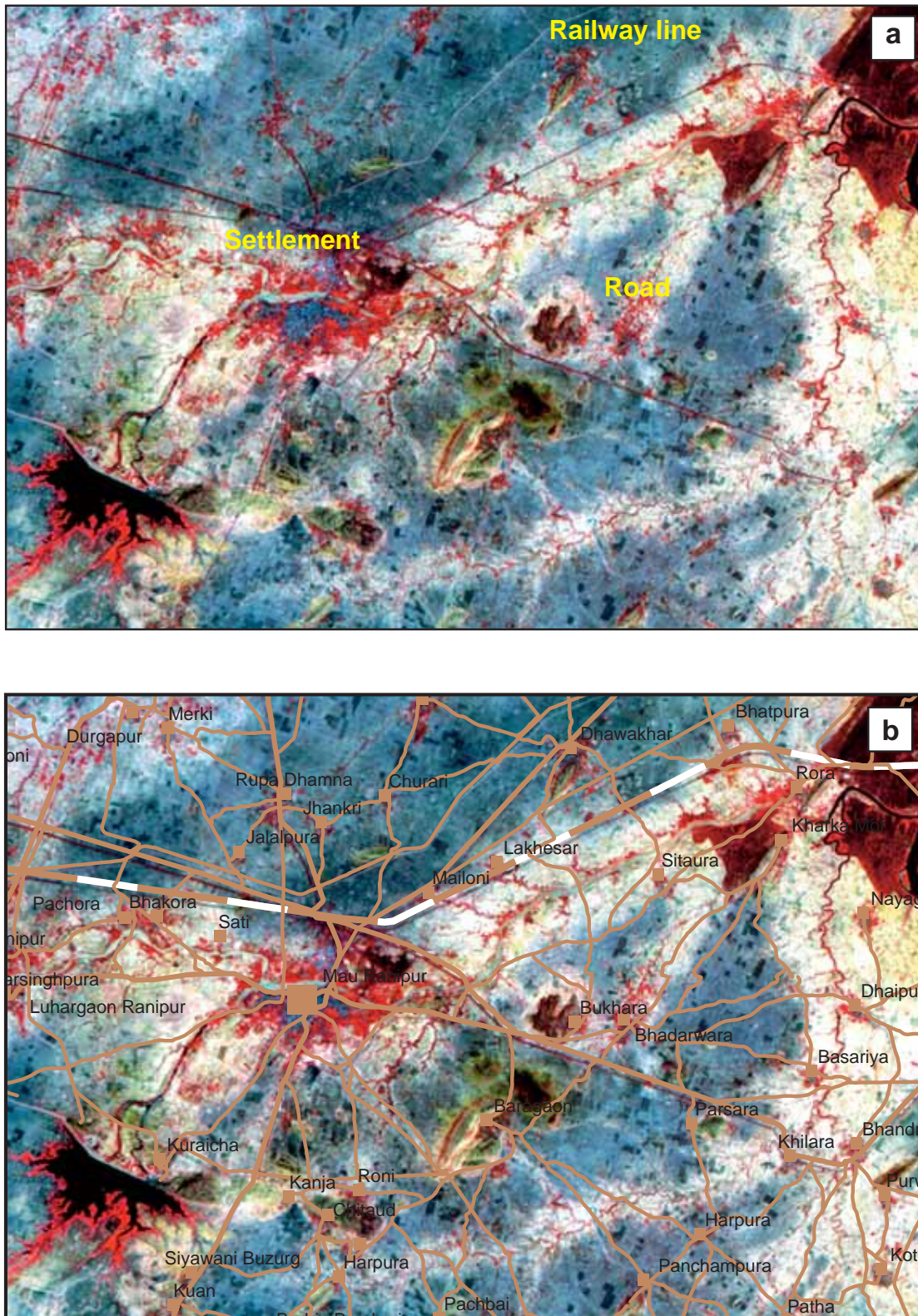


Fig-3.2: Satellite image showing a) signatures of various cultural features (settlements, roads, railway lines) and b) their extraction and mapping

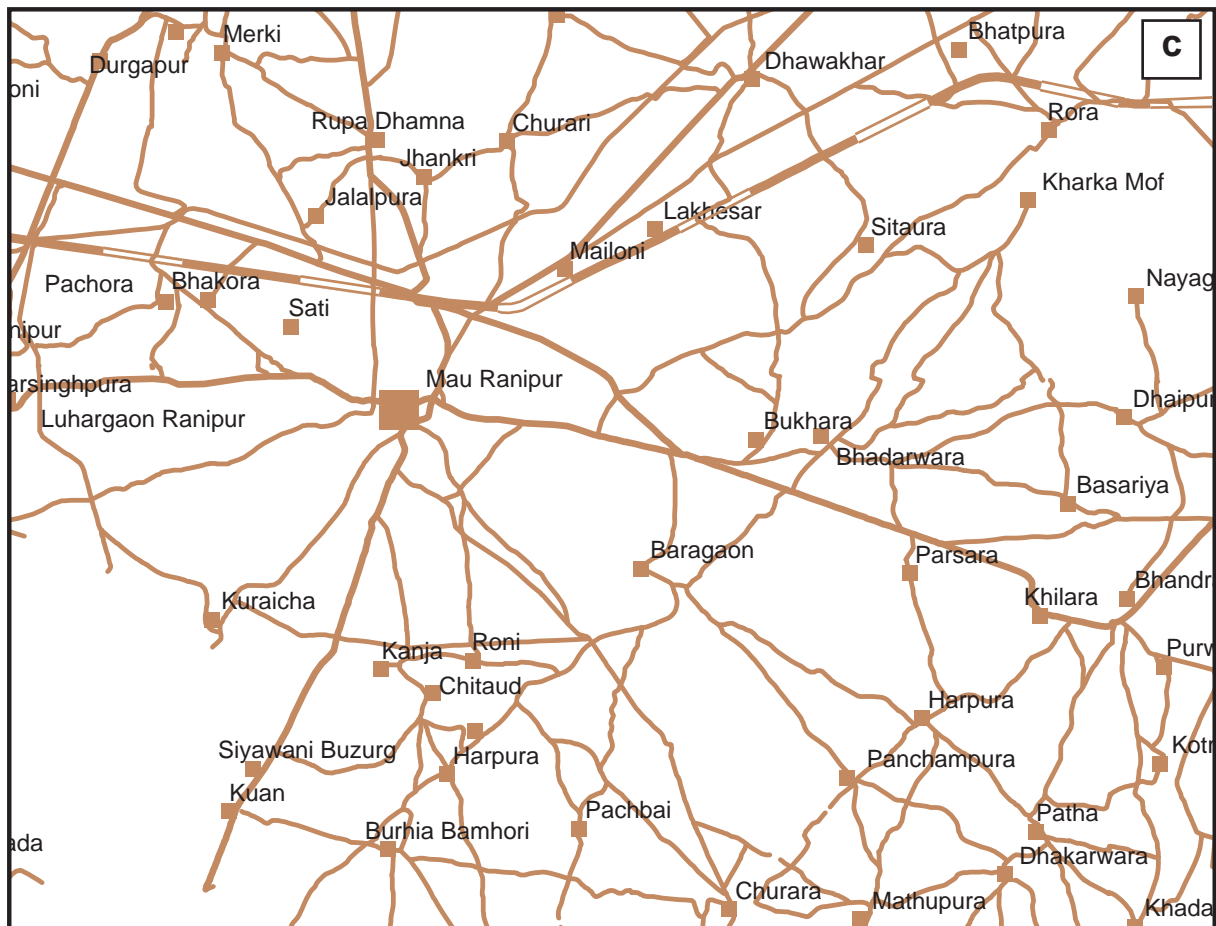


Fig-3.2: c) Base map – administrative, settlement, road network and railway line - layers

5. Drainage layer: The density and pattern of the rivers and stream network reflects the nature of the geological material. Density indicates the degree of the porosity- permeability of the geological material. Pattern indicated the structural fabric of the geological formation. In addition to this, the perennality and ephemerality of the rivers and major streams reveal the source of surface water, there by the recharge condition prevailing in the area. Satellite image provides synoptic view of the terrain which facilitates mapping of the drainage network and its analysis with regional perspective. Using the satellite data all the rivers and streams both perennial and ephemeral occurring in the map area are mapped. Rivers and major streams are mapped as polygon features and other drainage network is mapped as line features. In case of hilly areas and highly dissected terrain where drainage density is very high, some first order streams are omitted to reduce the clumsiness in the map. Along major rivers and streams where changes in the river / stream courses is more common, necessary corrections in the drainage courses are made using satellite image interpretation.

6. Water body layer: The water spread area of the water body indicates the amount of rainfall and the temporal variations in the water bodies indicate status of siltation, the composition of the silt and the infiltration capacity of the surrounding geological formation in which the water body is located. The full water level (FRL) is taken from the toposheet and within the FRL limits the water spread is mapped using multi temporal satellite data. The margin area derived from pre and post monsoon periods is classified as ephemeral part of the water body. All the water bodies except the very smaller ones seen on the imagery are marked.

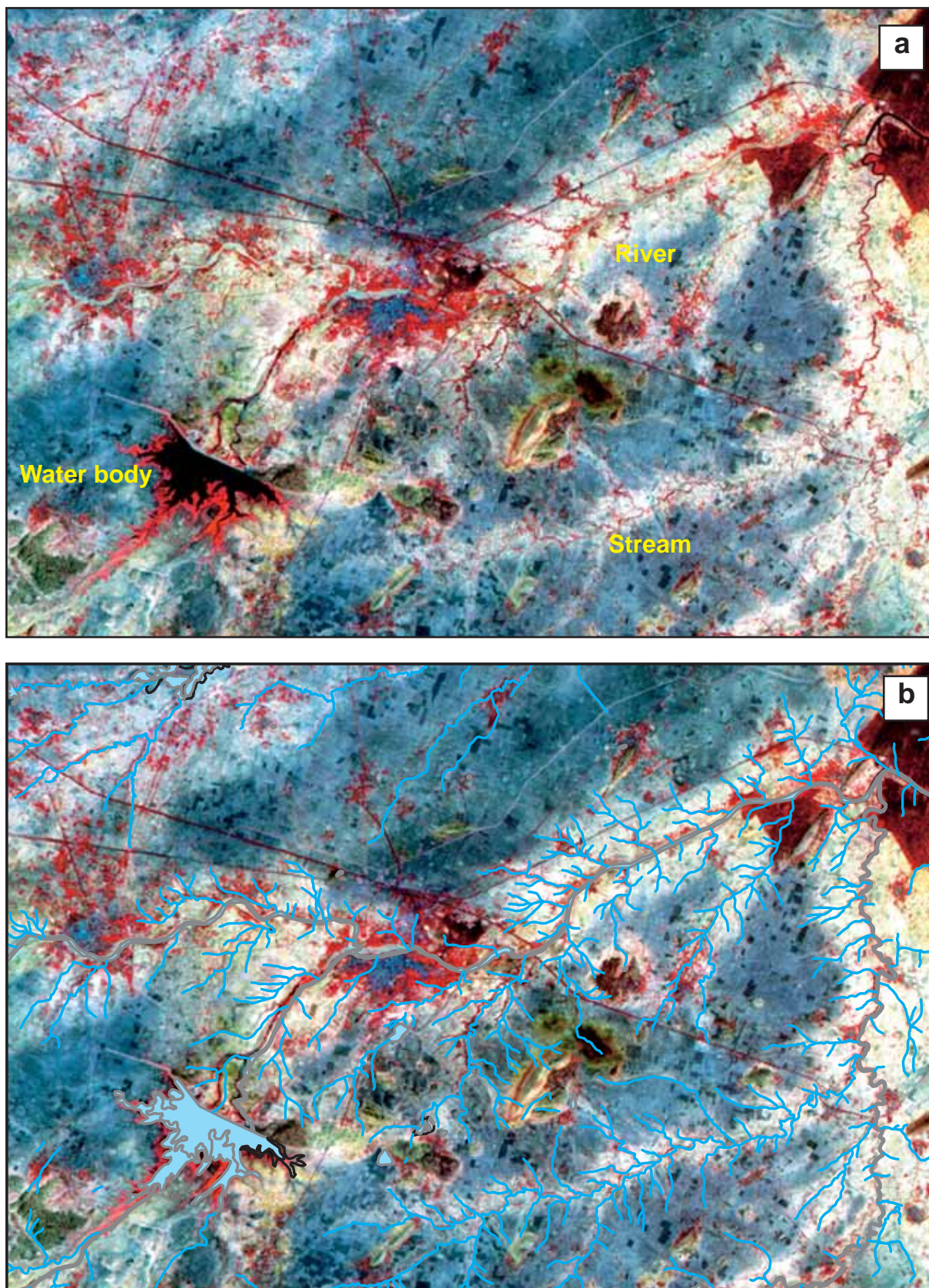


Fig-3.3: Satellite image showing a) signatures of various hydrological features (rivers, streams, water bodies) and b) their extraction and mapping

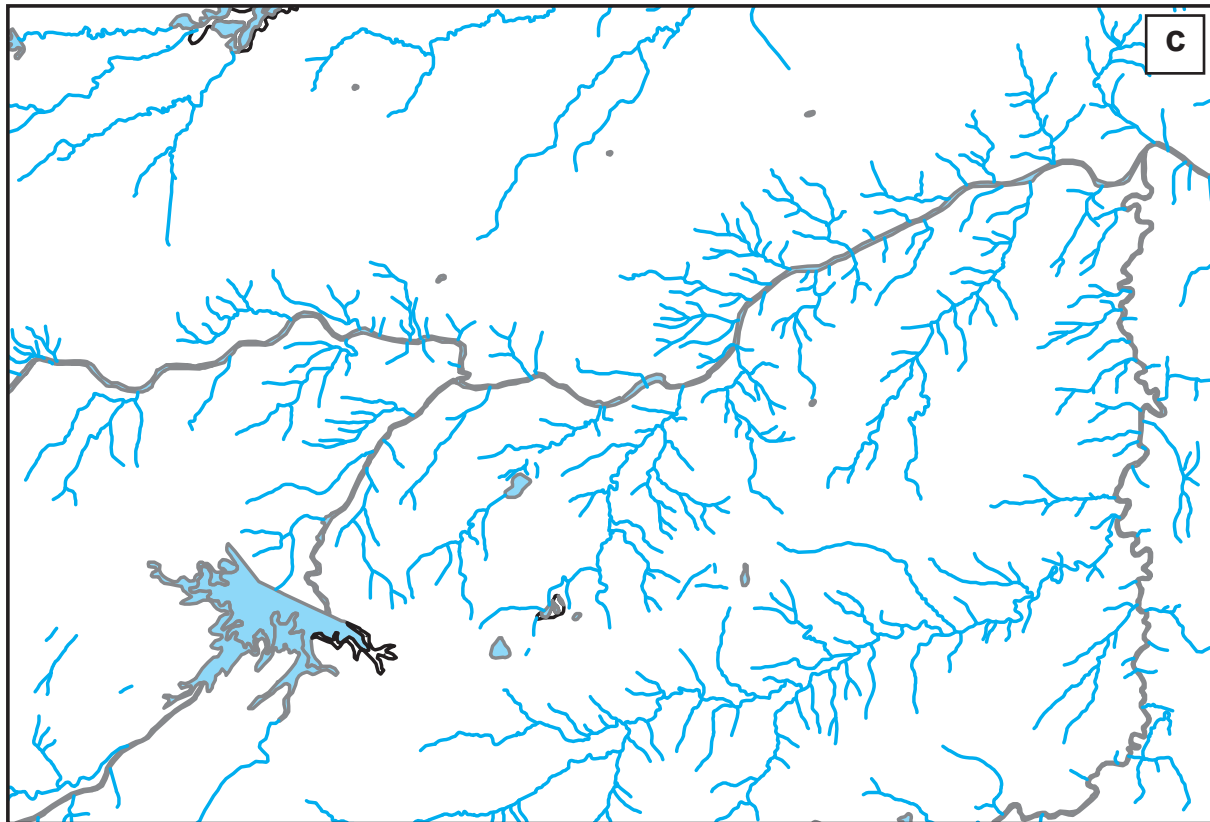


Fig-3.3: c) Hydrology – drainage network, water bodies, rainfall data and spring - layers

7. Canal layer: The entire major and minor canal network along with their distributaries occurring in the map area is considered for the study and mapped as line features in the layer. It forms as an additional source of recharge water. Area with canal irrigation is considered as having better recharge.

8. Spring layer: Springs are discharge zones formed at the locations where water table cuts the topography. They indicate the recharge condition in the horizon above the spring plane. Only location of spring is considered for the study. All the springs occurring particularly in hilly terrain are marked as point features.

9. Rain fall data layer: The rain fall data is considered in the form of rain gauge station with average amount of rainfall and marked as point feature. In case of absence of rain gauge station in the given map area, regional average annual rainfall in mm is taken into account. Either IMD or District Gazetteer is the source of rainfall data. The rain fall data is used to comprehend the amount of water available in the region and also to make correlation study with the surface hydrological features. Recharge component from the rainfall is evaluated conceptually.

10. Well data layer: Well inventory data is collected from all the hydrogeomorphic / aquifer units in such a way that the wells are distributed throughout the map. At least one well are observed in each unit so that the ground water prospects of each unit are evaluated judiciously. The observation wells are selected in such a way, that they are properly distributed throughout the map covering all the map units. Even in smaller units, at least one well are observed. In case, if wells are totally absent in a particular unit, then it is mentioned in the legend as “No Wells” and recharge is estimated in such units based on assumptions only. While selecting the wells for observation, preference is given in the following order-

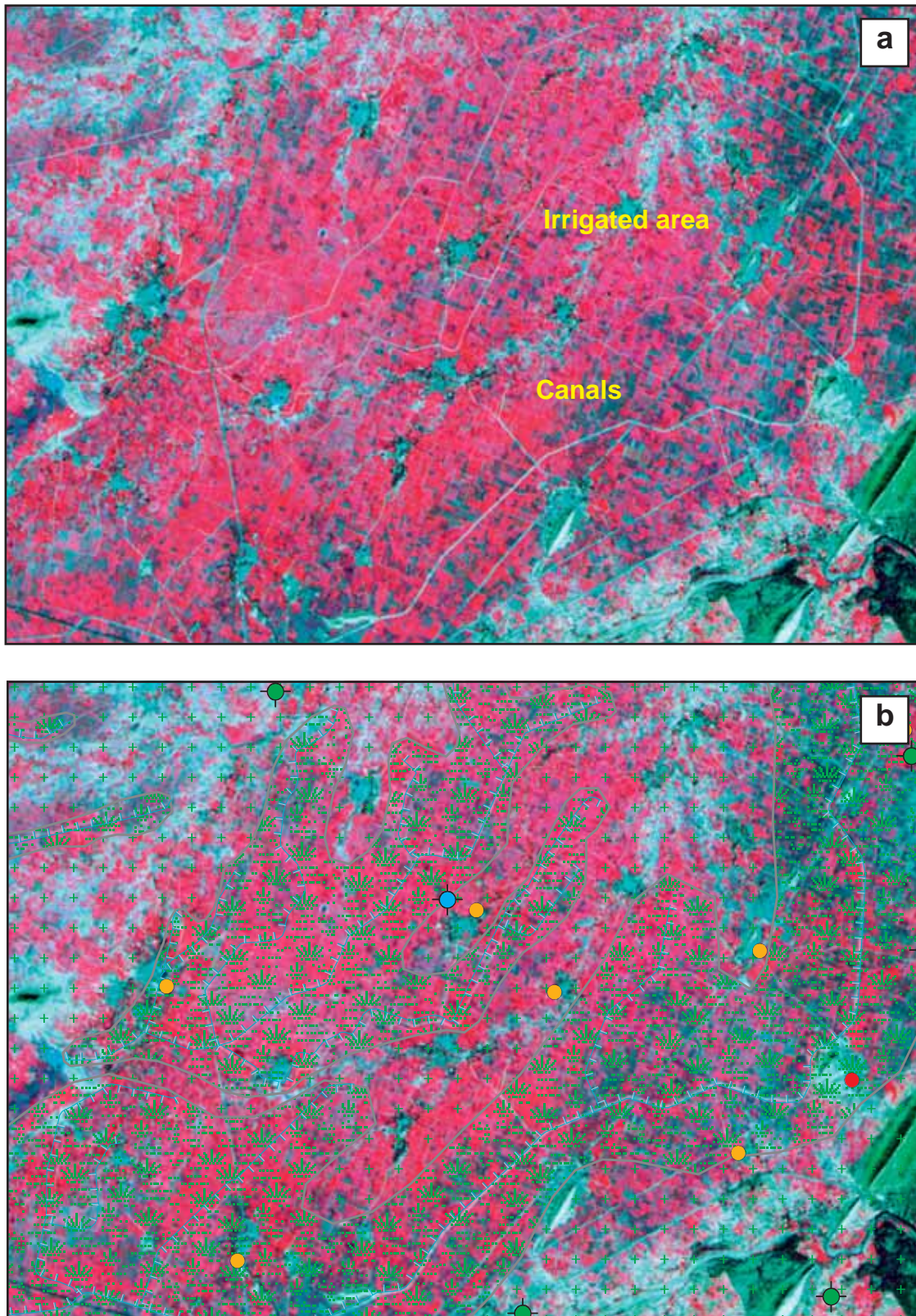


Fig-3.4: Satellite image showing a) signatures of various hydrological features (canals, irrigated area) and b) their extraction and mapping

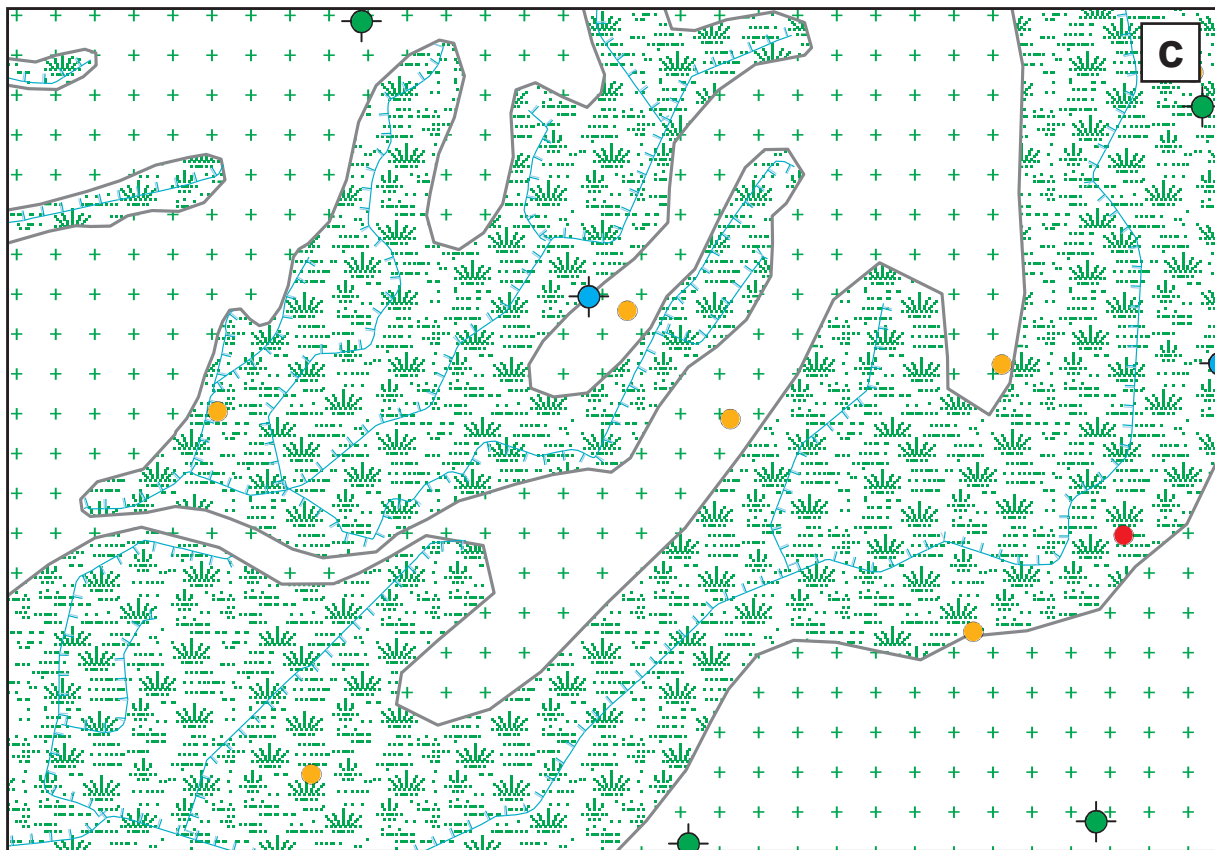


Fig-3.4: c) Hydrological - canals, wells, irrigated area - layers

- | | |
|-----------------------------------|-------------------------------------|
| 1. Irrigation bore / tube wells | 4. Hand-pump wells (drinking water) |
| 2. Water supply bore / tube wells | 5. Dug-wells community water supply |
| 3. Irrigation dug wells | 6. Dug-wells individual house |

Special care has also been taken to observe the depth of weathering, nature of weathered material, thickness and composition of deposited material, etc. within each unit. The details pertaining to the wells collected in the field include - type of well, depth to water table, water table fluctuation (i.e. pre - and post - monsoon water tables), yield, total depth of well, type of subsurface formations and any other related information. This information has been collected partly by observing the wells and partly by discussing with well owners, neighbours, villagers, Gram Panchayat representatives etc. In addition to this data, data pertaining to observation wells (water table fluctuations, pump test data, driller's log) if any available with the State and Central Govt. Depts., have also been used.

11. Irrigated area layer: Both canal and ground water irrigated areas are considered for the study. The presence of canal irrigation indicates that the area gets recharge from the canal irrigation return flow. The extent of ground water irrigated area also taken into account for estimating the status of ground water exploitation and the stress on the ground water regime. The irrigated area is mapped as polygon features.

3.1.3 Geological layers

Lithology/Rock type, Geological structure and Geomorphology/landform indicate the porosity-permeability of the geological formation. Hence, the geological indicators that are occurring in the map area are inventoried and mapped as independent layers based on the interpretation of satellite

data in conjunction with limited field checks. Existing geological and hydrogeological maps have also been used for reference. FCC satellite image showing diagnostic image characteristics of some of the rock types, geological structures, landforms and their delineation and mapping is illustrated in Fig-3.5 a & b respectively as an example.

12. Lithology layer: Considering the degree of primary porosity and permeability, the rocks are divided into 99 types. Each rock type stands for particular amount of primary porosity and permeability. Most of these rock types exhibit diagnostic image signatures on the satellite image. Where contrasting rock types occur, the boundaries can be seen very clearly on the satellite imagery with different colours / tones or landforms. In other cases, complementary evidences are considered to demarcate the boundaries between different rock types. Based on the interpretation of these signatures, the rock types that occur in the map area are mapped as a polygon layer as shown in (Fig 3.5 c) as an example. The rock types are identified with numeric codes, for example as 912 (Hornblende-Biotite Gneiss), 87 (Gneiss-Granetoid Complex), 811 (Closepet granite), etc on the map. The underlying rock type, if any is identified based on the stratigraphy sequence given in the existing geological maps.

13 & 14. Structural layers: The primary porosity-permeability of the rock is altered by schistosity / foliation, faulting / fracturing, folding resulting in the creation of secondary porosity-permeability. As a result, such zones form as locales for ground water occurrence and conduits for ground water movement. On the other hand, structural features such as dykes, quartz veins, other linear intrusives are normally impervious zones and act as barriers for ground water movement.

Based on the interpretation of satellite image both the categories of structures that are occurring in the map area are inventoried and mapped as a layer as shown in Fig 3.5 c in the form of line features using blue (faults and fractures) and red (dykes) line symbols. However, the faults/fractures that are mapped using satellite data are further classified in to confirmed and inferred ones based on the yield observation data of the wells located along the interpreted faults/fractures.

15. Geomorphology layer: The primary porosity-permeability gets modified significantly due to weathering, erosion and dissection resulting in creation of additional secondary porosity-permeability. Further, morphology of the lithological unit influences recharge. Depending on the morphology, a landform may act as run-off, recharge or discharge zone. Considering morphology, weathering, erosion and dissection, the landforms are divided into 160 types. Satellite image is an excellent data base for delineating different landforms. However, toposheets were consulted to comprehend the relief variations while demarcating landforms. Ground truth data is used to classify the landforms into shallow, moderate and deep categories based on their depth of weathering, thickness of deposited material, etc. Even then the contacts between shallow, moderate and deep categories are considered as gradational. Various types of landforms and their distribution occurring in the map area are mapped as a polygon layer as shown in Fig 3.5 c as an example. The landforms are identified with alphabetic code, for example as, SH (Structural Hill), DH (Denudation Hill) PD (Pediment) PPS (Pediplain Shallow Weathered), FV (Fracture Valley), etc on the map.

3.2 Derivative layers

The geological and hydrological layers are subjected to overlay analysis and integrated under GIS environment to derive hydrogeomorphology and ground water recharge structure layers.

16 & 17. Hydrogeomorphology layers: The hydrogeomorphology layers are derived in three steps. In the first step hydrogeomorphic units/aquifers are delineated, in the second step recharge

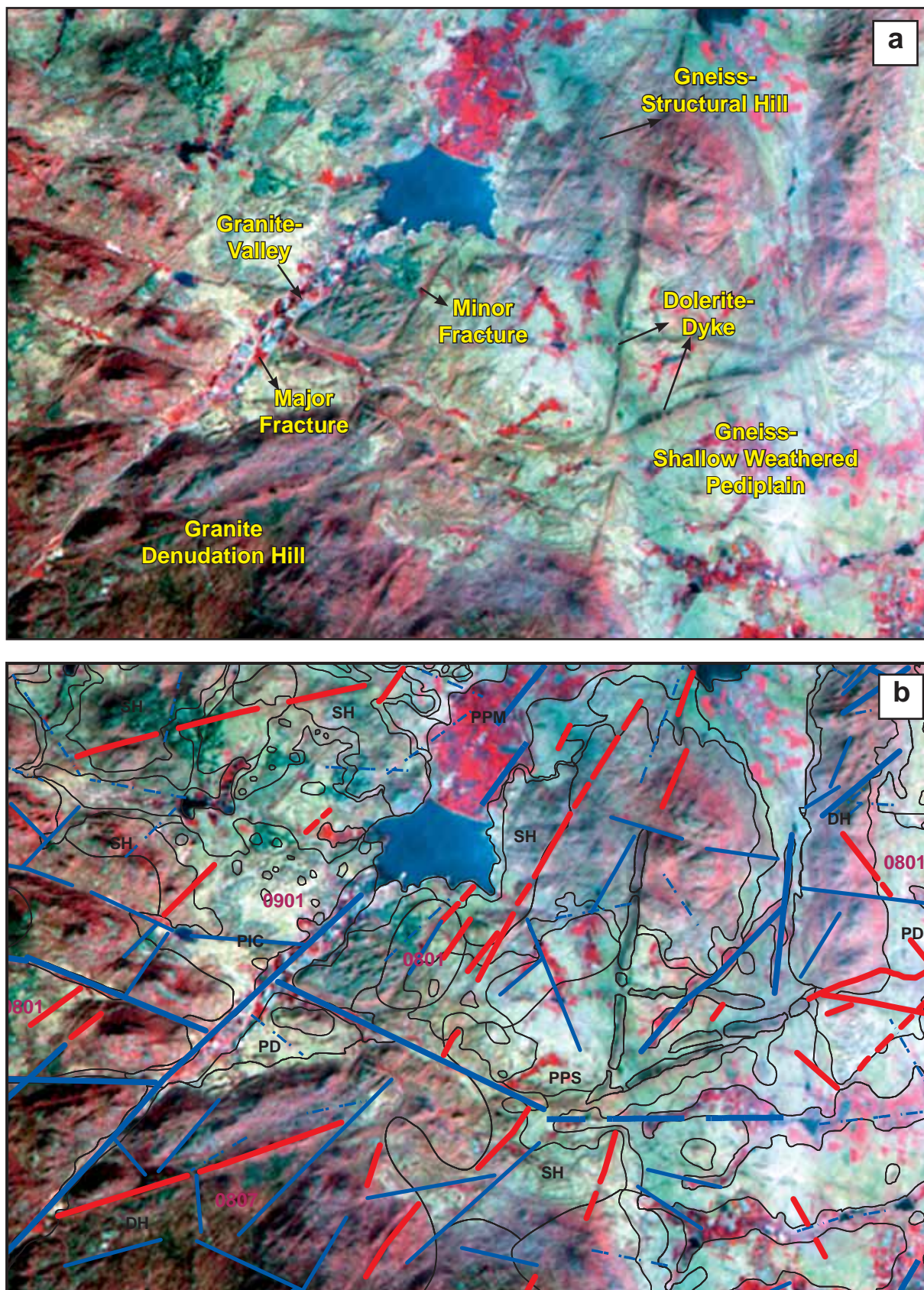


Fig-3.5: Satellite image showing a) signatures of various geological features (rock types, geological structures, and landforms) and b) their extraction and mapping

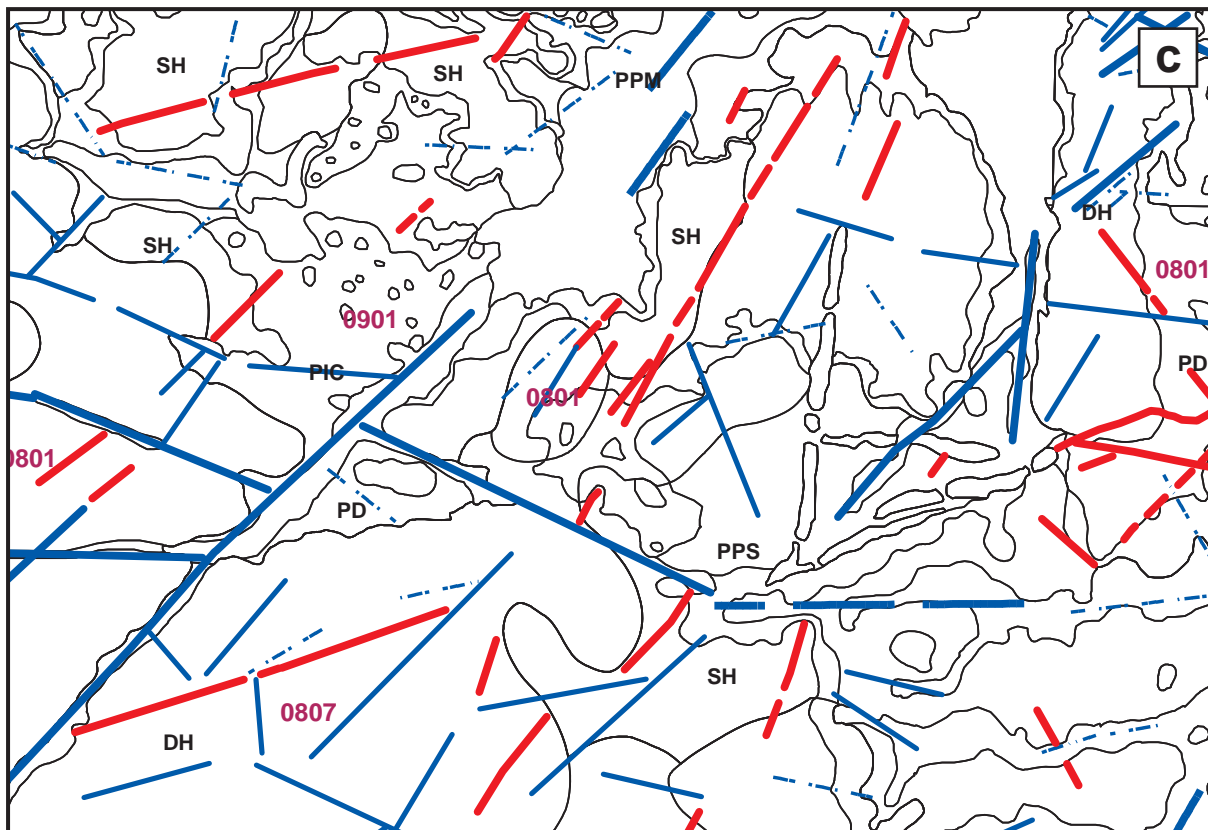


Fig-3.5: c) Geological - rock types, geological structures, and landforms - layers.

is evaluated and in the third step ground water prospects are estimated.

Delineation of aquifers: The lithology, geological structure and landform layers pertaining to map area are integrated in GIS environment. As a result a layer shown in Fig 3.6 as an example consisting of combined units having unique lithology, structure and landform are derived. In the process, the primary porosity-permeability of the rock formations and the secondary porosity-permeability developed due to structural deformation and geomorphic process are taken in to account. These integrated lithology-structure-landform units are referred as hydro geomorphic units / aquifers and are treated as homogenous areas with respect to the degree of porosity-permeability.

However, the hydrogeomorphic units derived from the integration of lithology and landform which are referred as lithology-landform controlled aquifers occupy normally large areas hence are shown as polygon features whereas the hydrogeomorphic units derived from the integration of structures which are referred as fault/fracture controlled aquifers normally occupy narrow linear zones hence are shown as line features in the layer. The polygon features thus generated are identified with alpha-numeric codes, for example as, SH-912, DH-87, PPS-87, PPM-912, FV-811 etc., wherein the alphabetic code represents the geomorphic content and the numeric code represents the lithological content of the hydro geomorphic unit. The line features are marked with colours.

Based on the type of aquifer material disposed in the subsurface at different levels with reference to its potential for storing and transmitting the ground water, the aquifers are classified in to six classes. The classes and the criteria used for classifying the aquifers is given in Table-3.1.

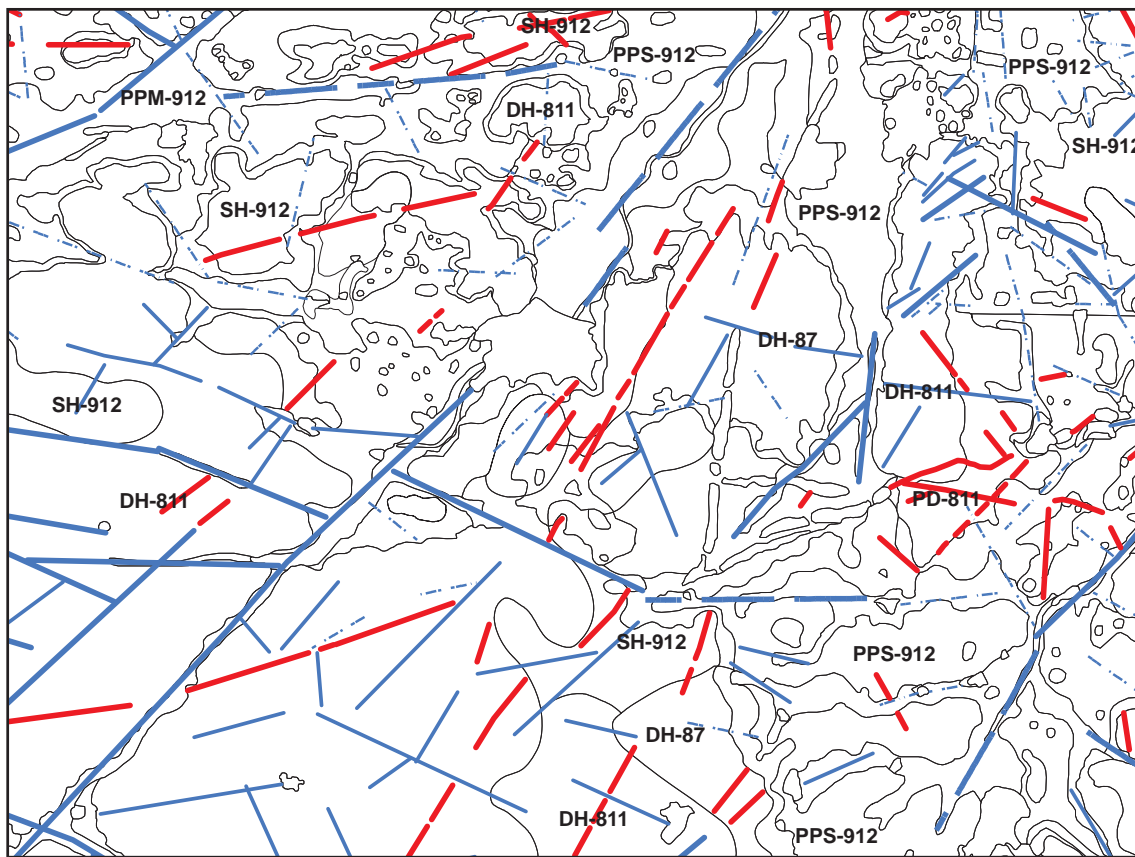


Fig-3.6: Hydrogeomorphology layer showing lithology-landform controlled aquifers as polygon features and fault/fracture controlled aquifers as line features

Mostly, the layered rock formations such as sedimentaries, Deccan traps and alluvial deposits are characterized by the presence of multi-aquifer systems, because of the inter-layering of different permeability horizons. Generally, shallow aquifers occur under unconfined condition, and deeper aquifers occur under either semi-confined or confined conditions. In order to increase the productivity of wells, multiple (more than one) granular zones (aquifers) of different thickness are to be tapped.

Estimation of recharge conditions: The hydrogeomorphic units / aquifers thus derived are estimated for the recharge that is taking place. In the first step, the hydrological parameters that are mapped are studied and analyzed qualitatively to assess the recharge to ground water. In the second step, the water level fluctuation data is analyzed for estimating the actual recharge. However the recharge is estimated considering data pertaining to one recharge cycle (falling during the ground water prospects mapping period) only.

Study and analysis of hydrological data: Initially, the recharge condition of the aquifer unit is evaluated based on the study and analysis of the hydrological features occurring in the given aquifer unit as they act as indicators of the recharge condition. For this purpose, the hydrological features which are relevant for recharge condition evaluation are inventoried and mapped as independent layers. Then they are integrated with aquifer units under GIS environment to estimate the recharge taking place in each unit.

Study and analysis of water level fluctuation data: The main sources of recharge are from the rainfall, water bodies, return flow from the irrigation, etc. However, the entire amount of water doesn't enter into the ground. It depends on the infiltration capacity of the soil and the hydro geological properties

Table - 3.1: Classification of aquifer material

Loose Sediments (LS)	Mainly Quaternary formations comprising of unconsolidated sediments represented by coastal, deltaic, aeolian, alluvial and flood plains.
Permeable Rock (PR)	The semi-consolidated sediments and vesicular volcanic rocks having primary porosity and permeability.
Weathered Rock (WR)	Mainly weathered zones in hard rock formations where occurrence and movement of ground water is controlled by depth of weathering.
Fractured Rock (FR)	The fractured zones in hard rock formations which generally act as conduits for movement of ground water.
Fissured Rock (FIR)	The hard rock formations like gneisses, schists, slates, quartzites, limestones, etc having jointing, bedding, cleavage and other weak planes which impart limited porosity and permeability to the rock.
Impervious Rock (IR)	Massive Rocks without significant porosity and permeability like massive granite, dolerite dyke, etc which act as barrier for ground water movement.

of the rock formations. Hence, the actual quantity of water available for recharge is assessed by studying the water level fluctuation data collected from the observation wells. Based on the quantity of water available for the recharge in each unit, the recharge conditions are categorized as excellent, very good, good, moderate, limited, poor or nil.

Estimation of ground water prospects: After delineating the aquifers and estimating the recharge to the aquifers, the ground water prospects of the aquifers are estimated in terms of type of wells suitable, depth range of wells that can be drilled, and expected yield range. First, the ground water prospects are estimated based on the analysis of hydrogeological characteristics of the parameters controlling the occurrence and movement of ground water. Next, the ground water prospects thus estimated are optimized with the type, depth and yield of at least 3-5 existing wells observed in the field in each aquifer unit. These observation wells are selected in such a way, that they are properly distributed throughout the map covering all the map units.

Types of wells suitable: The type of well suitable to the aquifer is selected based on depth to water table, material content and aquifer characteristics. The criteria followed for selecting the type of well is given in table - 3.2.

Table - 3.2: Criteria for suggesting type of well

Dug Well (DW)	Where, water table is very shallow and/or aquifers with low transmissivities are present (weathered, fissured/clayey formations)
Bore Well (BW)	Where, water table is deep and/or a thick column of weathered / fractured rocks or semi-consolidated rocks with fairly good transmissivities are present
Tube Well (TW)	Where, loose or collapsible unconsolidated and semi-consolidated sediments with fairly good transmissivities are present
Dug-cum-Bore Well (DBW)	Where, water table is at moderate depth, having semi-confined aquifers and the formation is not collapsible
Dug-cum-Tube Well (DTW)	Same as above (DBW), but where the formation is loose and collapsible requiring slotted casing
Ring Well (RW)	Same as DW, but where loose and collapsible formation is present

Depth Range of wells: The depth (in range) of the well to be drilled in the aquifer unit is decided considering the depth to ground water table, the thickness of the aquifer, the depth range of existing wells and knowing the depth range of productive aquifers in the unit.

Expected Yield range: Initially, considering the hydro geological characteristics of rock types, structures, landform and recharge conditions of the aquifer unit, the yield of the well is evaluated. Then the yields of the existing wells located in the unit are analyzed. Based on the correlation study, the expected yield range of wells in lpm or cu.m/day has been estimated for each unit. A more porous and pervious rock cannot give lower yield than a less porous and pervious rocks. Similarly, a shallow weathered zone on the same rock cannot give high yield than deeply weathered zone. In those aquifer units, where presently no wells are available, a tentative yield range has been given purely based on hydro geological considerations.

Note: 1) In a particular aquifer unit, two productive aquifers may occur. In such cases ground water prospects of both aquifers are estimated and recommended. 2) In a particular aquifer unit, more than one type of well may be suitable. Accordingly the wells that are suitable are suggested along with depth and yield.

18 & 19. Recharge structure layers: The hydrogeomorphic unit's layer has been integrated with hydrology as well as base map details layers derived from satellite data as shown in Fig-3.7 a, b and prepared the recharge structures layer showing the locations of site-specific recharge structures in the form of line and point features as shown in fig-3.7c. However, the locations of the recharge structures are tentative; the exact location has to be fixed based on the follow-up ground survey. Similarly, the types of recharge structures suggested indicate their hydrogeological suitability. The suitable engineering design for each type needs to be developed.

Prioritization of hydrogeomorphic units w.r.t recharge requirement: Sufficient recharge is essential to maintain the sustainability of ground water sources, particularly the drinking water wells in the hydrogeomorphic units/aquifers. In case the natural recharge is not sufficient, it has to be met through artificial recharge. Wherever, the natural recharge is insufficient, artificial recharging through site-specific structures has been recommended. Therefore the hydrogeomorphic units are evaluated in terms of the requirement for ground water recharging. Hydrogeomorphic unit is considered as unit area for evaluating the requirement for ground water recharge.

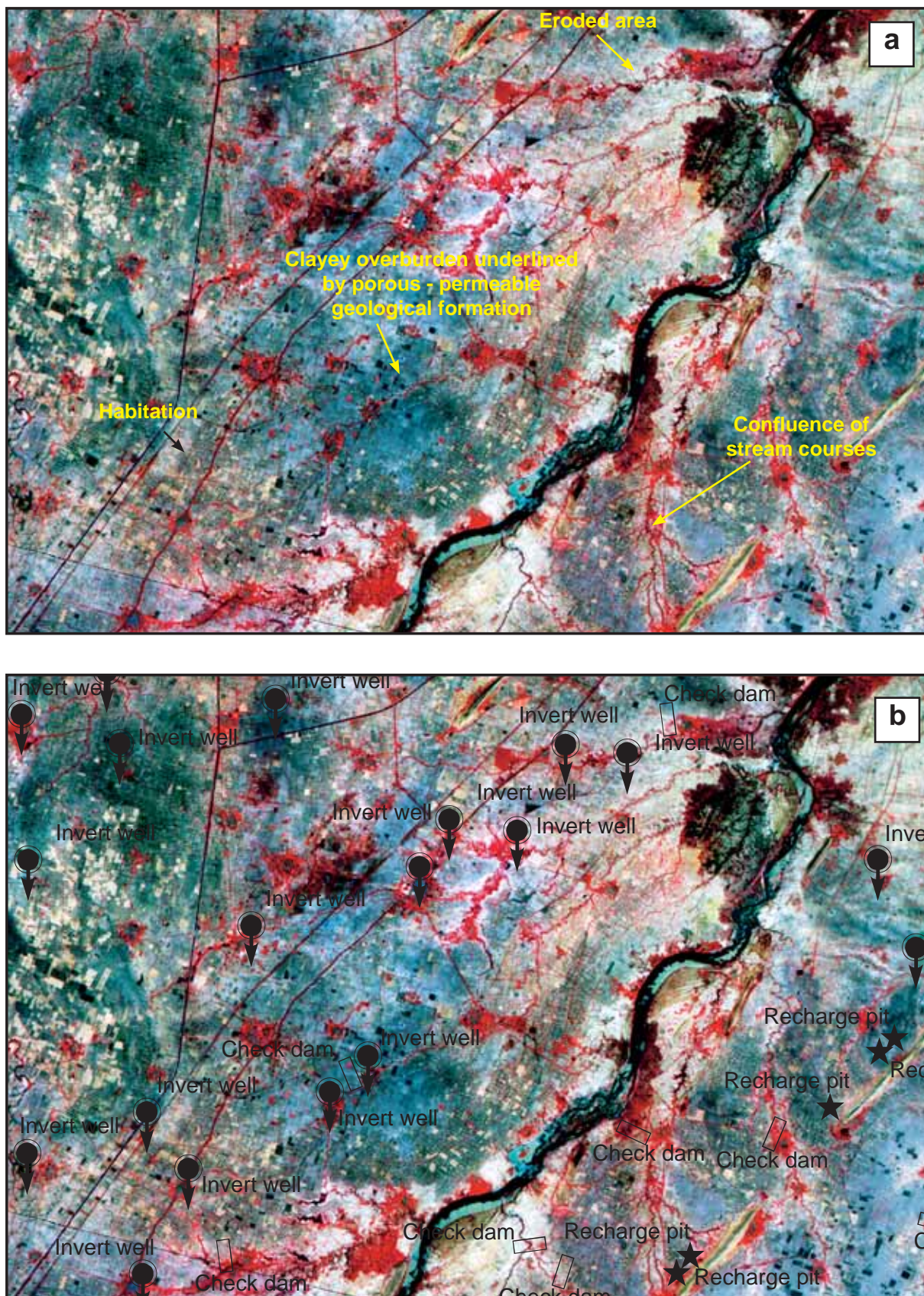


Fig-3.7: Satellite image showing a) various parameters governing the ground water recharge and b) identification and mapping of suitable locations of recharge structures

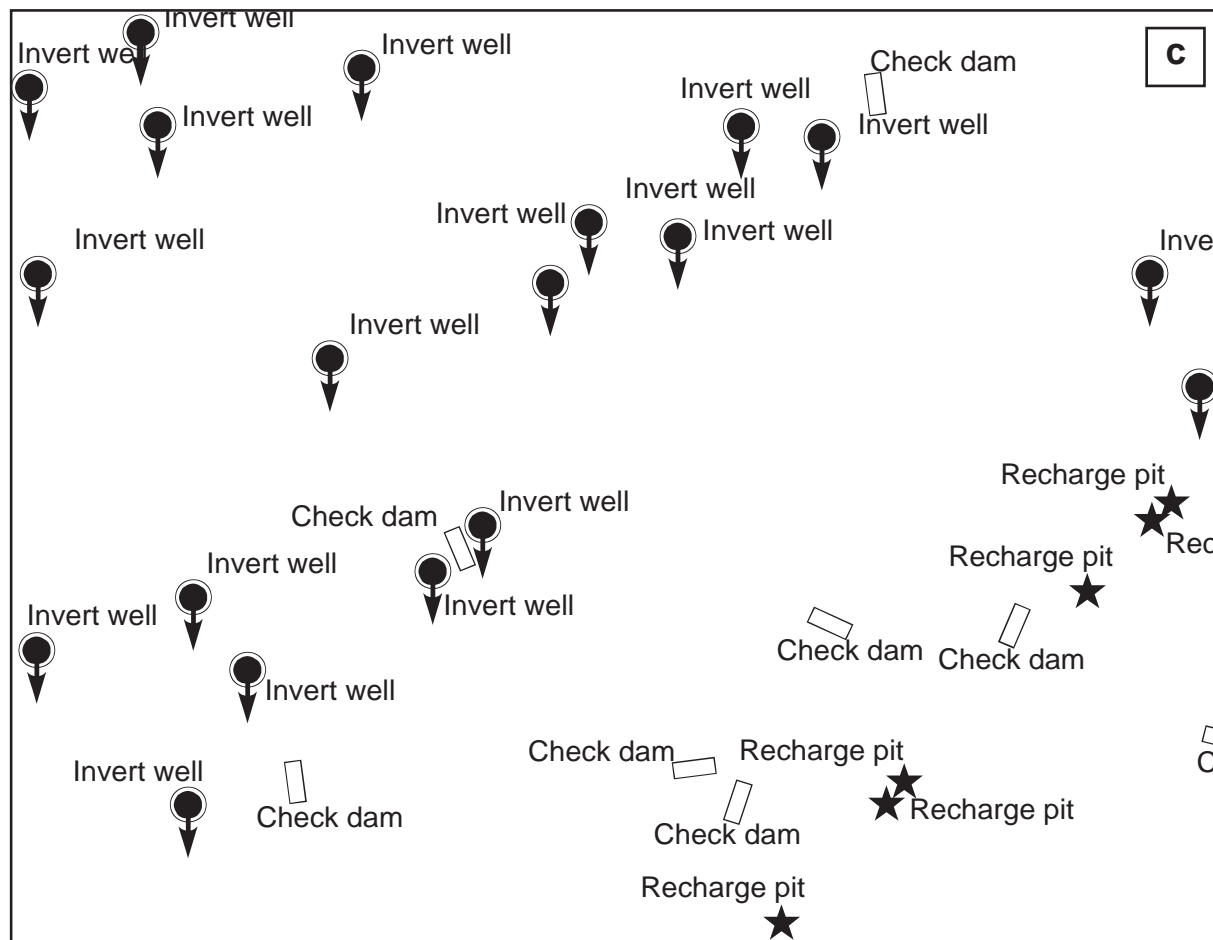


Fig-3.7: c) Recharge structures – line and point - layers

Criteria followed for classification of hydrogeomorphic units: The following criteria has been used for classifying the units in to different classes.

1. Presence of villages with drinking water scarcity (mainly due to the decline in water table)
2. Status of ground water development.
3. Areas where ground water levels are declining fast
4. Areas where water quality problem exists
5. Where recharge is poor/limited due to unfavorable hydrogeological condition

Based on the need for ground water recharge, the hydrogeomorphic units/aquifers occurring in the map area are divided in to five priority classes as shown in Table-3.3.

For example, in the hydrogeomorphic units where drinking water sources have dried up or water levels are declining fast or more number of drinking water scarcity villages are located or percentage of ground water irrigated area is very high or quality problem is reported (which can be improved by

Table-3.3: Types of hydro geomorphic units w.r.t requirement for ground water recharge

Sl. No	Type	Represented as
1	Hydrogeomorphic units where ground water recharge is required with high priority	High priority
2	Hydrogeomorphic units where ground water recharge is required with medium priority	Medium priority
3	Hydrogeomorphic units where ground water recharge is required with low priority	Low priority
4	Hydrogeomorphic units where ground water recharge is not required	Not required
5	Hydrogeomorphic units where ground water recharge is not feasible	Not suitable

dilution through recharge), 'Very High Priority' is indicated. Similarly, the units, which are mainly covered under forests or inhabited or shallow water table having good to excellent recharge from canal commands and surface water bodies and rivers etc, are given 'No Priority'. The remaining units are given the 'High Priority' / 'Moderate Priority' / Low Priority. For the zones which are not suitable for recharge structures, it is indicated as 'Not required'. The priority in which the hydrogeomorphic unit is classified is indicated by mentioning as Low Priority, Moderate Priority, High Priority, Very High Priority and Not required. This information is not depicted spatially on the body of the map. But, the two types of hydrogeomorphic units where ground water recharge is not required and is not feasible can be distinguished based on the absence of recharge structures in them from the other three types. However, all this information is provided in the 13th column of the dynamic map legend in the form of "statements" as mentioned in Table-3.3 against each map unit.

Identification of suitable locations within the hydrogeomorphic unit: The recharge water, normally, is available in the form of either overland flow or base flow. To harvest the water available in each form an appropriate type of recharge structure is identified and shown in Table-3.4. Six types of recharge structures are identified to harvest the overland flow - 1) Recharge pit, 2) Check Dam, 3) Percolation Tank, 4) Nala Bund 5) De-silting of Tank and 6) Invert Well / Recharge Well and one type of recharge structure i.e. Sub-surface Dyke to harvest the base flow.

Table-3.4: Recharge structures suitable for harvesting various forms of recharge water

Source of recharge water		Type of structure
Overland Flow	Surface run-off	Recharge Pit (RP)
	Stream flow - initial stage	Check Dam (CD)
	Stream flow – later stage	Percolation Tank (PT)
	Channel flow	Nala Bund (NB)
	Tank water	De-silting (DT)
	All forms of overland flow	Invert well / Recharge well(IW)
Base flow		Sub-surface dyke (SD)

The recharge pit is identified for harvesting the overland flow which is in run-off form; the check dam is identified to harvest the overland flow which is in initial stages of forming in to a stream (1st or 2nd order stream); the percolation tank is identified to harvest the overland flow which is in stream form whereas the nala bund is identified to harvest the overland flow which is in the form of channel flow. A part of the overland flow is being harvested in the already existing tanks and the tank acts as a source for recharge. However, the recharge will not be, as it is to be, due to silting up of the tank. Such tanks are identified for de-silting to facilitate better recharge from the tank water. In addition to this, the invert well / recharge well is identified to harvest the overland flow available in all forms where the recharge is obstructed due to the presence of impervious strata between the source and the aquifer.

Within the hydrogeomorphic units where recharge to ground water is required, locations which are suitable for constructing site-specific recharge structures are identified considering terrain conditions and the adequacy of source water either in the form of overland flow or base flow for harvesting. Preference to the vicinity of Non-Covered and Partially-Covered habitations is given in identifying the locations. Invariably, the locations are sited up-stream side of the habitations to have the maximum benefit of recharged water to the habitation except in case of sub-surface dyke. The subsurface dykes are located down-stream side of the habitation as the impounded sub-surface water facilitates recharge upstream.

Each type of recharge structure is to be considered as a “class” and identified in terms of its function. It is to be noted that they should not be treated as engineering structures where in the length / size, shape, strength, material to be used etc are taken in to account. For example, the percolation tank suggested at a location indicates that the location is porous and permeable which allows percolation of water to the maximum extent thereby recharging the ground water.

Criteria followed for identifying locations: The following aspects are taken in to account while identifying the locations of the recharge structures.

- Location of the habitation
- Adequacy of recharge water
- Hydrogeological properties of aquifer material
- Slope / terrain condition

The locations of recharge structures which are to be constructed for harvesting the overland flow

are identified about 200-300 m (approximately) upstream of the habitations. Whereas the location of recharge structures which is to be constructed for harvesting the base flow is identified about 200-300 m (approximately) downstream of the habitations. The recharge structures which are dependent on stream water are located mainly on 1st to 3rd order streams and at the most up to the initial stages of 4th order stream. No recharge structure is located on major streams / rivers occupying large area. The criteria for selection of locations for various types of recharge structures are given below.

Check Dam: On the 1st and 2nd order streams along the foot hill zones and the areas with 0-5% slope

Percolation Tank: On the 1st to 3rd order streams located in the plains and valleys having sufficient weathered zone / loose material / fractures

Nala Bund: On the 1st to 4th order streams flowing through the plains and valleys where acquisition of land for inundation of large areas is not possible. Limited water will be stored in river bed for some time which increases recharge

Invert Well / recharge Well: In areas where transmissivity of the upper strata is poor, for example in shales underlain by sandstones, in buried pediplains with top soil having low permeability, in Deccan Traps where vesicular basalt is overlain by massive basalt or thick black cotton soil or impervious zone

De-silting of Tanks: The de-silting is to be done in small tanks which are partially silted up (Siltation in the tanks is found by study of the image and ground truth).

Recharge Pit: Around the habitations where drainage does not exist, for example water divide areas, hill/plateau tops, etc. Recharge pits are preferred in the existing tanks also.

Sub-surface Dyke: On the stream courses flowing in unsaturated zones, for example vesicular / weathered / fractured basalt, lateritic terrain, etc., where the ground water seepage as base flow is significant. On the upstream side the subsurface storage improves.

3.3 Map composition

The information thus extracted from the satellite data at different stages, has been converted, simultaneously, into spatial data base (GIS layers). Using the GIS layers, the ground water prospects map is generated through different steps.

Ground water prospects map (map part): Finally, a ground water prospects map has been generated by composing both the primary and derivative layers. The map is composed in such a way that - a) the information pertaining to the factors controlling the occurrence and movement of ground water i.e. lithology, geomorphology, geological structures and recharge conditions is presented in the form of back-ground data, and b) the information pertaining to ground water prospects and ground water sustainability in the form of fore-ground data. The back-ground information includes lithological and geomorphological information represented in the form of alphanumeric codes, for example PPS-71, PPD-81, UPM-32, etc. wherein the alphabetic code represents the geomorphic content and the numeric code represents the lithological content. The structural information has been represented in the form of lines (line aquifers) of red and blue colors. Whereas the fore-ground information includes, VIBGYOR colour scheme with seven colours, i.e. violet to red, are used for depicting different yield ranges; within each *yield range*, 3 hatching patterns are used for depicting the *depth range* of wells. Similarly, the recharge structure lines and points are presented with different symbols.

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A map unit showing one of the three hatching patterns in a particular colour (from violet to red) indicates the expected yield range and suggested depth range of the wells. For example, a unit with *horizontal hatching* in *blue colour* indicates that the expected yield range in that unit is 200-400 lpm and the depth range of the well is <30 m. The inselbergs, linear ridges, dykes, etc which act as run-off zones/ barriers for ground water movement, are indicated with solid red colour, and the hills (SH, DH and RH) and dissected plateaus where the prospects are limited to valley portions only are indicated with red hatching. In addition to the above, the rivers / streams and perennial water bodies / tanks are shown in light *cyan* colour and roads, railways and settlements are shown in brown colour. A sample ground water prospects map thus generated is shown at **19**.

Ground water prospects map (legend part): Since no separate report has to be prepared for each map, an exhaustive self explanatory legend has been designed containing two parts. The upper part of the legend provides map unit-wise ground water prospect information and lower part provides the symbology details about the base map, hydrological and geological information, colour scheme for representing the yield range and depth range of wells, location map, toposheet index, administrative index and other reference information. The format of the legend is fixed to maintain the standards and uniformity.

4. Map referencing

The ground water prospects map is used mainly for two purposes, namely i) to identify ground water prospect area for locating ground water source within the prospect area, close to a habitation to be supplied with drinking water and ii) to locate the site for constructing a ground water recharge structure which are suggested on the body 19 of the map. This is best done by matching map features to the ground features based on direction and distance from a known point / feature both on the map and ground.

4.1 Identification of the village / habitation of interest

The first step in the process is to know the village / habitation of interest and map sheet number of the corresponding ground water prospects map. This can be known with the help of a district village index map showing taluk / block, village boundaries and their names superimposed with 1: 50, 000 scale toposheet index numbers. A sample village index map pertaining to Bangalore District, Karnataka state is provided in fig-5.5 on reduced scale at the end of the manual. The unique identification of any village / habitation is linked to the taluk / block and corresponding district. In case the habitation is a village, the district map facilitates the user to locate the specific village of interest and the corresponding toposheet. For example, the map sheet number of Chevella village, Alladurg block, Medak District of AP is 56 G/13 as per the sample map shown in fig-4.1.

In case the habitation is a hamlet of the village, the habitation name does not appear on the district map. Even then, the village can be considered as a habitation of interest, for time being, and the toposheet number can be known.

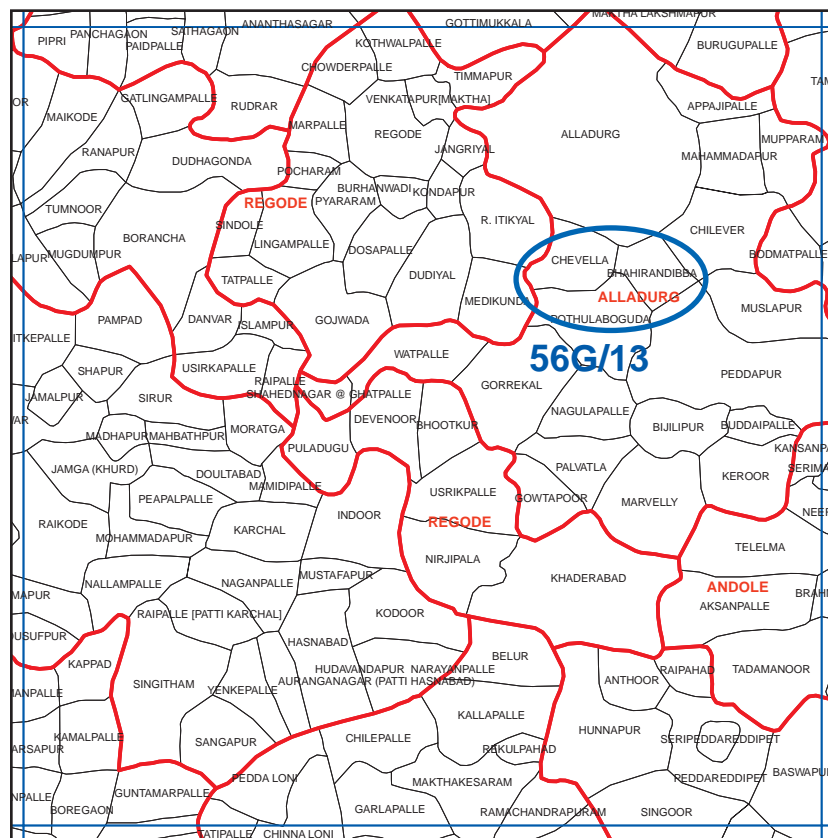


Fig-4.1: Village Index map of part of Medak District, AP showing 1: 50,000 scale toposheet Index number of a village

4.2 Browsing of relevant ground water prospects map

In the second step, the ground water prospects map of corresponding toposheet has to be located. Each and every ground water prospects map corresponds to Survey of India toposheet on 1: 50,000 scale and is identified by the same number with which the toposheet is identified. The number is given at 4 as shown on the sample ground water prospects map given with the manual. With the help of this toposheet number the relevant ground water prospects map can be browsed from the maps made available for the state.

4.3 Locating the habitation of interest in the ground water prospects map

In the third step, the location of the habitation of interest has to be located on the ground water prospects map. The ground water prospects map shows all the permanent habitations along with their names which are shown on the 1:50,000 scale toposheet. The name of the habitation of interest can be located on the map by searching the habitation names. While identifying the village / habitation of interest and its toposheet number in the first step itself, the broad location of the village / habitation on the toposheet can be ascertained. This broad location can be used as a reference for zeroing down the search and to identify exact location of the habitation based on the habitation name.

4.4 Locating the map feature on the ground

In the fourth step, the map features mainly the locations of the ground water prospect areas and the locations of site-specific ground water recharge structures shown on the map have to be located on the ground. The ground water prospects map shows not only ground water prospect areas and locations of site-specific ground water recharge structures but also the geological, hydrological and cultural features. Moreover, the ground water prospect areas and locations of site-specific ground water recharge structures are shown as attribute features to geological, hydrological and cultural features on the map. In the ground water prospects map pertaining to parts of Jhansi District, U.P given as Fig-4.2a as an example, a fault / fracture controlled aquifer suitable for high yielding moderately deep bore wells is shown as a linear zone along with an anomalous stream course. A lithology-landform controlled aquifer suitable for moderately yielding shallow dug wells is shown as an attribute to a lithology-landform unit.

Similarly, in the map given as 4.2b, a check dam is shown on the 2nd order stream course at the confluence of one 1st order stream with another 2nd order stream. A recharge pit is shown on the water divide near a partially covered (drinking water supply point of view) habitation.

As ground water prospect areas and recharge structures are shown as attribute features to geological, hydrological, and cultural features, identification of these features on the ground itself amounts to the identification of ground water prospect areas and recharge structures..

Configuration of the features i.e. size, shape, pattern, etc., of the features depicted on the map exactly matches with configuration of the corresponding objects on the ground. It is to be noted that, the configuration of the features that is possible to depict on the map on 1:50,000 scale is sufficient enough to establish a fairly good correlation between map features and corresponding ground objects. Further all these features shown on the map, except the geological features can be recognized by all, including engineers. Identification of geological objects on the ground requires geological knowledge which can be expected only from hydrogeologists.

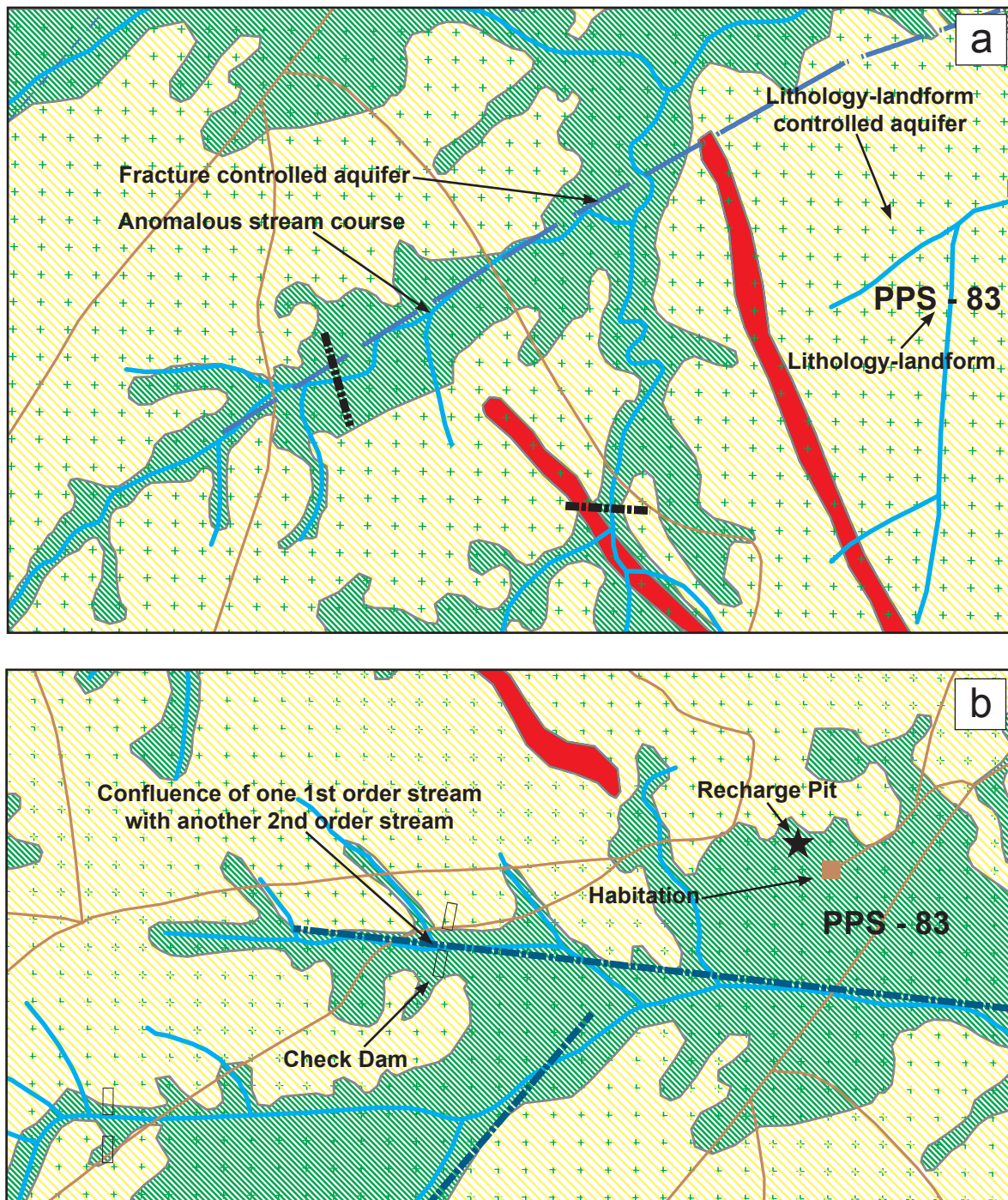


Fig-4.2: Ground water prospects map of part of Jhansi Dist., UP showing
 a) relation between anomalous stream course and fracture controlled aquifer and
 b) relation between confluence of two stream courses and a check dam

4.4.1 Identification of locations by feature matching

However, for locating a ground water prospect area or a recharge structure on the ground, for that matter, any feature shown on the map, the map features need to be matched with the corresponding ground objects. To avoid committing of mistakes and to achieve accuracy in locating the map features on the ground, the feature matching can be done in two steps.

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In the first step, the geological, hydrological and cultural features shown on the map are to be matched with corresponding ground objects at macro-level. Prominent features like hills, valleys, rivers, large water bodies, national / state highways – railway lines and their crossings, major settlements, etc which are close to the location of targeted map feature can be taken as a reference for matching. This is an easy exercise by which one can locate the area of interest on the ground within no time. Basically, matching of the map features with the corresponding ground objects at macro-level helps in navigation to the interested location on the ground. In other words, it will narrow down the area of search. In the second step, within the narrowed down area, the geological, hydrological and cultural features are to be matched with corresponding ground objects at micro-level. Intersection points, head and tails – convexes and concaves – twists and turns of the associated features, distances and directions of the targeted feature to the associated feature, stream orders and stream confluences on which the feature is located, etc., can be taken as reference to find out the exact location of the ground water prospect area or recharge structure.

For example, a fault / fracture controlled aquifer and a check dam, shown on the map given as fig 4.3, are to be identified on the ground. As per the map, the aquifer is occurring as a linear zone as an attribute feature to a stream course flowing through a narrow valley surrounded by hills, west of a habitation. In the first step, the narrow valley is to be located. Initially by matching the habitation shown on the map by name with the habitation on the ground, the valley occurring on the west of

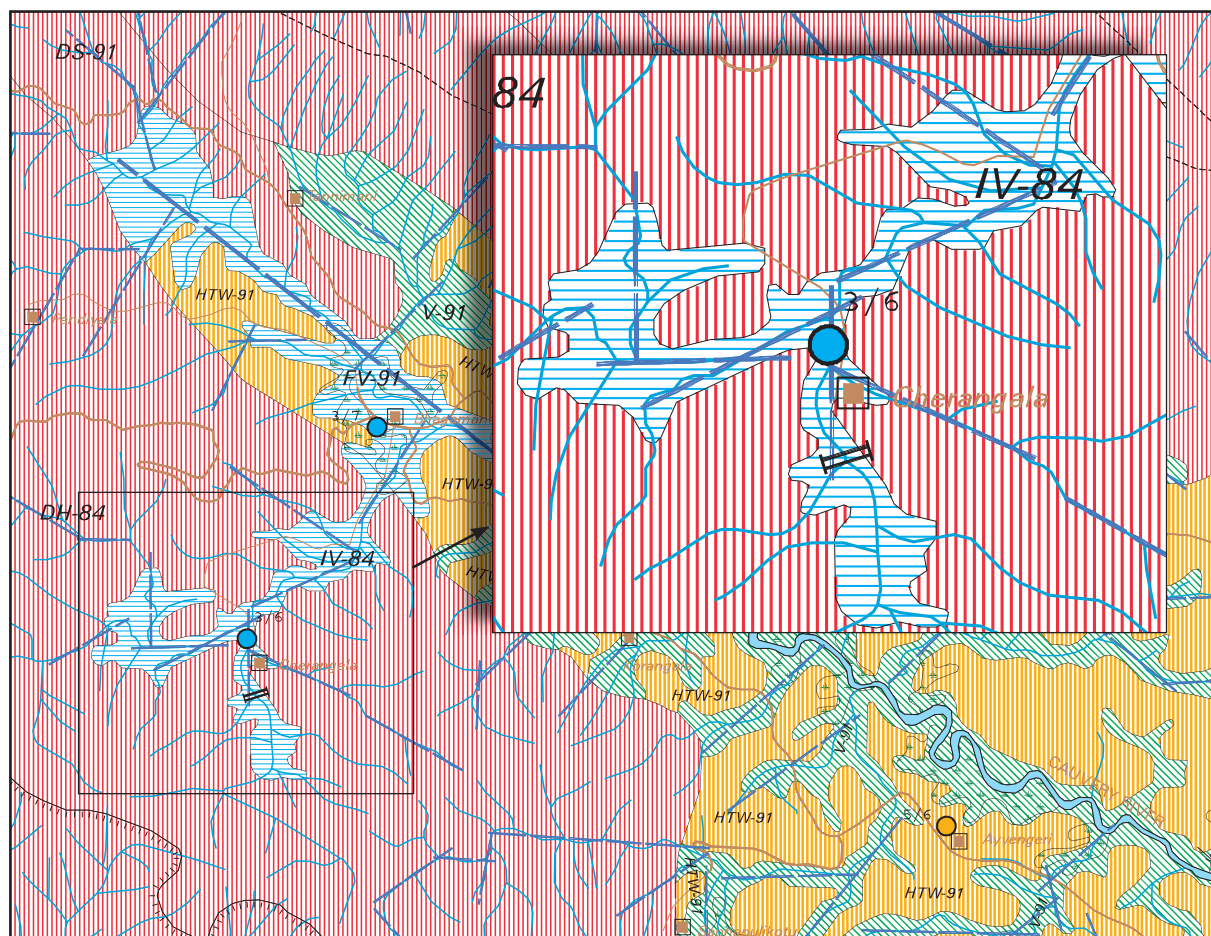


Fig. 4.3: Ground water prospects map of parts of Coorg & South Kanara districts, Karnataka showing map features in regional as well as local scales for identifying ground water prospect areas and recharge structures

the habitation can be located. Then within the valley, the stream course can be located. In the second step, the configuration of the stream course with reference to its relation with attribute feature i.e. the linear ground water potential zone is to be considered. The potential zone can be located on the ground by matching the features' configuration (twists and turns of the stream course) with the configuration of the stream course on the ground.

Similarly, a check dam is shown on the map occurring in the valley as an attribute to the weathered zone formed along the stream course. It is shown on the southern side of the habitation and at the confluence of a 2nd order stream with a 1st order stream. In the first step, the valley in which habitation is present is to be located on the ground. Initially by matching the habitation shown on the map by name with the habitation on the ground, the valley which forms part of the habitation can be located. Then within the valley, the stream course can be located. In the second step, the confluence of the 3rd order stream with the 1st order stream occurring within $\frac{1}{2}$ a kilometer distance south of the habitation can be identified on the ground based on the stream ordering. Once the confluence is identified, the identification of the location of the check dam becomes easy. The location can be anywhere on the 3rd order stream lying between the confluence and the habitation.

Survey of India Toposheet – a tool for improving accuracy: As mentioned earlier, the ground water prospects map contain most of the cultural and hydrological features that are there on Survey of India toposheet on 1: 50,000 scale and the features on the map and on the toposheet corresponds to each other in terms of area, shape and distance. The toposheets which are prepared long back however may not contain a few dynamic components of hydrological features and a few cultural features which have come up in recent times. Apart from this, the toposheets contain additional cultural features such as religious structures, prominent well locations, broad land use / land cover details, etc and more importantly the contours with 20m interval giving elevation information. Further, the ground water prospect areas and the locations of recharge structures shown as attribute features of cultural and hydrological features on the map have same attribute relation with the cultural and hydrological features shown on the toposheet as these features corresponds to each other both on the map and toposheet. Moreover, all these features and data are depicted on the toposheet in such a way that a virtual terrain can be perceived due to which best correlation between map and ground can be established so that any location on the map can easily be identified on the ground. Ground water prospects map and corresponding toposheet pertaining to part of Umaria district, MP is shown in fig 4.4 a and b respectively as an example to demonstrate the contents and their correspondence with each other.

Therefore, it is suggested to use the ground water prospects map along with the corresponding toposheet in order to take advantage of additional features and elevation information available on the toposheet which are critical for identifying ground water prospect areas and locations of recharge structures. Where hydrological and cultural features are not there or density is less, identification of ground water prospect areas and locations of recharge structures becomes easy and more accurate with the help of additional features such as religious structures, prominent wells; land use / land cover details etc. available on the toposheet.

Because of contours the topography can be visualized in 3-dimensional view. This helps in matching of the map features with corresponding ground objects very easily. Particularly, the lithology-landform units can be matched fairly well with corresponding ground objects, so that, the attribute ground water potential areas can be located on the ground with better accuracy. For example, the plain, pediment and hill zones shown on the map can be located on the map with the help of contours; widely spaced contour area as plain, moderately spaced contour area as pediment

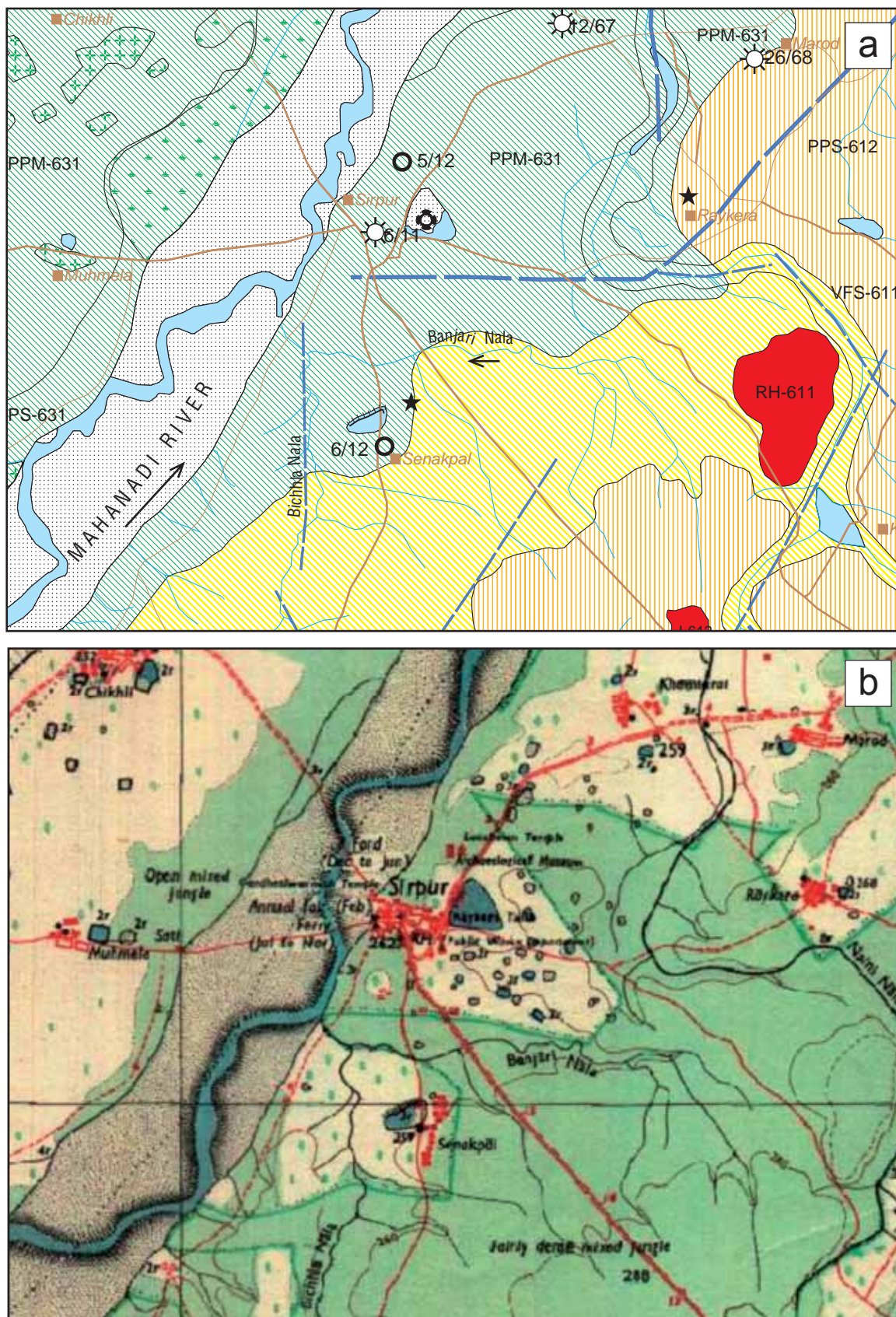


Fig. 4.4: a) Ground water prospects map covering Sirpur habitation and its surroundings, M.P. b) corresponding SOI toposheet showing additional features

and closely spaced contour area as hill. Usually, the break in slope coincides with lithology-landform unit boundary which in turn facilitates identification of location of ground water potential area on the ground. Further, contour information is highly useful in identification of recharge structures where no control feature is available to match. Slope is taken as one of the criteria for selecting the location of the most of the recharge structures such as, check dams, percolation tanks, nala bunds, sub-surface dykes, recharge pits. Hence, slope can be taken as a control parameter while matching the map features with ground objects. In fact, the surface slope and stream gradient on the ground also can be estimated with the help of contours available on the toposheet and the same can be used for identifying the locations of recharge structures.

The same approach of feature matching is to be followed for identifying map features on the ground. However, the attribute features i.e. ground water prospect areas and locations of recharge structures need to be transferred on to the toposheet to see their relation with cultural and hydrological features shown on the toposheet. If the user is capable of presuming the presence of features without transferring them physically on to the toposheet, it can be used straight away for identifying the features on the ground.

4.4.2 Identification of locations with GPS

The soft copy ground water prospects maps available in geo-pdf format contain latitude-longitude information. The user can get co-ordinates at each and every location on the map as shown on the map given in Fig-4.5 as an example.

But, the hard copy ground water prospects maps doesn't contain co-ordinate information. This

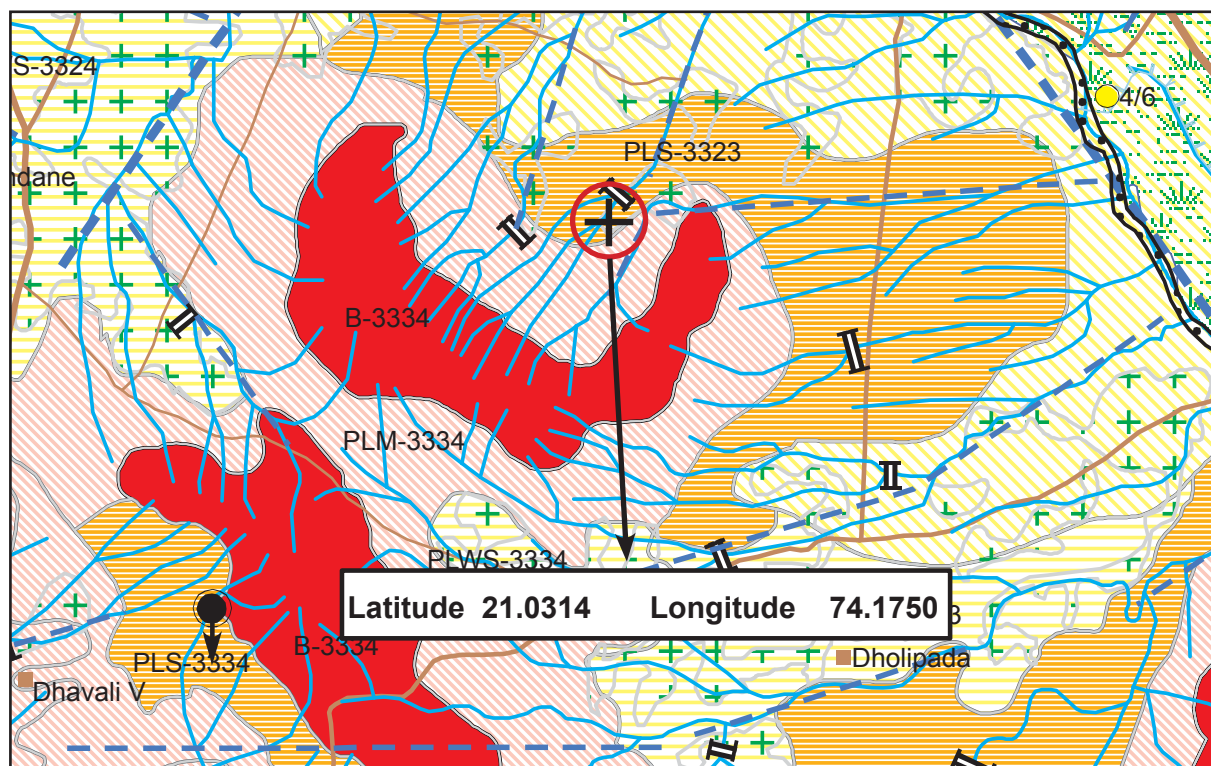


Fig-4.5: Ground water prospects map in pdf format showing latitude and longitude information (for the location marked as + in black)

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information has not been provided in accordance with map policy. However, since the ground water prospects maps are made corresponding to Survey of India toposheet, the same co-ordinates is valid for the ground water prospects map also. User can transfer the toposheet co-ordinates on to the ground water prospects map and use for deriving the coordinates of an interested map feature i.e., a ground water prospect area or a recharge structure.

In order to identify the ground water prospect area or a location of recharge structure on the ground, the coordinates of the same on the map need to be identified and search for same coordinates on the ground using GPS instrument. Wherever, the map and ground coordinates matches that become the ground water prospect area or the location of recharge structure. It is to be noted that the projection system of the map and GPS should be same. The ground water prospects maps of Andhra Pradesh (eastern part), Karnataka, Kerala, Madhya Pradesh, Chhattisgarh, Rajasthan, Jharkhand, Gujarat, Orissa and Himachal Pradesh are in Polyconic Projection and Everest Datum. The Projection and Datum of the GPS also should be same while taking the coordinate information on the ground in these states.

However, locating the ground water prospect area and recharge structures using GPS has got certain limitations. Two types of GPS are available – 1) Differential GPS 2) Hand-held GPS. High levels of accuracy can be achieved with Differential GPS. But they are not handy and are expensive. Hand-held GPS are versatile and are best to use on any outdoor activities. But accuracy level is coarse. GPS accuracy is affected by a number of factors, including satellite positions, noise in the radio signal, atmospheric conditions, and natural barriers to the signal. Noise resulting from static or interference from something near the receiver or something on the same frequency can create an error between 1 to 10 meters. Objects such as mountains or buildings between the satellite and the receiver can also produce error, sometimes up to 30 meters. The most accurate determination of position occurs when the satellite and receiver have a clear view of each other and no other objects interfere. Therefore, GPS can be used for navigating purposes and precise location can be reached by feature matching on the ground.

5. Use of the map

Supply of drinking water using ground water as a source is a complex task which involves many technical issues such as, identification of ground water prospect area, evaluation of its sustainability, evaluation of its quality, identification of locations for site-specific recharge structures, development of wells, construction of recharge structures, etc. It is difficult to address these issues right in the field just based on ground observations at local level. Scientific data on local and regional scales is a prerequisite. The ground water prospects maps forms as comprehensive data base on ground water which can address some of these issues. The maps can be used, basically, for identification of ground water prospect areas and locations of site-specific recharge structures. It is expected that the ground water prospect areas thus identified are developed for supplying drinking water to Not Covered (NC) and Partially Covered (PC) habitations. Similarly, the recharge structures are constructed at the identified locations for making the ground water sources sustainable.

5.1 Identification of potential ground water sources

The ground water prospects map shows the distribution of different aquifers - lithology-landform controlled aquifers as well as fault/fracture controlled aquifers - along with their ground water potential in terms of the depth to which the wells are to be drilled and the yield that can be expected from the drilled wells in the aquifer. The map also shows the locations of the habitations along with their names, district and state in which they are falling. In addition to this, the status of drinking water supply to the habitations in terms of NC and PC is given. Of course, as the NC and PC categorization of the habitations is dynamic one, it has to be updated based on the current status.

Based on the status of coverage or practical requirement of drinking water, the habitations can be selected. The map shows the aquifers available in and around the target habitations. A study has to be carried out using the map and habitation data in terms of quantity of ground water required to meet the demand for drinking water of the habitation and the yield and quantity of ground water the aquifers occurring in the vicinity of the habitation can provide. Based on the requirement of the habitation vs prospects of the aquifer on which the habitation is sitting or the aquifer close to the habitation or more than one aquifer occurring in the vicinity of the habitation can be selected for developing wells. In each aquifer more than one well also can be developed by taking draw down of the wells in to consideration. Ground water prospects map covering part of Umaria District of MP showing occurrence and distribution of aquifers in the vicinity of habitations is given as Fig-5.1 as an example.

The wells can be developed straight away anywhere in the confirmed fault / fracture controlled aquifers or lithology-landform controlled aquifers where the success rate is reported as high. However, to identify exact site for drilling the well, a suitable geophysical survey can be carried out. In other aquifers locations for developing the wells have to be identified based on the follow-up ground hydrogeological survey or geophysical investigation. The ground hydrogeological or geophysical surveys are cumbersome and time taking. It is difficult to carry out these surveys in vast areas where no knowledge on ground water occurrence and distribution is available. However, the aquifer information provided in the map can be effectively used for selecting target areas for these investigations. The information helps in narrowing down the target areas for ground water search.

It is to be noted that the aquifers occurring on the top geological formation are only represented on the map along with depth and yield information. The depth and yield information of underlying aquifers, if any, are provided in the legend. This has to be taken in to account while identifying the locations for drilling, and estimating the depth to which the wells are to be drilled and the yield that

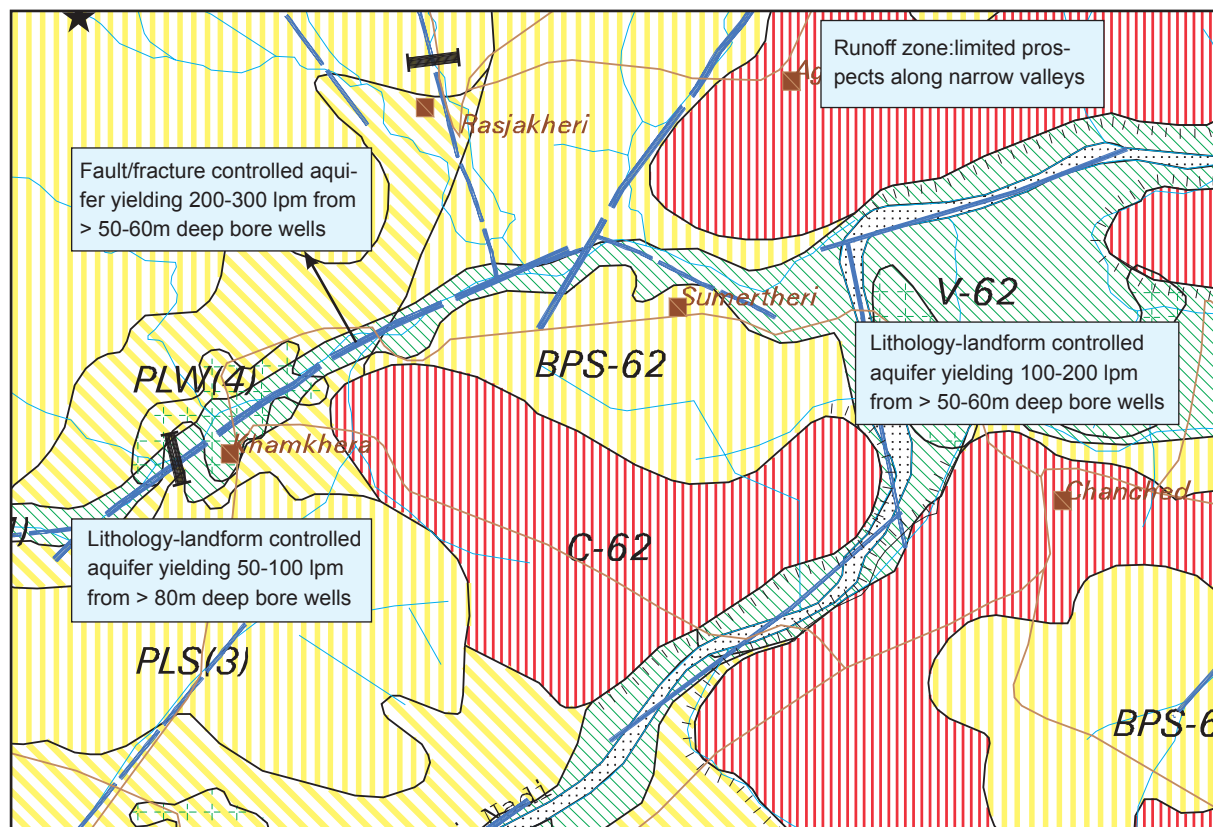


Fig-5.1: Sample ground water prospects map showing potential ground water sources

can be expected from the drilled wells and proceed accordingly for developing the wells.

5.2 Identification of locations for site-specific recharge structures

The ground water prospects map, in addition to ground water prospect areas, also shows suitable locations for site-specific recharge structures. There are two aspects – i) location of recharge structure and ii) type of recharge structure – that are to be considered while using the map for recharge structures. The location of the recharge structures can be identified on the ground based on feature / co-ordinates matching. However, while identifying the locations on the ground it has to be ensured that not only the feature / co-ordinates are matched with corresponding ground objects but also the hydrogeological parameters based on which the location is marked on the map are to be matched with corresponding hydrogeological parameters on the ground. For example, on the ground water prospects map provided in fig 5.2, the locations of recharge structures are shown on the upstream side of the habitations so that the drinking water sources located in the habitations are recharged directly. While locating the recharge structures on the ground, it is to be ensured that the location falls on the upstream side of the habitations.

There are seven types of recharge structures - Recharge Pit, Check Dam, Percolation Tank, Nala Bund, De-silting of Tank, Invert Well (Recharge Well), and Subsurface Dyke. One of them which are suitable for the given location is recommended on the map. These seven types of recharge structures are to be treated as seven categories of structures. The classification is made not on the basis of engineering considerations, such as, length and width of the structure, material to be used for construction, foundation type, etc. The classification is made based on the hydrogeological

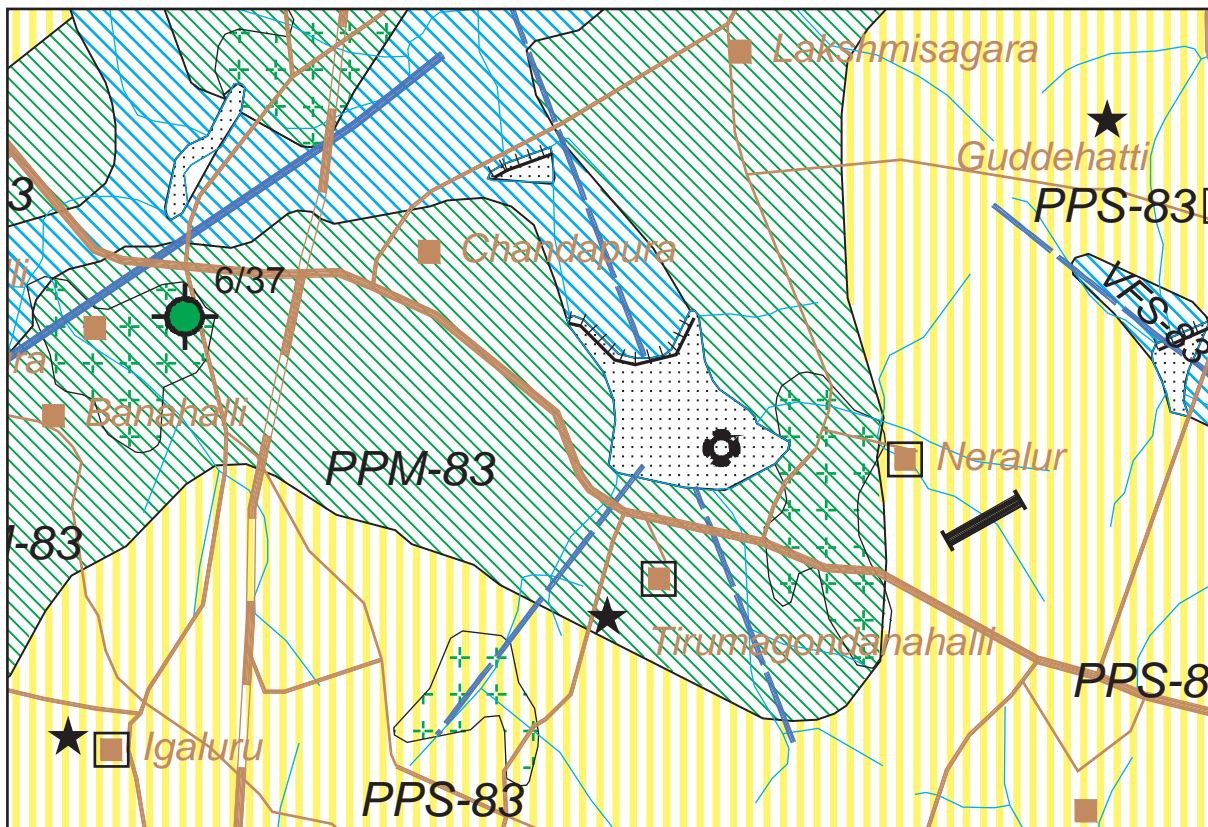


Fig-5.2: Sample ground water prospects map, part of Tumkur dist, Karnataka showing site-specific recharge structures

considerations such as, type of source recharge water available for harvesting, terrain condition, aquifer properties, etc. In each category, appropriate engineering structure can be designed depending on the ground condition. The design of the engineering structure for a particular type of recharge structure need not be same in all the locations. The design can vary from location to location depending on the local conditions.

The locations for recharge structures are suggested in the aquifers where recharge is required. Whether a drinking water well is there or not and whether a drinking water well is going to be drilled in future or not was not the criteria for suggesting the locations. Therefore, the recharge structure located anywhere in the aquifer recharges the wells which are already existing and the wells which are going to be drilled in the aquifer in future; of course, immediately in the downstream side and in due course of time in the far away areas. It is also to be noted that the recharge is a regional phenomenon. Hence the effect of a recharge structure at a particular location will have influence not only on the targeted drinking water source but also on the ground water source located at a far away distance in due course of time. If no location is there on the map at the drinking water source because it was not feasible, the location suggested in the same aquifer unit situated at can also be considered. Hence, all the locations suggested on the map can be taken up for construction. Since ground water resource is depleting fast due to over exploitation, the ground water sources which are yielding water at present may go dry in near future. It is suggested to construct at least one recharge structure at every drinking water source to make the ground water sustainable. It is suggested that if a recharge structure is already constructed at the location suggested on the map by user department or some other department, such locations can be ignored.

It is to be noted that the ground water prospects maps of Phase I and Phase II states provide

locations of recharge structures only in the vicinity of NC and PC habitations. But as the data base for identification of site-specific recharge structures is available on the map and the criteria to be followed for selecting a suitable location is also known, as given in the manual; locations for recharge structures can be identified wherever they are feasible including the habitations for which the locations are not shown on the map. Watershed is considered as the basic unit for identification of the locations and selection of the type of recharge structures suitable to the location. Hence it is suggested to implement the construction of recharge structures which include identification of locations, transferring of the locations on to the ground and evaluating the effect of the recharge structure in the frame work of a watershed.

5.3 Development of drinking water security plans

The ground water prospects map shows the locations of habitations, occurrence and distribution of ground water prospect areas and locations for site-specific recharge structures. In addition to this, the hydrological data which includes stream / river network and water bodies are also shown. All these data is available on one platform under integrated environment. Therefore the maps can be made use as a suitable data base for developing a ground water based drinking water security plan for a habitation or for a group of habitations. Watershed is considered as a natural unit for evaluating ground water recharge and discharge in turn for development and management of the resource. The ground water prospects maps with all the required data as shown in fig-5.3a as an example, supports watershed-wise planning for ground water development and management. It can be seen from the ground water prospect map of a watershed given as an example in fig-5.3b, the availability of the ground water data for planning development and management of ground water resource to meet the drinking water requirement of a habitation located in the watershed.

The ground water based drinking water security plan can be developed for a habitation or a group of habitations depending on the availability and the sustainability of ground water resource. Drinking water requirement of a habitation, over a period of time, can be worked out based on the demography data. The quantity of ground water that is possible to extract from the aquifers occurring in the vicinity of the habitation can be estimated based on the yield of the aquifers recommended in the map. Depending on the potentiality of the aquifer for yielding required quantity of ground water, one or more than one aquifer can be identified for development of wells and extracting the ground water. In case of the habitations covered partially by drinking water supply from the existing wells, the balance requirement of drinking water can be worked out and to meet this balance requirement the aquifers occurring in the vicinity of the habitation are to be exploited. In the same way, one or more than one aquifer can be identified, depending on the potentiality of the aquifer for yielding required quantity of ground water for development of wells and extracting the ground water. Similarly, the requirement for artificial recharge to maintain sustainability of the resource can be known from the map. Wherever artificial recharge is required suitable locations for constructing site-specific recharge structures are recommended on the map. Recharge structures can be constructed at these locations to maintain the sustainability of the drinking water sources of the habitation.

In case if the aquifers occurring in the vicinity of the habitation are not productive and required quantity of ground water is not possible to extract from them and sustainability of ground water resource cannot be maintained by artificial recharging, the aquifers occurring at a distance from the habitation can be exploited and the drinking water be supplied to the habitation by transporting the ground water. Even this also not feasible, the aquifers common to a group of habitations can be exploited and a scheme which can supply drinking water to the respective group of habitations can be developed. One ground water prospects map covers approximately 700 sq.km area in which

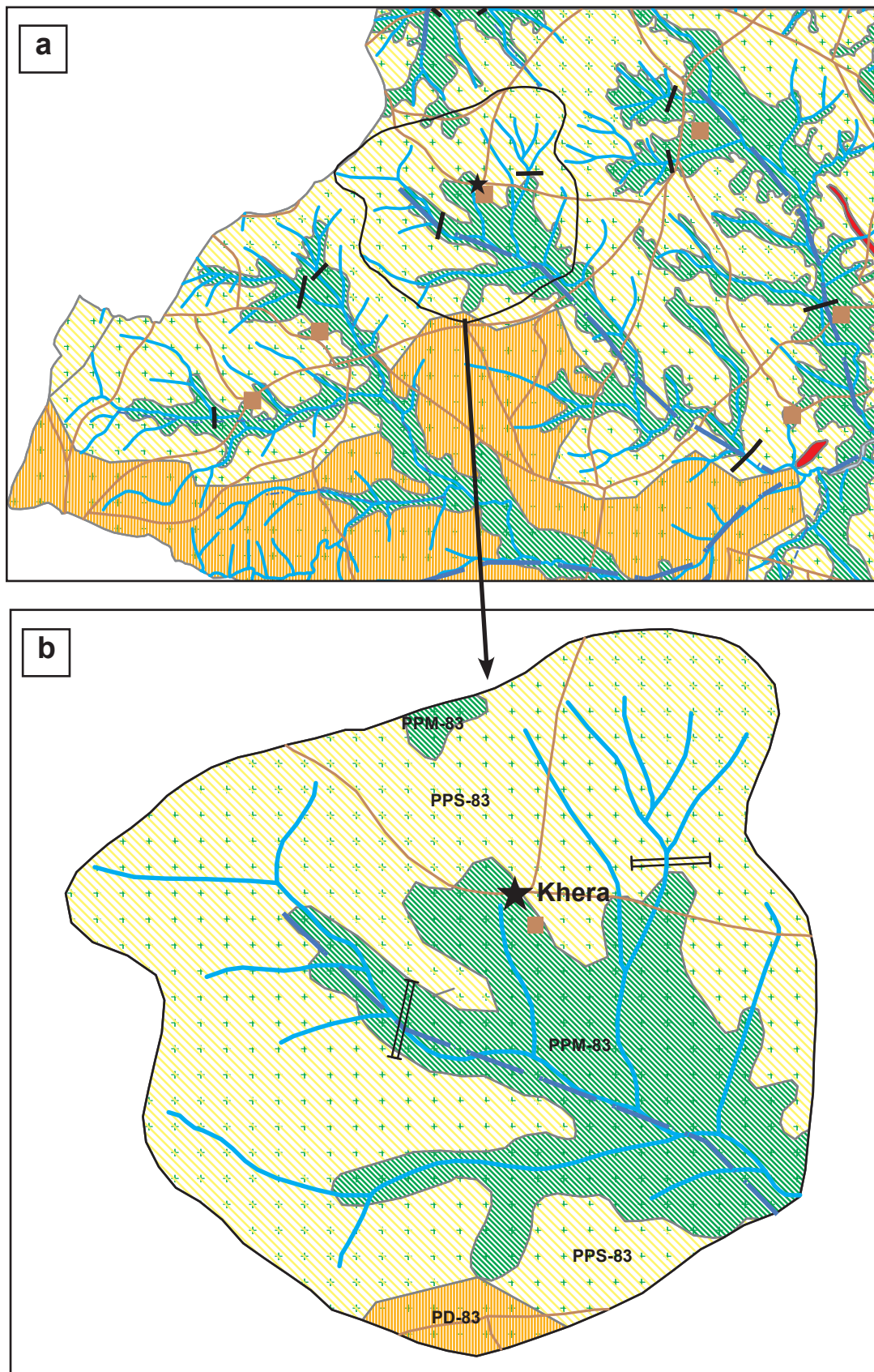


Fig-5.3: Sample ground water prospects map showing a) watershed boundaries and b) watershed – wise ground water prospects

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normally 80-100 habitations are likely to occur. It is also possible to have block/district/region wise ground water based drinking water security plans. Since the hard copy ground water prospects maps contain base map details on 1:50,000 scale, the distances can be approximately measured and tentative drinking water supply network also can be planned.

The ground water data that is provided watershed-wise on the ground water prospects map which can be made use for developing a ground water based drinking water security plan for Khera village of Jhansi Dist., UP is shown in Fig-5.4 as an example.

As far as the aquifers are concerned, there are three types of aquifers occurring in the vicinity of the habitation. The habitation is located in the aquifer which yields 50-100 lpm of ground water. As option-1, If the quantity of ground water is sufficient to meet the drinking water requirement of the habitation, a well can be developed and supply the water. If the quantity of ground water from this aquifer is not sufficient, remaining aquifers can be exploited as per the requirement. As

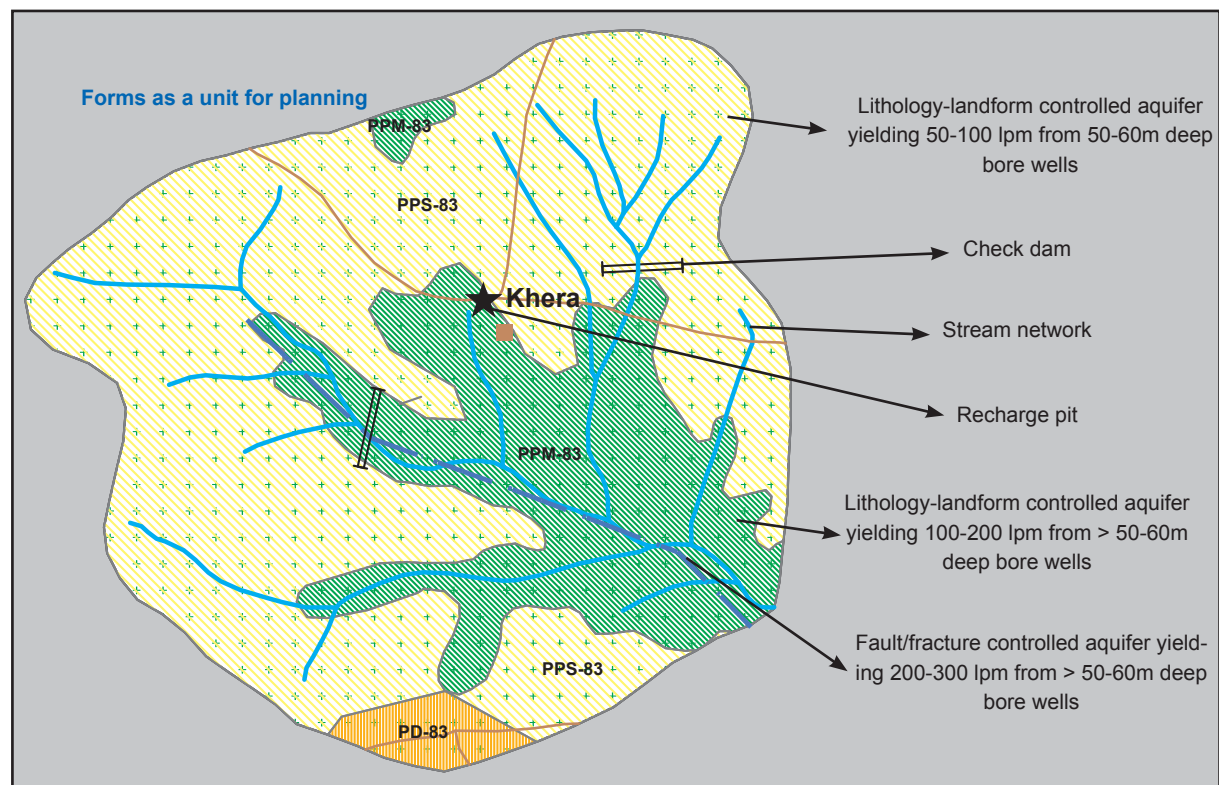


Fig-5.4: Ground water prospects map of a watershed forming a platform for developing habitation-wise drinking water security plan

far as the sustainability of the ground water resource is concerned, there is an over draft of ground water from all the three aquifers. In order to maintain sustainability of the ground water, there are two recharge structures recommended in the watershed. By constructing the recharge structures at these locations the ground water can be artificially recharged and drinking water sources can be made sustainable.

5.4 Other applications of the map

The ground water prospects maps, in addition to ground water data, contain voluminous data pertaining to various themes such as, base map details, hydrology and geology. This thematic data

can be used as an input for studying various other resources. For example, the hydrological data which includes stream / river network, water bodies, springs etc., can be used for identifying surface water sources for supplying drinking water to the habitations.

Whereas the ground water data available in the map can be used as a critical input for ground water resource estimation and budgeting. The hydrogeomorphic units are delineated mainly based on two dimensional data interpreted from satellite imagery. This data can be used for mapping the geometry of the aquifers. The ground water data available in the maps is on 1:50,000 scale. It can be up scaled and used for studying the ground water resource at micro level. NRSC is carrying out multi-resource mapping at cadastral level using high resolution satellite data mainly for panchayat level planning under Space Based Information System for Decentralized Planning (SIS-DP) programme. This project has been sponsored by Planning Commission. The ground water data available in the maps can be used for mapping of ground water resource under this project. The ground water data available in digital form can be organized in to a system so that the data can be modeled to find out solutions to user specific problems. However, in order to use the different datasets under integrated environment, the groundwater data generated under RGNDWM project need to be brought to a standard geo-database format.

5.5 Limitations of the map

The maps prepared under the project serves as a ground water database. It can be used for addressing various issues related to ground water.

However, the maps are prepared by considering both static parameters such as lithology, geomorphology and geological structure as well as dynamic parameters such as rainfall, streams/ rivers, water bodies, canals and well data. The hydrogeomorphic units / aquifers are derived based on the integration of data pertaining to static parameters which remains unchanged and can be used as spatial units for estimating ground water potential from time to time. However, the recharge in each hydrogeomorphic unit / aquifer estimated based on the dynamic parameters and is likely to change over a period of time. Therefore, it needs to be re-estimated from time to time and update the maps accordingly. The users are expected to carry out this exercise and update the information so that the maps can be used continuously.

5.6 Summary of the description on the use of the maps

Utility of the maps in identifying both ground water prospect areas as well as site-specific recharge structures has been explained in detail in the preceding sections of the manual. However, the same is summarized in the form of following sequential steps for quick reference of the users of the maps while implementing the recommendations suggested in the map.

5.6.1 Steps involved in identification of ground water prospect areas

- i. With the help of District Village Map provided in one of the pouches of the manual:
 - a. Identify the topo sheet in which the habitation of interest is falling.
 - b. Based on the topo sheet number identify the relevant ground water prospects map in which the habitation of interest is present from the bundle of maps pertaining to State.
 - c. Locate the habitation of interest on the ground water prospects map by matching the village / habitation names.
- ii. On the map, it is found that the habitation is surrounded by one or more than one aquifers. Study the aquifers that are present in the vicinity of the habitation with reference to quantity of water required for the habitation, yield from the aquifers and distance of the aquifers from

- the habitation. Select one or more than one aquifers along with tentative locations for drilling depending on the analysis considering requirement vs availability.
- iii. Locate the selected aquifers and locations for drilling on the ground by matching the features present on the map with the corresponding features occurring on the ground. Initially, the aquifer in its entirety can be located and later the exact location can be located by zeroing down the area of search within the aquifer boundary. While zeroing down the area, availability of government land within the aquifer boundary can also be considered as a criterion.
 - iv. Initial step of locating of the aquifer on the ground in its entirety can be achieved by matching the geographical coordinates taken from the map with that of the geographical coordinates taken from the ground also.
 - v. In general, carry out follow-up hydrogeological and geophysical survey at the location thus selected to confirm the hydrogeological data provided in the map at the location and to identify exact location for drilling the well.
 - vi. In case of the confirmed fault / fracture controlled aquifers or lithology-landform controlled aquifers where the success rate is reported as high, consider the location for drilling. Resistivity survey may be conducted to pin-point exact location for drilling the well.
 - vii. At the selected location, if the location is falling in lithology-landform controlled aquifer, the type of well to be drilled is to be decided as per the type suggested in the map legend against the respective aquifer in the 7th column; the depth to which the well is to be drilled is to be decided as per the hachuring pattern given on the map at the location and the yield expected from the well can be known from the colour given on the map at the location.
 - viii. If the location is falling in fault/fracture controlled aquifer, the type of the well to be drilled is bore well; the depth to which the well is to be drilled is to be decided as per the hachuring pattern given on the map for the surrounding aquifer and the yield expected from the well is higher than the surrounding aquifer by one class.

5.6.2 Steps involved in identification of locations for site-specific recharge structures

- i. With the help of District Village Map provided in one of the pouches of the manual:
 - a. Identify the topo sheet in which the habitation of interest is falling.
 - b. Based on the topo sheet number identify the relevant ground water prospects map in which the habitation of interest is present from the bundle of maps pertaining to State.
 - c. Locate the habitation of interest on the ground water prospects map by matching the village / habitation names.
- ii. On the map, it is found that the habitation is surrounded by one or more than one recharge structures. Study the location and type of recharge structures in terms of their influence on the existing and proposed drinking water supply wells and their impact on the aquifers surrounding the habitation. Select one or more than one recharge structures depending on the analysis considering requirement vs availability.
- iii. Locate the selected recharge structures on the ground by matching the features present on the map with the corresponding features occurring on the ground. Initially, the aquifer / hydrological feature in which the recharge structure is sited can be located and later the exact

site can be located by zeroing down the area of search within the aquifer / hydrological feature. While zeroing down the area, availability of government land within the aquifer boundary can also be considered as a criterion.

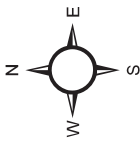
- iv. Initial step of locating of the aquifer / hydrological feature on the ground in its entirety can be achieved by matching the geographical coordinates taken from the map with that of the geographical coordinates taken from the ground also.
- v. Carry out follow-up topographical and hydrogeological survey on the site thus selected to confirm the hydrogeological data vs type of recharge structure and to identify exact location for constructing the recharge structure.
- vi. Develop an appropriate engineering design for the suggested recharge structure using suitable construction material by considering micro-level topographical, geological and hydrological parameters occurring at the site specific to the type of structure.

References

1. Ground water prospects mapping for Rajiv Gandhi National Drinking Water Mission (RGNDWM) - Technical Manual; NRSC; 2008
2. Ground water prospects maps - prepared by NRSC; available with State Government Line Departments; 2000 - till date
3. Village index maps - prepared by NRSC; 2011(source of information-Survey of India)

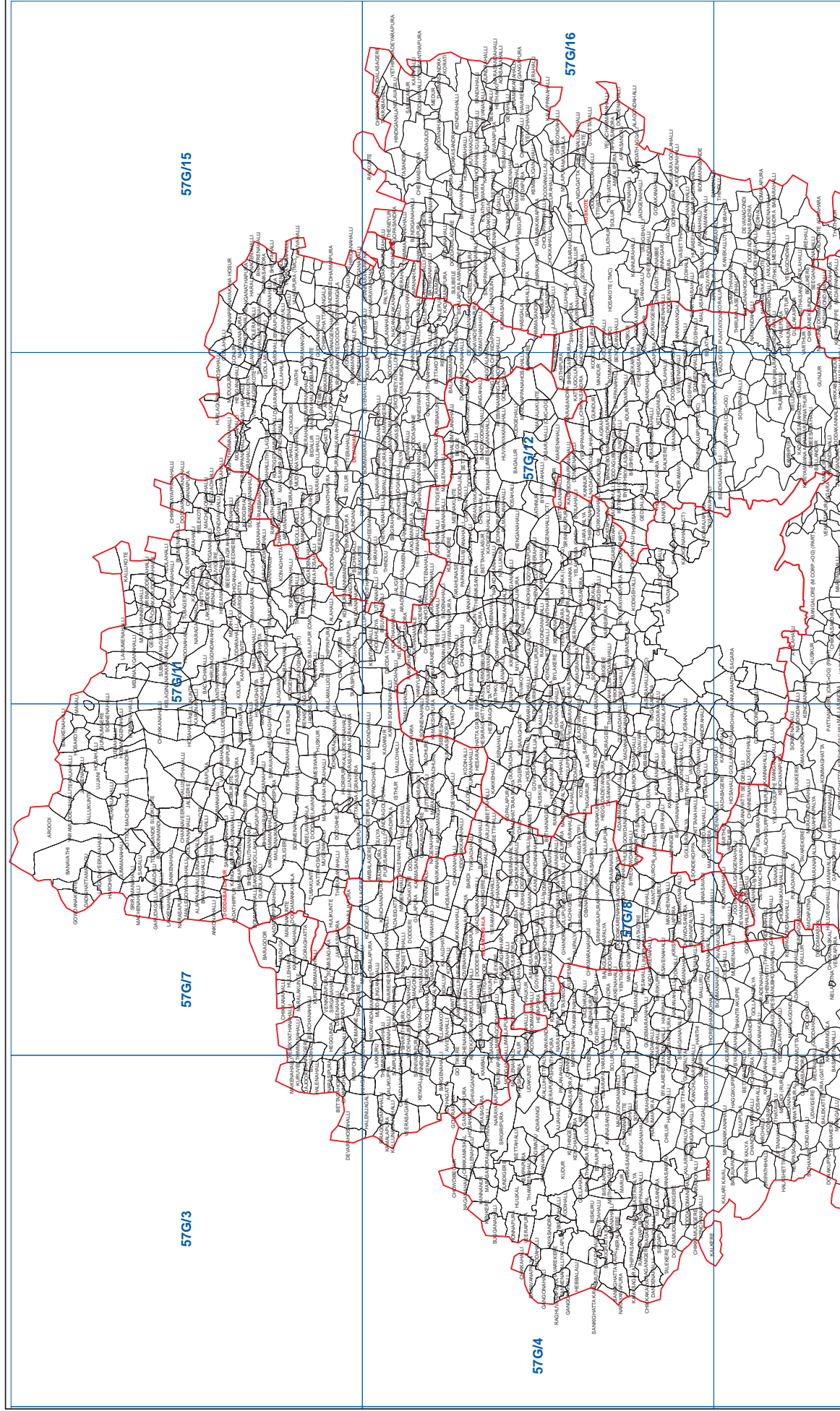
Village Index Map

Bangalore District, Karnataka



Legend

-  50K Grid
-  Taluk Boundary
-  Village Boundary



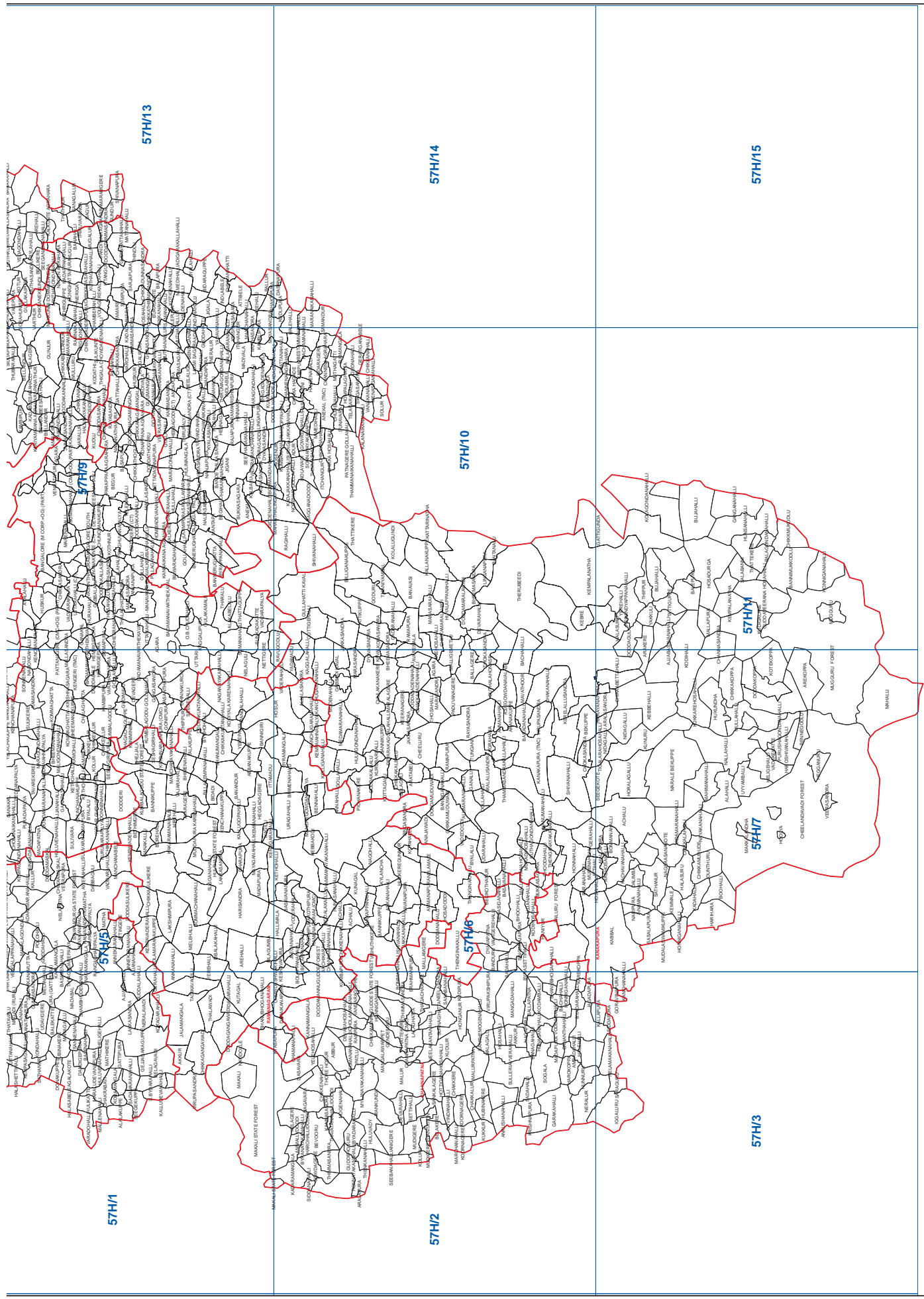
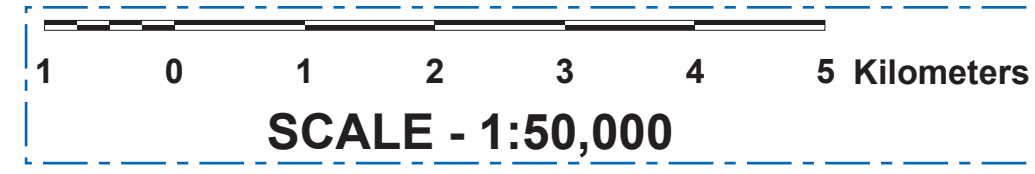


Fig-5.5: A sample village index map pertaining to Bangalore District of Karnataka



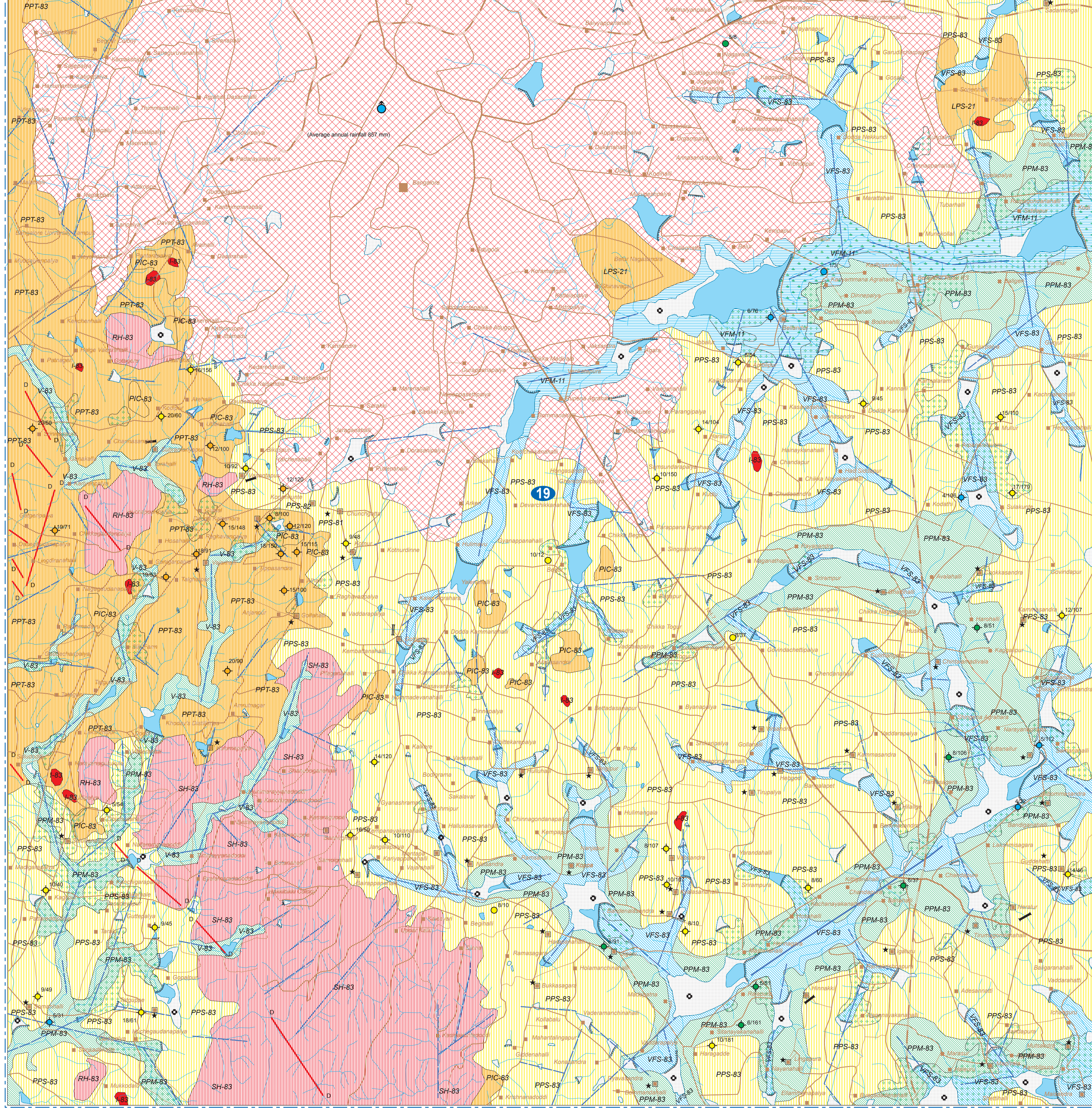
GROUND WATER PROSPECTS MAP

(PREPARED FROM SATELLITE IMAGE INTERPRETATION WITH LIMITED FIELD CHECKS)



MAP SHEET NO. 57H/9

BANGALORE DISTRICT, KARNATAKA



© NATIONAL REMOTE SENSING AGENCY, DEPT. OF SPACE, GOVT. OF INDIA. DATA USED: IRS-1D LISS-3 FCC dated 22 March 2000, GROUND TRUTH & WELL OBSERVATION during March, June 2000 & April 2002. Published Geological maps & Literature. Software Designed & Developed by Hydrology Division, NRSA (AMC version-0)

20 LEGEND

MAP UNIT (HYDROGEO MORPHIC UNIT)	GEOLOGICAL SEQUENCE/ROCK TYPE	GEOMORPHIC UNIT/LANDFORM	DEPTH TO WATER LEVEL (AVERAGE IN METERS)	RECHARGE CONDITIONS	GROUND WATER PROSPECTS	RECHARGE STRUCTURES SUITABLE & PRIORITY	REMARKS (PROBLEMS / LIMITATIONS)	
VFM-11	ALLUVIUM - SAND & SILT DOMINANT (11)	VALLE Y'FILL-MODERATE (VFM) (12-15 m)	2-6 m DW-1	VERY GOOD	LS+WR-FIR	DW BW	6-10 m 25-30 m 150-175 cu m/day 300-400 lpm High P 15-20 DT High Priority	It occurs in southern part over lesser extent. Unconsolidated sediments and weathered gneiss form good aquifer. High potential zone due to recharge from tank and tank irrigated areas. Suitable for further development. Desalination on high priority due to large accumulation of sand.
LPS-21	LATERITE (21)	LATERITE PLAIN-SHALLOW (LPS) (6-9 m)	NO WELLS OBSERVED	LIMITED	WR-FIR	BW	80-100 m 30-40 lpm Low P Nil RP Moderate Priority	More run-off as this zone forms topographic high. Exploitation is minimal as plantations of eucalyptus and casuarina have been developed. Very few habitations. Not suitable for ground water development.
PPS-81	GRANITE (81)	PEDIPLAIN-SHALLOW (PPS) (6-8 m)	10-18 m BW-1	MODERATE	WR-FIR	BW	80-100 m 75-100 lpm Moderate P 5-10 RP/PPT Moderate Priority	Weathered and fissured granite form aquifer. More run-off as it forms topographic high. Better prospects in the vicinity of PPM and VFS.
PPS-82	MIGMATITE (82)	PEDIPLAIN-SHALLOW (PPS) (6-8 m)	10-18 m BW-1	MODERATE	WR-FIR	BW	80-100 m 75-100 lpm Moderate P 5-10 RP/PPT Moderate Priority	Weathered and fissured migmatite form aquifer. More run-off as it forms topographic high. Better prospects in the vicinity of PPM and VFS.
VFS-83	BANDED BIOTITE GNEISS & HORNBLENDE GNEISS (83)	VALLE Y'FILL-SHALLOW (VFS) (8-10 m)	2-6 m BW-4	GOOD	LS+WR-FIR	DW BW	10-12 m 60-80 m 100-150 cu m/day 200-300 lpm Moderate P 20-30 DT High Priority	Loose sediments and weathered gneiss form aquifer. Potential zone due to recharge from tanks and tank irrigated areas. Desalination on high priority due to large accumulation of sand and silt. Suitable for ground water development.
PPM-83		PEDIPLAIN-MODERATE (PPM) (10-12 m)	5-8 m BW-6	GOOD	WR-FIR	DW BW	12-15 m 60-80 m 75-100 cu m/day 150-200 lpm Moderate P 20-25 RP/PPT Moderate Priority	Weathered and fissured gneiss form aquifer. Moderately good potential zone as it lies adjacent to VFM and VFS. Suitable for ground water development.
PPS-83		PEDIPLAIN-SHALLOW (PPS) (6-8 m)	10-18 m BW-21	MODERATE	WR-FIR	BW	80-100 m 75-100 lpm Moderate P 5-10 RP/PPT Moderate Priority	Weathered and fissured gneiss form aquifer. More run-off as it forms topographic high. Better prospects in the vicinity of PPM and VFS.
V-83		VALLEY (V)	NO WELLS OBSERVED	GOOD	WR-FIR	DW BW	12-15 m 60-80 m 75-100 cu m/day 150-200 lpm Moderate P Negligible Not Required	Weathered and fissured gneiss form aquifer. Very good prospects as it receives run-off water from other units. Lineament zones form high potential zones.
PPT-83	PEDIMENT-INSELBERG COMPLEX (PIC)	NO WELLS OBSERVED	15-20 m BW-14	LIMITED	WR-FIR	BW	90-110 m 20-30 lpm Low P Negligible RP/PPT Low Priority	Weathered and fissured gneiss form aquifer. Considerable run-off due to dissection, relief slope and rock out crops. Better prospects in valley portions.
PIC-83	PEDIMENT-INSELBERG COMPLEX (PIC)	NO WELLS OBSERVED	NO WELLS OBSERVED	POOR	WR-FIR	BW	90-110 m 15-25 lpm Low P Nil Not Required	Weathered and fissured gneiss form aquifer. More run-off due to frequent rock out crops. Prospects limited to areas free of rock out crops. Prospects inferred based on PPT-83. Not suitable for ground water development. No habitations.
I-83	INSELBERG (I)	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	Run off zone; Not suitable for ground water development.
RH-83	RESIDUAL HILL (RH)	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	Mainly run off zone; Prospects limited to valley portions only.
SH-83	STRUCTURAL HILL (SH)	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	NO WELLS OBSERVED	Mainly run off zone; Prospects limited to valley portions only.

F - F / - - - - - These are fault / fracture zones, which generally act as conduits for movement of ground water in hard rocks. Along these zones, the yields are significantly higher and wells are likely to be sustainable for longer duration. However, the inferred fractures need to be confirmed by detailed ground surveys.
 D - D / - - - - - These are the dykes, quartz reefs, pegmatites etc. which generally act as barriers for ground water movement.
 N.B. - The depth range and yield range of wells may vary within the unit because of certain inhomogeneities. Fractures / lineaments which are clearly observed / inferred from the satellite image are indicated on the map. There could be some - - - - - observed fractures which also influence the ground water prospects. Locations of the recharge structures shown in the map are tentative. This map is useful for narrowing down the target zones, and exact locations on the ground for wells and - - - - - recharge structures should be identified based on follow-up ground hydrogeological / geophysical surveys.

BANGALORE CITY

16 COMMON MAP INDEX 17 18 21

GROUND WATER PROSPECTS INFORMATION

YIELD RANGE OF WELLS	COLOR CODE	DEPTH RANGE OF WELLS
> 800 LPM	Violet	SHALLOW (< 30 METERS)
400-800 LPM	Indigo	MODERATE (30-60 METERS)
200-400 LPM	Blue	DEEP (> 60 METERS)
100-200 LPM	Green	
50-100 LPM	Yellow	
10-50 LPM	Orange	
Prospects limited to valley portions only (VFS, PPT, etc.)	Red	

HYDROLOGICAL INFORMATION

DESCRIPTION	SYMBOL
CANAL/TANK IRRIGATED AREA	[Symbol]
GROUND WATER IRRIGATED AREA	[Symbol]
RAIN GAUGE STATION (With average annual rainfall in mm)	[Symbol]
RECHARGE STRUCTURES SUGGESTED	[Symbol]
PERCOLATION TANK	[Symbol]
NALA BUND	[Symbol]
CHECK DAM	[Symbol]
RECHARGE WELL	[Symbol]
DESILTING OF TANK	[Symbol]
RECHARGE PIT	[Symbol]
WELLS OBSERVED DURING FIELD VISIT	[Symbol]
YIELD RANGE (IN LPM)	[Symbol]
BORE / TUBE WELL (IN m ³ /day)	[Symbol]
> 800 LPM	[Symbol]
400-800 LPM	[Symbol]
200-400 LPM	[Symbol]
100-200 LPM	[Symbol]
50-100 LPM	[Symbol]
10-50 LPM	[Symbol]
< 10 LPM	[Symbol]

STRUCTURAL INFORMATION

DIPS	BEDDING	SCHISTOSITY/FOLIATION
GENTLE (< 15°)	[Symbol]	[Symbol]
MODERATE (15°-45°)	[Symbol]	[Symbol]
STEEP (45°-90°)	[Symbol]	[Symbol]
SUB-VERTICAL TO VERTICAL (> 90°)	[Symbol]	[Symbol]
ANTICLINE / ANTIFORM	[Symbol]	[Symbol]
SYNCLINE / SYNFORM	[Symbol]	[Symbol]
TRENCH LINE	[Symbol]	[Symbol]
ESCARPMENT	[Symbol]	[Symbol]
LITHOLOGIC / GEOMORPHIC UNIT BOUNDARY	[Symbol]	[Symbol]
FAULT	[Symbol]	[Symbol]
FRacture / LINEAMENT (Inferred)	[Symbol]	[Symbol]
FRacture / LINEAMENT (Observed)	[Symbol]	[Symbol]
DYKE	[Symbol]	[Symbol]
QUARTZ REEF (Confirmed / Inferred)	[Symbol]	[Symbol]
PEGMATITE (Confirmed / Inferred)	[Symbol]	[Symbol]

BASE MAP INFORMATION

SYMBOL	DESCRIPTION
[Symbol]	RIVER / STREAM
[Symbol]	WATER BODY / SPRING
[Symbol]	CANAL
[Symbol]	NATIONAL HIGHWAY
[Symbol]	STATE HIGHWAY
[Symbol]	METALLED ROAD
[Symbol]	OTHER ROAD
[Symbol]	RAILWAY
[Symbol]	CITY / VILLAGE
[Symbol]	HABITATIONS: NOT COVERED (NCV) / PARTIALLY COVERED (PC)
[Symbol]	BOUNDARY
[Symbol]	STATE
[Symbol]	DISTRICT

OTHER INFORMATION
Average annual rainfall is 857 mm.

LOCATION INFORMATION

MAPSHEET INDEX
57G 57H 57I
57J 57K 57L
57M 57N 57O
57P 57Q 57R

ADMINISTRATIVE INDEX
BANGALORE

PREPARED BY
TECHNOLOGY INFORMATICS DESIGN ENDEAVOUR
#19, 9TH CROSS, 6TH MAIN,
MALLESWARAM, BANGALORE - 560 003

TECHNICAL GUIDANCE & QUALITY CHECK
NATIONAL REMOTE SENSING AGENCY
DEPT. OF SPACE, GOVT OF INDIA
BALANAGAR
HYDERABAD-37

PARTICIPATING ORGANISATIONS
1) P.H.E Dept. Govt. of Karnataka
2) G.W. Dept. Govt. of Karnataka
3) Karnataka State Remote Sensing centre
BALANAGAR
4) Central Ground Water Board

METHODOLOGY & PROJECT EXECUTION
NATIONAL REMOTE SENSING AGENCY
DEPT. OF SPACE, GOVT. OF INDIA
BALANAGAR, HYDERABAD

SPONSORED BY
RAJIV GANDHI NATIONAL DRINKING WATER MISSION
MINISTRY OF RURAL DEVELOPMENT
GOVT. OF INDIA, NEW DELHI

- Legend**
- 50K Grid
 - Taluk Boundary
 - Village Boundary

BANGALORE District, KARNATAKA

