DISTRICT GROUND WATER INFORMATION BOOKLET

BHOPAL DISTRICT

MADHYA PRADESH

Ministry of Water Resources

Central Ground Water Board

North Central Region

BHOPAL

2013

BHOPAL DISTRICT AT A GLANCE

S.No.	Items	Statistics	
1.	**General Information**		
	i) Geographical area	2772 km^2	
	ii) Administrative Divisions (As on 2013) Number of Tehsil/Blocks Number Villages	 2/2 1084	
	iii) Population (Census 2011)	2,368,145	
	iv) Average Annual Rainfall	1126.7 mm	
2.	**Geomorphology**		
	1. Major Physiographic Units:	i. Extension of Vindhyan range ii. Extension of Malwa plateau	
	2. Major Drainage:	i. Parwati river & its tributaries ii. Betwa river & its tributaries	
3.	**Land Use**	Km^2	
	a) Forest area:	441.0	
	b) Net area sown:	2320	
	c) Cultivable area:	2032.03	
4.	**Major Soil Types**	Black cotton soil	
5.	**Area Under Principal Crops (June' 2012)**	772.68 Km^2	
6.	**Irrigation by Different Sources**	No.	Area irrigated ($km^{2)}$
	Dug wells	14221	287
	Tube wells/Bore wells	11260	275
	Tanks/Ponds	34	12
	Canals	30	57
	Other Sources		256
	Net Irrigated Area		887
	Gross Irrigated Area)		887
7.	**Number 0f Ground Water Monitoring Wells of CGWB (As on 31.3.2007)**		
	Number of Dug Wells Number of Piezometers	29 4	
8	**Predominant Geological Formations**	Deccan Trap basalts, Vindhyan shales and sandstone	
9	**Hydrogeology**		
	Major Water Bearing Formation	Weathered/vesicular basalt, flow contacts and fractured sandstone.	

	Pre-monsoon depth to water level during 2012 Postmonsoon depth to water level during 2012 Long-term water level trend in 10 years (2003-2012)	5.15-18.4 m bgl 1.24 – 11.61 m bgl (0.08-0.37)(Pre-monsoon) m/year fall 0.02-2.5 (Post-monsoon) m/year rise
10.	**Ground Water Exploration By CGWB (As on 31.3.2013)**	
	No of wells drilled (EW, OW, PZ, SH, Total)	17EW,5 OW, 6 PZ
	Depth Range	30.6 – 309.46 m. bgl
	Discharge	Meager – 10.4 lps
	Specific Capacity	5.36 – 41.53 lpm/m
	Transmissivity	0.27 – 164.7 m^2 /day
11.	**Ground Water Quality**	
	Presence of Chemical constituents more than permissible limit (e.g. EC, F, As, Fe)	Nitrate
	Type of Water	Alkaline
12	**Dynamic Ground Water Resources (2009)**	(MCM)
	Net Ground Water available	327.24
	Gross Annual Ground Water Draft	266.14
	Projected Demand for Domestic and Industrial uses up to 2035	31.46
	Stage of Ground Water Development	75%
13	**Awareness and Training Activity**	
	Mass Awareness Programme Organised Number of Participant: Workshop Number of Participant:	6 More than 500 2 230
	Water Management Training Programme Number of Participant:	7 More than 500
14	**Efforts of Artificial Recharge & Rainwater Harvesting**	
	Projects completed by CGWB	One
	Projects under technical guidance of CGWB	Dugwell recharge
15	**Ground Water Control and Regulation**	
	Number of OE Blocks	Nil
	Number of Semi-Critical Blocks	1
	Number of Notified Blocks	Nil
16	**Major Groundwater Problems and Issues**	Depletion in groundwater level and deterioration of groundwater quality

1.0 INTRODUCTION

Bhopal district, spanning over an area of about 2772 km^2, lies in the central part of the state of Madhya Pradesh. Prior to independence of India, it was a part of Bhopal state, which was founded by Nawab Dost Mohammad Khan in the year 1722. The reorganization of states in November 1956, made Bhopal the capital of Madhya Pradesh State, but it remained the part of Sehore district. In year 1972 Bhopal became the new district under Bhopal commissioner's division. The district is bounded by Guna district on the north, Vidisha district on the northeast, Raisen district on the east and Sehore and Rajgarh district on the southwest and west respectively. The district lies between North latitude $23^o05'$ and $23^o54'$ and east longitude $77^o10'$ and $77^o40'$, falling in Survey of India Topo sheet No. 55 E. Bhopal city is the district as well as state head quarter. Bhopal is well connected with all parts of country by Air, Rail and roads. It lies on Delhi-Bhopal-Mumbai and Delhi-Bhopal-Chennai main railway line. Two national highways NH 12 (Jabalpur – Jaipur) and NH 69 (Kanpur-Dewas) passes from the district. The index map of Bhopal district is shown in figure-1. As per 2001 census, the population of Bhopal district is about 33,26,228 with rural population of about 18,43,510 and urban population of 4,82,718. Thus the district is largely an urban district. For administrative purposes the district is divided into 2 tehsil and 2 blocks. It has one city (Bhopal), one town (Berasia) and 512 villages. The details of administrative units are given in table -1.

Table - 1: Administrative units of Bhopal district, M.P.

S.No	Tehsil	Block	Area ($Km^{2)}$	No of villages	No of city/town
1.	Huzur	Phanda	997.78	225	1
2.	Berasia	Berasia	1424.03	287	1

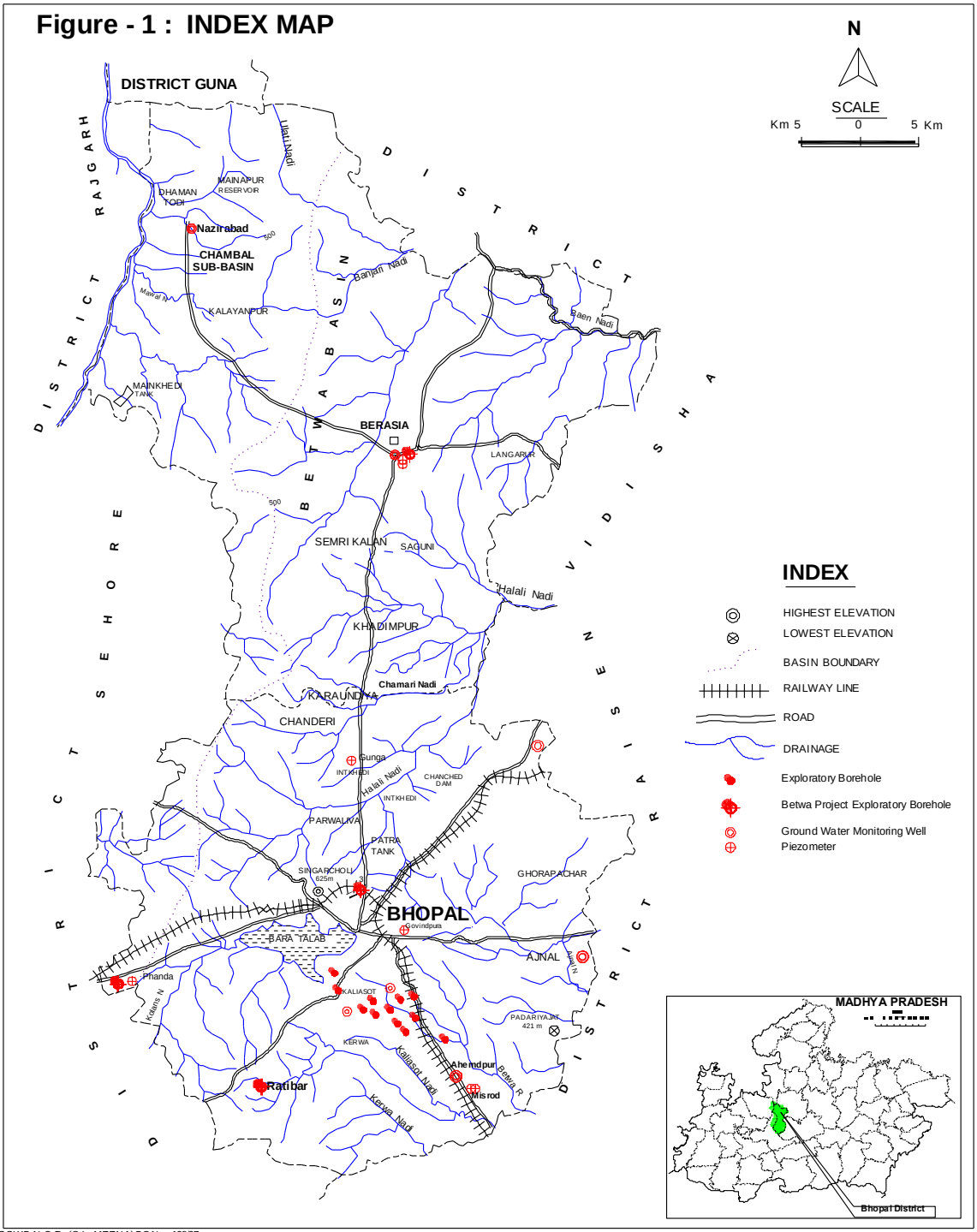
The classification of the total area of the district reflects the extent of development of agricultural activities in the district and also represents the potential of cultivation of the area. The area under different land use and their percentage to the reported area of the district for the year 2006 is given in table -2.

Table-2: Land use pattern of Bhopal district.

S.No.	Type	Area in km^2
1	a) Forest area:	441.0
2	b) Net area sown:	2320
3	c) Cultivable area:	2032.03
4	a) Forest area:	441.0
5	b) Net area sown:	2320

The agricultural activity in Bhopal district is mainly dependent on the monsoon. At present the main source of irrigation in the district are wells and tanks. During the administration of Nawab of Bhopal state, only two minor irrigation schemes (Chanchal dam and Ajnal Pickup weir) were in operation with irrigation potential of 6.59 km^2. After the reorganization of states in 1956 there was a gradual increase in surface water development.

Figure - 1 : INDEX MAP



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Central Ground Water Board (CGWB) ACTIVITES:

- In AAP 2012-13 aquifer mapping project was initiated in parts of Kolhans watershed of Bhopal and Sehore district.
- In the most part of the district, the comprehensive hydrogeological surveys were conducted during Indo-British Betwa groundwater project during 1975-1980.
- Shri Saurabh Gupta, Scientist conducted systematic hydrogeological surveys in district during 1990. Shri. Pratul Saxena, Scientists & Shri. G B Rao, Scientist conducted reappraisal hydrogeological surveys of Bhopal district during 2003-04.
- Under the World Bank assisted Hydrology Project-I, 2 shallow piezometers at Misrod and Gunga and 4 deep piezometers at Misrod, Phanda, Govindpura, and Berasia have been drilled by the CGWB for water level and quality monitoring.
- Under the Indo-British Betwa groundwater project four exploratory boreholes at Berasia, Phanda, Ratibar and Nabibag have been constructed.
- Under the ground water exploration programme of the CGWB, three (Gandhi Nagar, Barkatullah University and GSI office Campus) exploratory wells and eleven deposit wells have been drilled in the district.
- In central sector scheme, groundwater conservation studies have been carried out in WALMI campus near Kaliasot dam and a sub-surface dyke has with monitoring piezometers has been constructed.

Bhopal Water Supply:

Sustainable water supply of desired quality in adequate quantity catering to growing need is one of the main issues of Bhopal city. It includes 56 municipal wards spread over an area of 296 km^2. The population has increased from 1,85,000 in year 1961 to 14,82,718 in year 2001 indicating an increase of 800 % over a period of 40 years. The major requirement of drinking water supply in Bhopal city is met from surface water sources, namely Upper Lake and Kolar reservoir. Besides, more than 400 tube wells and few large diameters dug wells and hand pumps also meet the requirement. In addition, unaccounted privately owned dug wells and bore wells installed in individual house holds, housing colonies, industries and business complexes also cater the requirement. A quantity of approx 241 MLD (108 MLD from Upper Lake + 133 MLD from Kolar Dam) is released from surface water sources and 22 MLD is available from groundwater sources. After accounting for distribution and generation losses the net water supply of 210 MLD is available from surface water sources. The total water supply available from both the sources is 232 MLD against water demand of 350 MLD. Thus, the present water supply falls short of about 120 MLD. There is a proposal to release additional water supply from Kolar reservoir as well as bring the water from Narmada River.

2.0 RAINFALL AND CLIMATE

The climate of Bhopal district is characterized by a hot summer and well-distributed rainfall during the southwest monsoon season. The year can be divided in to four seasons. The winter commences from middle of November and lasts till the end of February. The period from March to about first week of June is the summer season. May is the hottest month of the year. The southwest monsoon starts from middle of June and lasts till end of September. October and middle of November constitute the post monsoon or retreating monsoon season.

The climate of the Bhopal district is classified by the Thornthwait precipitation effectiveness method. It is based on the assumption that total monthly rainfall and temperature determine the climate. The annual precipitation effectiveness of the district is 63.7, which indicate that the climate in the district is humid and forest type vegetation.

The temperature starts rising from the beginning of February and reaching maximum in the month of May. The normal daily mean monthly maximum temperature is 40.7^0C and daily mean minimum temperature is 25.3^0C. The individual day maximum temperature in May goes up to 44^0C. The individual day minimum temperature is recorded 10.2^0C in the month of January. The summer season is the driest period of the year. The humidity comes down lowest in April. It varies between 26 % and 88 % at different time in different seasons. The wind velocity is high during the monsoon period as compared to pre and post monsoon. The wind velocity is highest in June around 18.9 km/hr and lowest is 7.0 km/hr in November.

There are nine rainguage stations in the district. One is maintained by IMD at Bairagarh, one by revenue department at Berasia, one by agriculture department at Bhopal and 6 other by irrigation department. All these stations are having long-term rainfall data. On the basis of Bairagarh and Berasia rainguage stations data, the average annual rainfall of Bhopal district is about 1126.7 mm, while based on IMD station at Bairagarh; the annual normal rainfall of Bhopal is 1260.2 mm. Bhopal receives maximum rainfall during southwest monsoon period. About 92 % of the total rainfall takes place only during the monsoon period. The maximum rainfall (about 39 %) takes place during the month of July. In winter occasional rainfall of about 6 % takes place. During summer only about 2 % of the annual rainfall takes place. Thus, from October to middle of June only about 8 % of the annual rainfall takes place.

3.0 GEOMORPHOLOGY & SOIL TYPES

Bhopal district forms the part of Malwa plateau with generally an undulating topography. The Vindhyan hill range occupies the eastern part of Phanda block, including a major part of Bhopal city. In ancient days the

range was known as Vindhyyandri, forming the southern boundary of the Madhy Desha or middle region. The highest elevation of 622 m amsl in the district is recorded at Singar Choli, a hillock of Vindhyan range near Bhopal airport. The lowest elevation in the district is recorded about 421 m amsl near village Padariya Jat in Phanda block.

The district covers part of two river sub-basins. Betwa river sub basin covers 82 % of the area and lower Chambal basin covers 18 % area of district. The district is drained by river Betwa with its main tributaries like Kaliasot, Kerwa, Ajnal, Bah, Halali and Kolans. River Parwati forms the northwestern boundary of the district and its main tributaries Mawal and Ulti drain the area. The drainage patterns of district are shown in figure-1 and summarized details of catchments are given in table-3.

Table-3: Summarized data of main drainage in Bhopal district.

S.No.	Name of river	Catchments area in Bhopal district (Km^2)	% Area of basin in Bhopal district	Length of river in Bhopal district (Km)
A. Betwa Basin				
1	Kaliasot	18.16	8.2	27
2	Kerwa	12.75	5.7	30
3	Ajnal	17.62	7.9	24
4	Halali	68.56	30.90	33
5	Bah	66.75	30.10	37
6	Kolans	36.52	16.15	19
7	Betwa main River	1.64	0.7	-
B. Lower Chambal Basin				
8	Mawal	11.0	22.5	29.00
9	Ulti	6.10	12.5	16.00
10	Parwati main river	31.90	65.0	-

Almost three-fourths area of the district is covered with black cotton soils forms by the weathering of basaltic rocks. The rest part of the district area is covered with yellowish-red, mixed soils derived from sandstone and shale. The alluvial soils are found along the river courses. The higher elevations i.e. the hilly regions have a cover of murum, which is made up of small rounded pieces of weathered basalts. The Vindhyans have a thin cover of sandy loams. The alluvium is derived from hill slopes by numerous streams and watercourses.

4.0 GROUNDWATER SCENARIO

4.1 Geology

The general geological successions in the district are given in table-4.

Table-4: General geological successions of Bhopal district.

Age	Stratigraphic Unit	Lithology
Quaternary to Recent		Alluvium and Laterite
---------- Unconformity ----------		
Upper Cretaceous to Lower Eocene	Deccan trap	Basalt
Upper Proterozoic	Vindhyan Super Group (Bhander Group)	Sandstone and shale

The investigations conducted by CGWB during Indo-British Betwa Groundwater Project have brought out the regional structures of Betwa basin of Bhopal district. A series of alternating synform and antiforms with their axial trace running in ENE-WSW direction have been delineated in the upper Betwa basin of district. In central part of Bhopal district a synform can be seen at northern boundary of Phanda valley running in NW-SE direction.

4.2 Hydrogeology

The general hydrogeological conditions of the district are depicted in figure-2 and formation wise settings are discussed below.

4.2.1 Vindhyan Super Group

The rocks of the Vindhyan Super Group are exposed in the southern and southeastern part of district, including the area in and around Bhopal city. These rocks form NW-SE trending ridges and small isolated hillocks (inliers). The Upper Bhander sandstone is reddish brown to purple in colour, massive, medium to coarse grained, exhibiting well-defined bedding with plenty of current bedding and occasional ripple marks. The strike of the formation varies from NNW-SSW to N-S with dips varying from nearly horizontal to 5^0 in eastern direction. The sandstone is highly jointed with four sets of prominent vertical joints in NW-SE, WNW-ESE, NE-SW and NNE-SSW directions and nearly horizontal bedding joint. Because of its compact nature the Bhander sandstone is poor repository of groundwater. In sandstone, the joints and fractures control the occurrence of groundwater in areas located in topographical depression and adjacent to surface water bodies. The soil and weathered profile developed on the Vindhyan is generally thin and as a result groundwater occurs at shallow depth under unconfined conditions in the areas where the rock is jointed, fractured and weathered. The Vindhyan rocks underlying the weathered basalts in topographical depressions are found often to form moderate aquifers. The surface water runoff along the slopes of hillocks formed by Vindhyan inliers is recharged to the deeper jointed and fractured sandstone through overlying cover of weathered basalt.

4.2.2 Deccan Trap

The Deccan trap basalts occur in the district as lava flow infillings in the valleys of pre-existing Vindhyan topography. The Vindhyan sandstone show `baking effect' due to the hot lava coming in contact with sandstones as seen

near Bhadbhada. The lava flows are mostly `$P_{ahoehoe}$' character and less of `A_a' character. The individual lava flow range from 10 to 30 m in thickness and consist generally of two units i.e. the upper most vesicular/amygdaloidal basalts with their weathering top portion often overlain by grey or red clay and the massive thin amygduler layer (with pipe emaygdulars) towards the bottom.

Shallow groundwater occurs in the weathered, vesicular, jointed and fractured basalt under unconfined conditions. In areas where the weathered basalt layer is extensive a continuous phreatic aquifer can be traced to some distance. However, due to low permeability of weathered basalts the aquifer sustains limited groundwater withdrawal, mainly through open wells. On higher ground the weathered basalts may be thin or even absent. In such condition groundwater occurrence is restricted to the joints and fractures. The groundwater in Deccan traps at deeper levels occurs under semi-confined to confine conditioned, at the different lava flow contacts, at Deccan trap and underlying Vindhyan contact or in the deeper jointed/fractured and vesicular amygdular basaltic horizons.

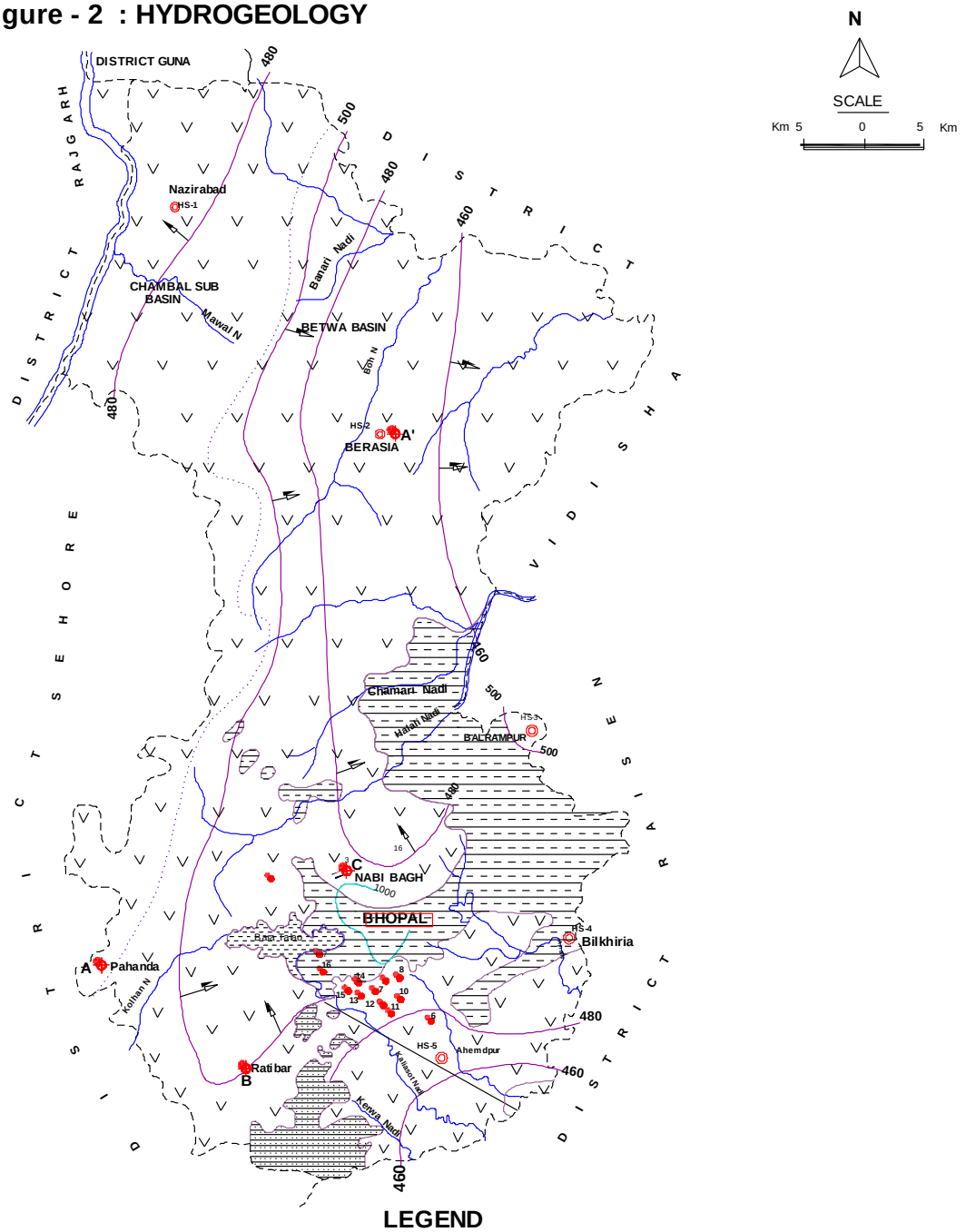
The thickness of the individual aquifers varies from a few centimeters to a few meters and is generally restricted in their regional extent. The recharge to the deep aquifers takes place from the phreatic aquifers through deep joints, faults and contact zones. The red bole horizons (clay) generally act as semi confining or confining layers for the deeper aquifers.

4.2.3 *Alluvium and Laterite*

Localized patches of alluvium cover occur along the banks of major and minor rivers and streams in the district. In general it is difficult to differentiate between alluvium and product of black cotton soil underlain by yellow clay with kankar. In Misrod valley the thickness of this alluvium/colluvium reaches up to 30 m. Groundwater under confined condition is reported in Misrod area.

Laterite capping on top of Deccan trap basalt are seen in localized patches like west of Berasia and near Bilkhiria on Raisen road. The rocks are generally bouldery in nature, highly ferruginous and weathered to yellowish red soil.

Figure - 2 : HYDROGEOLOGY



LEGEND

AGE	LITHO-STRATIGRAPHIC UNIT	LITHOLOGY	WATER BEARING HORIZONS	GROUND WATER POTENTIAL (Yield-lps)
Upper Cretaceous to Eocene	Deccan Trap	Basalt	Weathered basaltic, jointed & fractured horizons, inter flow contacts and vesicular basalt not filled with secondary mineral	Moderate Yield propects (Generally 1 to 5)
Un Conformity				
Upper Proterozoic	Vindhyans	Sandstone & Shale	Bhander Group — Upper / Lower: Restricted to weathred residium, Joints & fractured in sandstones located in topographic depressions	Limited Yield propects (Generally less than 1 l.p.s. upto 5 l.p.s in shallow tubewell wells located at favorable sites)

HYDROGEOLOGICAL FEATURES
- Water table contour,mamsl
- Electrical conductivity Contour (in us/cm at 25° c
- Direction of ground water flow
- Major Lineament

HYDROLOGIC FEATURES
- River & streams
- Surface water divide

GROUND WATER STRUCTURES
- Exploratory Borehole
- Betwa Project Exploratory Borehole
- Ground Water Monitoring Well

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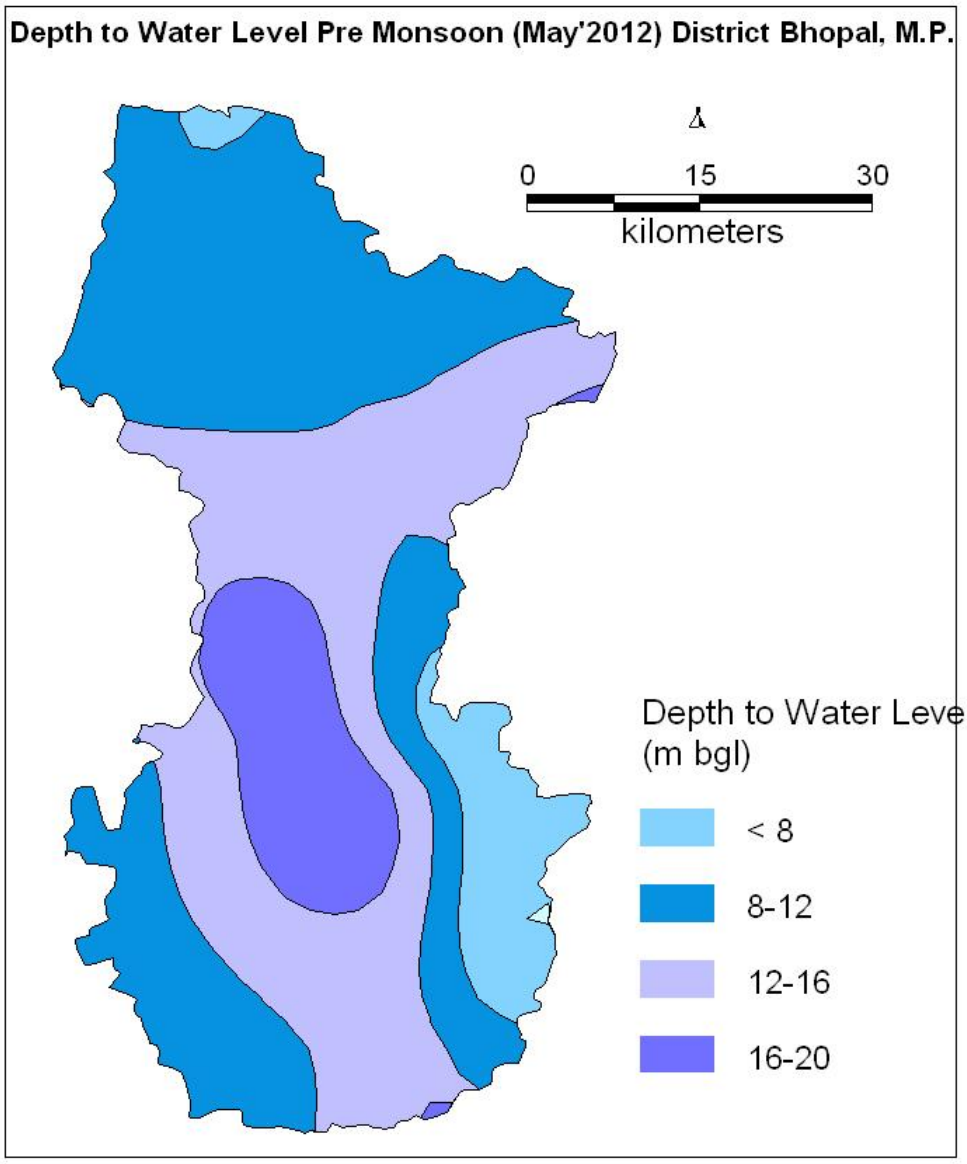
4.3 Ground Water Levels

Variation of groundwater levels in an area is an important component of hydrological cycle because it is a physical reflection of aquifer systems. As the change in groundwater level is directly related to groundwater balance and its continuous records provide direct information of subsurface geo-environmental changes due to withdrawal of groundwater. To monitor the seasonal and annual change in quantity and quality of groundwater, CGWB has established 24 Ground Water Monitoring dugwells and 4 Peizometers in entire Bhopal district. The monitoring of groundwater levels in these wells is being carried out by CGWB during the month of May, August, November and January. The brief details of groundwater level in Bhopal district for the year 2012 are being discussed below:

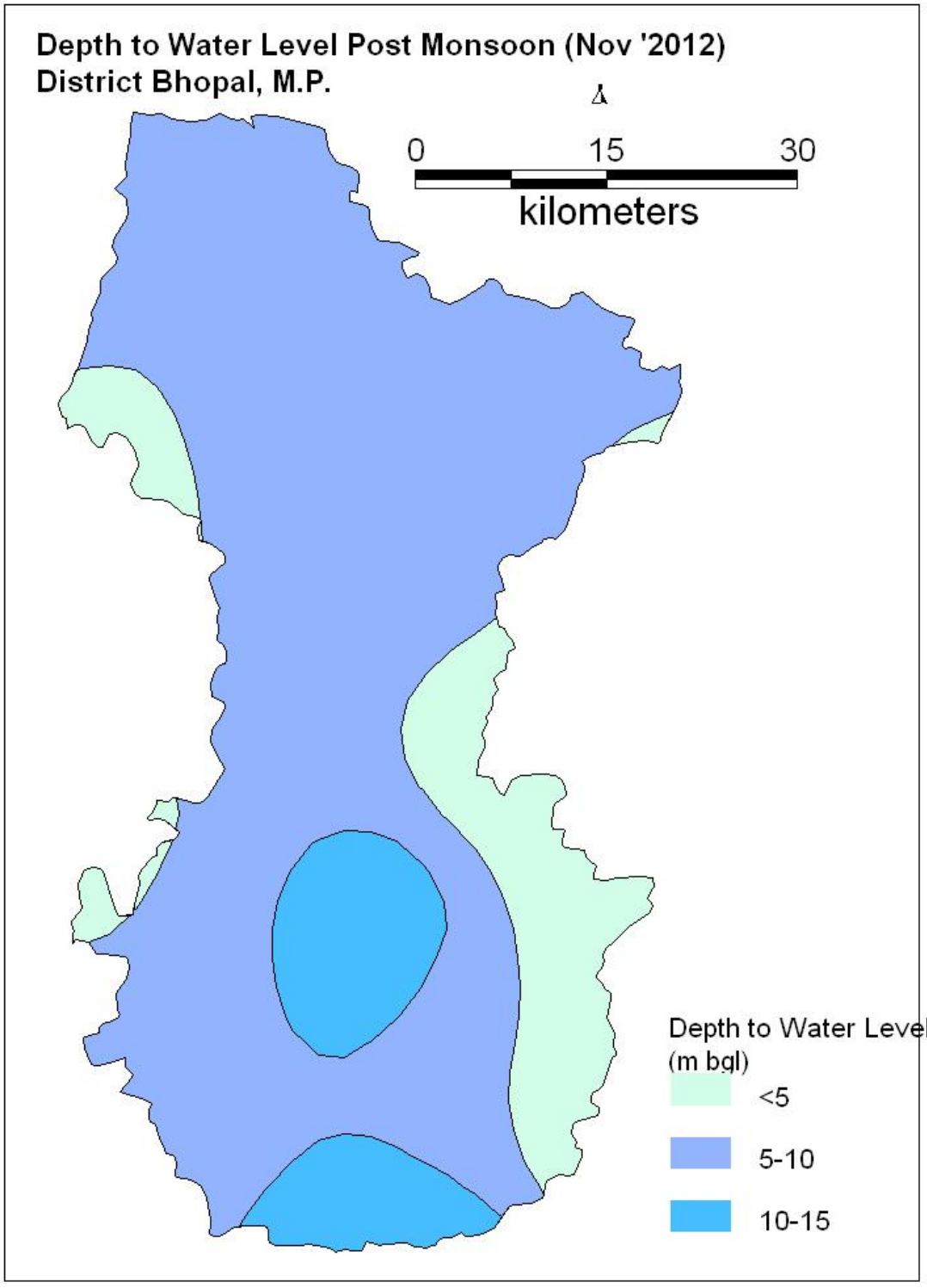
4.3.1 Pre-monsoon (May 2012)

The pre-monsoon depth to water level (figure-3) in Bhopal district ranges between 5.15 m bgl at Balrampurghati to 18.4 m bgl at Islamnagar in Phanda block. The most part of both blocks of the district have water level in the range of 10-18 m bgl during the pre monsoon. The northern part of district in Berasia block and eastern part of district in Phanda block have the water level in the range of 5-10 m bgl.



4.3.2 Post-monsoon (November 2012)

During post-monsoon period of the same year, November 2012, (figure-4) the water level ranges from 1.24 m bgl at Balampurghati to 11.61 m bgl at Islamnagar. It is observed that in most part of the district the water level lies between 5 to 10 m bgl during this period. In the central part of Phanda block the water level lies between 10-13 m bgl. However in the eastern part of Phanda block and southeastern part of Berasia block the water level lies between 0.5-6 m bgl.



4.3.3 Water level fluctuation (May 2012 to November2012)

A comparison of pre-monsoon water level data with the post-monsoon water level data reveals that there is rise of water level in entire district during post-monsoon (0.02-2.5 m/year rise) while fall during pre-monsoon(0.08-0.37m/year fall).

4.4 Aquifer Parameters

The exploratory drilling has been carried out in areas occupied by Deccan Traps underlain by Vindhyan shale and sandstone. In Deccan Traps, the vesicular, weathered and fractured basalt form the aquifers while in Vindhyans, fractured sandstones and shales forms aquifer. These exploratory wells have been drilled down to the maximum depth of 309.46 m bgl and their yields have been recorded maximum up to 10.4 lps. The piezometers were restricted to the depth range of 30 m, 60 m, 90 m and 120 m bgl only. The specific capacity of bore wells has been determined in the range of 5.36 to 41.53 lpm/m of draw down.

4.5 Ground Water Resources

Dynamic dround water resources of the district have been estimated for base year -2008/09, on block wise basis. Out of 2,77,237 ha of geographical area, 2,64,8400 ha (96%) is ground water recharge worthy area and 12,437 ha (4%) is hilly area. There are two number of assessment units (block) in the district which fall under non-command sub unit. Berasia block of the district is categorized as safe block (safe in 2003/04), and highest stage of ground water development is computed as 93 % for Phanda Block as Semi critical (same in 2003/04). The net ground water availability in the district is 32,724 ham and ground water draft for all uses is 26,214 ham, making stage of Ground water development 81% (71 % in 2003/04) as a whole for district. After making allocation for future domestic and industrial supply for next 25 years, balance available ground water for future irrigation would be 5,253 ham. The Net annual ground water available in the Bhopal district and ground water draft from all uses for both the blocks is shown in table-5.

Table-5: Ground Water Resources & Stage of Development in Bhopal District.

S. No.	District/ Assessment Unit	Sub-unit Command/ Non-Command/	Net Annual Ground water Availability (ham)	Existing Gross Ground water Draft for Irrigation (ham)	Existing Gross Ground water Draft for Domestic & Industrial water Supply (ham)	Existing Gross Ground water Draft for All uses (ham)	Provision for domestic, and industrial requirement supply to next 25 year (2033) (ham)	Net Ground water Availability for future irrigation development (ham)	Stage of Ground water Development (%)	Category
	Bhopal									
1	Barasia	Command								
		Non-Command	16189	10421	773	11194	1098	4670	69	Safe
		Block Total	**16189**	**10421**	**773**	**11194**	**1098**	**4670**	**69**	Safe
2	Phanda	Command								
		Non-Command	16535	13905	1516	15420	2047	583	93	Semi Critical
		Block Total	**16535**	**13905**	**1516**	**15420**	**2047**	**583**	**93**	Semi Critical
		District Total	**32724**	**24326**	**2289**	**26614**	**3146**	**5253**	**81**	

4.6 Ground Water Quality

Ground water quality in Bhopal district is assessed annually by CGWB on the basis of analysis of ground water samples collected from 5 No. of hydrograph stations in the district. On the basis of the data for the year 2011, the water quality is described as follows:

Quality of Ground Water for Drinking Purpose: The pH values of all the water samples varied in between 7.40 to 7.70 hence proved alkaline in nature and were within permissible limit (6.5 to 8.5) as described by BIS (IS: 10500: 2009). The EC values were found to be in the range of 504 and 1239 µS/cm at 25^0 C (Islamnagar, highest) and were on the side of permissible limit (3000 µS/cm at 25 ^{0}C) as described by BIS (IS: 10500: 2009). The anion chemistry shows that the chloride concentration ranged 25 - 167 mg/l in the area surveilled and all locations reported to have chloride concentration within the desirable safe limit of 250 mg/l as set by BIS (IS: 10500:2009).. The concentration of NO_3^- exceeding 45 mg/l (BIS, IS: 10500: 2009) were reported in two wells with highest as 60 mg/l of Islamnagar. This higher concentration of NO_3^- can be attributed from anthropological sources. A scrutiny of data shows that Islamnagar's well recorded fluoride concentration (1.80 mg/l) more than 1.5 mg/l of BIS (IS: 10500: 2009 permissible limit

Quality of Ground Water for Irrigation: The chemical quality of water is an important factor to be considered in evaluating its suitability for irrigation purpose. The parameters such as Electrical conductance (EC), Sodium adsorption ratio (SAR), percent sodium (% Na), and Residual sodium carbonate (RSC) are used to classify the water quality for irrigation purpose. A diagram for classifying waters for irrigation purpose was suggested by the U.S. Salinity Laboratory in 1954. The plot of U.S. Salinity Laboratory diagram suggested that wells of Islamnagar and Nagirabad were grouped under C_3-S_1 *(High Salinity & Low Sodium)* class. This water can be used for irrigation purpose applying restriction on drainage, whereas all other wells (60%) named Bilkheria, Balrampurghati and Berasia were observed under C_2-S_1 *Class (Medium Salinity & Low Sodium)* which means that these waters can be used for all type of crops on soils of low to high permeability.

4.7 Status of Ground Water Development

Ground water is the main source for drinking and irrigation in the Bhopal district. About 60% of irrigation in the district is from groundwater, though the level of irrigation in the district is only 28%. The total number of dug wells and tube wells in the district during 2011-12 were 14221 and 11260 respectively. On the drinking water front, Bhopal city have water supply from surface water (Upper Lake and Kolar Dam), while the outskirts of Bhopal city is totally dependent on groundwater. 511 villages in the district have tube wells for water supply. It is estimated that there is a steady rise in ground water development in the district. During the year 2009, the stage of groundwater development in the district was 81%, which has increased considerably from 2004 estimates.

5.0 GROUND WATER RELATED ISSUES & MANAGEMENT STRATEGY

It is felt that the over exploitation, indiscriminate development of groundwater, anthropogenic and irrigation practices have led to many groundwater related problems, which need proper management of groundwater resources. These problems are being discussed below.

5.1 Groundwater Depletion

It is observed in Bhopal district, that the stage of groundwater development is quite high (75%). In certain areas the withdrawal of groundwater is more than recharges causing depletion in groundwater level. It is observed that the fluctuation in water level is mainly due to rainfall and withdrawal of groundwater. The study on the long term analysis of water level, conducted by CGWB, indicate that water level in Bhopal district have shown a steady decline of 0.08 to 0.37 m during past one decade. The incidence of rainfall remaining more or less same in the period of question the only possible reason for the decline in groundwater level appears to be over development of groundwater resources indiscriminately through ever increasing number of tube wells tapping the unconfined aquifers for agricultural, industrial and domestic uses. To remedy the ill effects, the following steps are required to be taken for effective groundwater management in Bhopal district.

5.1.1 Groundwater recharge

Due to fast industrialization and urbanization in Bhopal district, there is a reduction in open green areas resulted in substantial decrease in natural recharge to groundwater. Also, the encroachment of drainage system has caused reduction in percolation of rainwater to the groundwater thereby affecting the natural recharge. It is reported that huge amount of surface water available during rainy season goes as runoff. Hence it can be harnessed through suitable artificial recharge techniques to groundwater. Construction of various suitable artificial groundwater recharge structures will result in augmentation of the groundwater aquifers and prevent further decline of groundwater level. As the area is urban, the roof top rainwater harvesting technique should be adopted in a big way. As the geology of the area along with climatological and pedalogical parameters provide the hydrogeological environment which governs the groundwater recharge, modern techniques like remote sensing and geophysics should be applied for finalization of location, extent and design of artificial groundwater recharge structures.

5.1.2 Water conservation

It is evident that to solve the problem of depletion in groundwater level, it is necessary that the groundwater withdrawal should be reduced substantially. Some of the options available are:

5.1.2.1 Recycling of water:

Due to limited groundwater resources and increased demand of water there is a need of recycling of water for its conservation. The treated sewage water can judiciously be utilized to reduce stress on exploitation of groundwater for various purposes including domestic, industrial and horticultural needs.

5.1.2.2 Change in cropping pattern:

In last few decades the cropping pattern in Bhopal district has changed substantially. In some parts of district, the farmers have started multi crop cultivation due to profitability which will caused extensive development of groundwater resources. There is a need to change the cropping pattern in the area and adopt cultivation of those crops, which require less irrigation.

5.1.2.3 Change in irrigation policy and power pricing

It is observed that in many parts of Bhopal district the complete irrigation is being done through flooding. As the district is covered with hard rock terrain and is water scare, the flooding practice of irrigation requires change. Sprinkler and drip irrigation should be adopted in the area wherever feasible. In this regards the government should come forward and provide infrastructure and other benefits. In most parts of district the irrigation is being done through dug well and tube wells using power pump. Rates of power for tube well irrigation are irrational and require modification. There should be no free power for irrigation so the consumers should take due cares for its economic and judicious use. Instead of flat rates, metering may be introduced.

5.1.2.4 Mass awareness program

The management of groundwater resources cannot be successful without public participation. It requires educating the public regarding judicious use of water. To make the public aware, it is necessary to educate the people through mass awareness program at grass root level and impart training on rainwater harvesting and artificial recharge techniques for groundwater augmentation.

5.1.2.5 *Groundwater regulation*

As the groundwater condition in Bhopal district is in alarming stage, groundwater regulation may be enforced for its judicious exploitation and use.

5.2 Groundwater Pollution

Due to increasing industrialization and fast population growth in Bhopal district, anthropogenic activities have led to pollution of groundwater in certain areas. The main sources of pollution are domestic and municipal waste, agricultural practices and industrial activities. Most of the localities/villages in Bhopal district do not have proper sewage treatment system; the groundwater gets polluted with variety of nutritional constituents and pathogenic microbes.

Use of various chemical fertilizers and pesticides has led to increase of nitrates, phosphates and other organic component in groundwater. Untreated effluents discharged in/on ground has caused increased level of heavy metals. Some organic compounds have also led to deterioration of quality of groundwater.

5.2.1 *Action Plan*

It is fact that the groundwater pollution in the area increasing day by day there is a need to take up the comprehensive groundwater pollution studies in the Bhopal district township. It is necessary to initiate measures to control further groundwater pollution. Dilution of pollutant concentration through groundwater recharge can be effective to mitigate the hazards of high concentration of chemical constituents. It is also desirable to formulate water supply schemes utilizing such water for purpose other than drinking.

6. AWARENESS & TRAINING ACTIVITY

Central Ground Water Board, North Central Region, Bhopal is organizing several Mass Awareness Programme (MAP) and Water Management Training Programme (WMTP) in the different parts of Madhya Pradesh. In this regard several MAP and WMTP have been conducted in Bhopal district also.

6.1 MAP and WMTP by CGWB

Since year 2000, 4 MAP and 6 WMTP have been conducted in Bhopal district. First MAP was conducted at Paryawas Bhawan on 11th October 2000. More than 100 participants were participated in the programme. On 02.07.2002 a MAP was organized at Hotel Lake View Ashok for various agencies working in the field of groundwater. A MAP through quiz competition was organized for school children at Kendriya Vidyalaya No.1 on 29/09/2003. On 29/03/2005 a MAP was organized for farmers of Raisen district at RRL, Bhopal.

The first WMTP was conducted on 14th February at Paryawas Bhawan. More than 50 participants from various Govt. department and NGO's were trained. During 16-18th March, about 50 officers and staff members of National Museum of Man, Bhopal were trained for various processes and techniques of artificial recharge to groundwater and rainwater harvesting. A groundwater week was observed during 01-05th February 2005 at Resources Development Institute (RDI). More than 50 NGO trainees were trained. A groundwater rally and painting competition for school children was also organized. On 28.03.2005 a WMTP cum workshop was organized at RRL, Bhopal. A WMTP, especially for NGOs was organized on 3rd March 2006. During 01-02nd December 2006 a 2 days WMTP was organized for the various NGO groups working with Water Aid India.

Two regional workshop related to groundwater related activity of Madhya Pradesh have been organized at Bhopal during 2008-09 and

2012-2013.

6.2 Participation in Exhibition, Mela, Fair etc

During the visit of Hindi Sansadiya Karya Smiti to Bhopal an exhibition was related to groundwater was organized at Hotel Lake View Ashok on 29.07.2005.

During 15-20th May 2002 a stall was installed at Mela at Bittan Market Bhopal. Various posters explaining the Rainwater Harvesting, Artificial recharge to groundwater and groundwater pollution was demonstrated to visitors. A one-month exhibition was organized at Bhopal Mela during 24.12.2003 to 25.01.2004. Various working models and posters explaining the Rainwater Harvesting, Artificial recharge to groundwater, geophysical surveys and groundwater pollution were demonstrated to various visitors.

7.0 RECOMMENDATIONS

I. Bhopal district is presenting a sensible picture from ground water point of view. Though, presently ground water is meeting the most water needs of the district but it may not go very long in future. The average water levels of the district are deep, the decadal fluctuations and the long-term trends are showing a decline, and the water balance left is limited. The population and progress coupled with poor aquifers are responsible for this alarming situation. Thus special caution is to be observed while developing this natural resource.

II. The groundwater development in Bhopal district, both for irrigation and domestic purposes, is being done on need basis without proper backup of scientific investigations. Some times failure of monsoon led to crisis of even drinking water in district. A serious thought should be given to plan future development of groundwater on scientific lines. For a planned and coordinated development of groundwater resources it is essential that detailed hydrogeological, remote sensing and geophysical investigation should be carried out before taking decision on finalization of sites for drilling wells for irrigation and domestic use. The lithological details along with aquifer wise yield records should be maintained for future inferences.

III. The groundwater resource evaluation for year 2011 indicates that the stage of groundwater development in district has reached to 75% (79% and 72% in Phanda and Berasia block respectively). The Net annual ground water available in the Bhopal district is 372.66 MCM and draft from all uses is 280.75 MCM, Net ground water available for future irrigation use is 83.36 MCM only. Thus it has become imperative for further detailed hydrogeological investigation in district for water balance studies making watershed as a unit.

IV. Bhopal district is mainly a hard rock area and the decision for the type of groundwater structures for groundwater development is dictated by local

hydrogeological situation. Figure-5 shows the areas recommended for different type of groundwater structure for groundwater development in Bhopal district.

a. In areas of phreatic aquifers with low permeability large diameter dug wells is the only suitable groundwater structure. The dug well should be located as for as possible in topographic depressions, nearer to rivers and streams and if possible nearer to zone of structural disturbances. In Deccan trap areas of the district, instead of increasing the diameter of dug wells drilling of horizontal bore into the dug well should be preferred to increase the yield of dug well.
b. In certain areas of district where dug well do not penetrate fully to the aquifer, it is recommended that dug cum bore wells may be constructed.
c. It is observed that shallow tube wells at the base of Vindhyan hillocks, in a narrow belt covered by the weathered profile of Deccan trap basalts, are generally successful. The Deccan trap/Vindhyan contact and joints/fractures in Vindhyan sandstone are productive and should be tapped.

d. The studies under Betwa groundwater project have indicated an average yield of 60 m deep tube well is about 120 lpm and for every 60 m drilled below this depth, the average additional yield is only 20 lpm. This analysis shows that it is more economical to construct shallow tube wells. In the areas where the thickness of Deccan trap exceeds 60 m and the shallow aquifers are not promising, effort can be made to construct deep tube wells penetrating the maximum thickness of Deccan trap.
e. As the Intertrappean are present between two flows and are collapsible in nature, telescopic drilling should be adopted for screening/casing the collapsible strata to increase the longevity and yield of boreholes.
f. In view of the limited regional extent of joints/fracturing, it is possible to miss a good water bearing horizons in a small diameter borehole during the drilling. It is recommended that technique of hydro-fracturing/bore blasting should be tried to enhance the yield of boreholes.
g. For wells constructed for drinking water it is much more important to ensure that the intake section of tube well is not directly in connection with pollution from ground surface.

V. It is observed that in most part of the district there is high fluctuation in depth to water level during pre and post monsoon period. Also, there is substantial surplus monsoon run off going as unutilized needs to be conserved through artificial recharge techniques. In order to get sustainable yield from groundwater structures the need for augmentation of groundwater resources through artificial recharge structure is imperative. Artificial Recharge practices in rural areas should be taken up earnestly to improve the ground water quantity and quality. The selection of sites should be done on scientific basis by conducting hydrogeological and geophysical investigations.

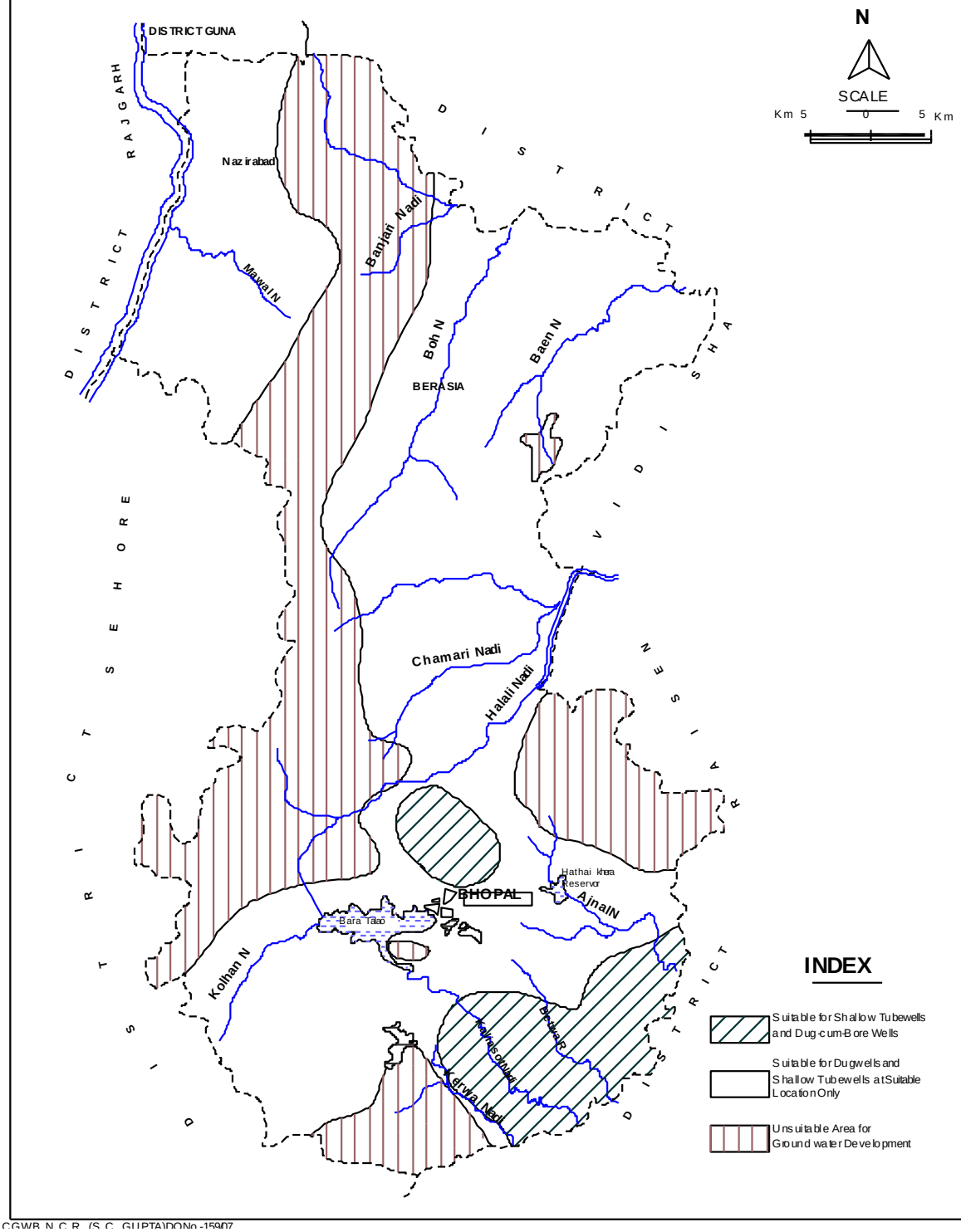
VI. The Roof Top Rainwater Harvesting technique has wide scope in the areas covered with weathered basalt. In Vindhyan rock formation, tube wells can be used for this purpose. Roof top rainwater harvesting should be made mandatory considering the water scarcity in urban areas. This would mitigate the situation.

VII. Unscientific use of fertilizer/pesticides for agriculture and disposal of untreated industrial effluents through unlined drain in most of the industrial areas of district will be very dangerous for groundwater quality in near future. There is a urgent need to control such type of activities to check the groundwater pollution.

VIII. The deforestation of forestland to accommodate the population growth causes heavy run off and insufficient subsurface recharge to groundwater storage in foothill zone. A forestation programme in such areas needs to be taken up. This would not only check soil erosion and improve the environment but also conserve surface runoff and recharge the phreatic aquifers in the area.

IX. Change in cropping pattern is another measure, which will relieve the situation. Presently Soya bean crop is being grown in large areas, which has a high water requirement. There is a need to change the cropping pattern in the area and adopt cultivation of those crops, which require less irrigation.

Figure - 5 : RECOMENDED AREA FOR GROUND WATER DEVELOPMENT



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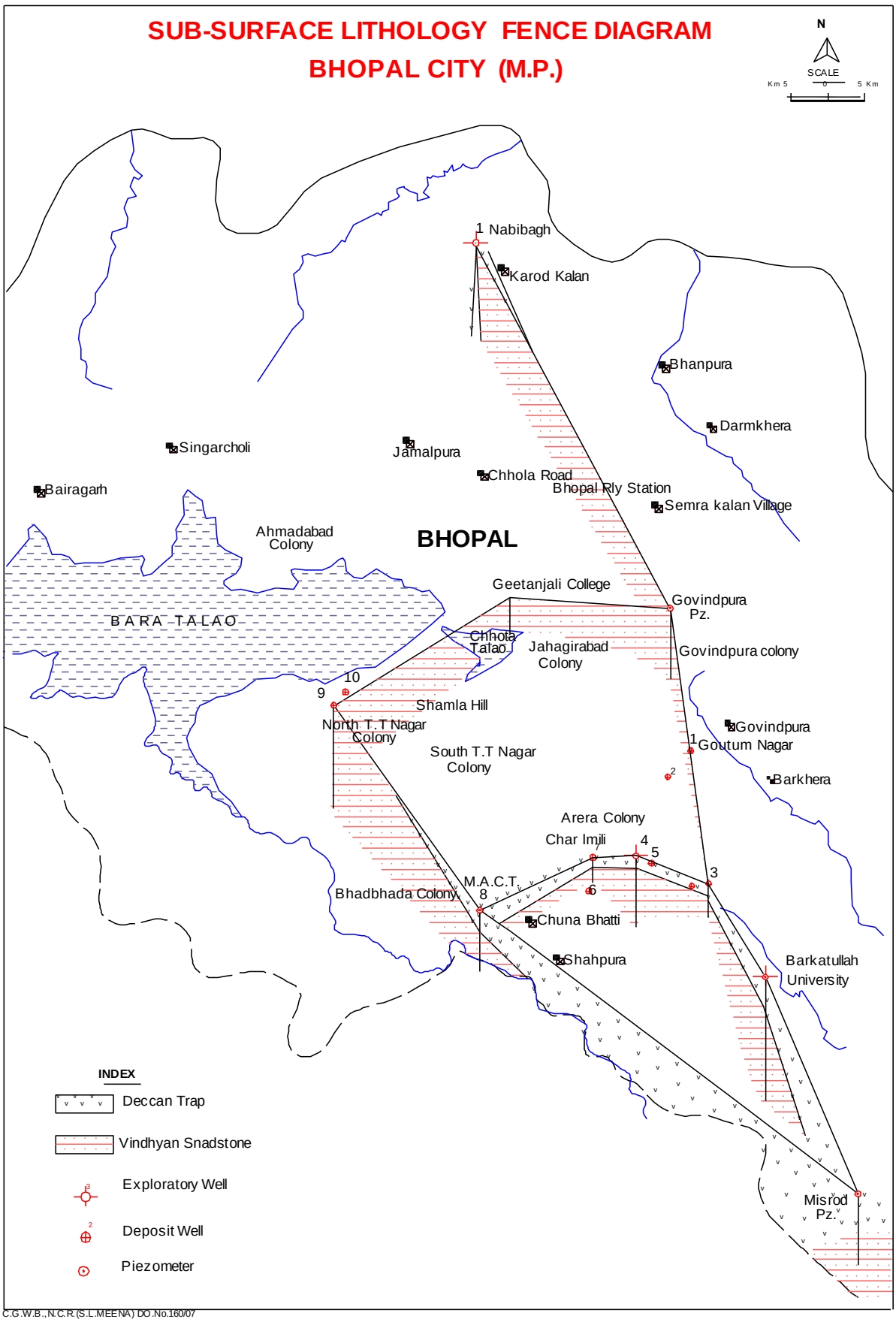
SUB-SURFACE LITHOLOGY FENCE DIAGRAM
BHOPAL CITY (M.P.)



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