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Summer Internship Report On

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GIS MAPPING OF GROUNDWATER FLUCTUATION: A CASE STUDY OF BHOPAL, MADHYA PRADESH, INDIA

SURPERVISED

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RAJ KUMAR KASHYAP

Date: 01-Aug-16

Place: Rishikesh

DECLARATION

I hereby declare that the work presented in this report entitled "GIS MAPPING OF GROUNDWATER FLUCTUATION: A CASE STUDY OF BHOPAL, MADHYA PRADESH, INDIA" in partial fulfilment of the degree of M.Sc. IInd year (Geology) at **Pt. LMS Gov. P.G. COLLEGE, Rishikesh,** is an authentic work of my own done under the guidance of **Dr. L. N. Thakural**, Scientist 'C', National Institute of Hydrology, Roorkee.

(RAJ KUMAR KASHYAP)

Date: 01- Aug- 16

Place: Roorkee

CERTIFICATE

It is certified that **Mr. Raj Kumar Kashyap**, Enrollment No. GA-123367, a student of M.Sc IInd year (Geology), Govt. P.G. College, Rishikesh, completed the internship project from June 02, 2016 to July 22, 2016 at **National Institute of Hydrology**, Roorkee under my supervision and this report is based on his own work.

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CONTENTS

ABSTRACT

Bhopal district is the central part of Madhya Pradesh and it is a fast developing region in Madhya Pradesh, India. Groundwater is a major source of water supply for the district which is reflected by regular extraction of groundwater through ever increasing number of municipal, industrial and private bore wells. Levels of groundwater are generally gathered at random points. Such studies provide early indicators of changes in groundwater resource and help to understand how to protect it. A total of 12 bore wells were selected for the study with Phanda and Berasia block of the district. Spatial coordinates were registered on site for each bore well with a GPS instrument and water depth below the ground level is measured during pre-monsoon and post-monsoon season using manual method. In the present study Kriging technique was used to interpolate the groundwater levels in Bhopal district. Spherical Model was found the best fit after drawing a semi-variogram from the output of the spatial correlation operation. Interpolation of pre and post monsoon groundwater levels was carried out for the year 2003 to 2013. Finally, the water table fluctuation maps were generated showing the annual fluctuation and the areas under rising/falling trend of groundwater table were delineated. The results reveal that the groundwater table in the central to northwest part of Bhopal district is declining in recent years. These maps are very useful for urban planning and sustainable groundwater usage.

Keywords: *Groundwater, Upper Lake, Betwa River, GIS Mapping, Groundwater Fluctuation, Malwa Plateau.*

I. INTRODUCTION

Groundwater is commonly understood to mean water occupying all the voids within a geologic stratum. This saturated zone is to be distinguished from an unsaturated or aeration, zone where voids are filled with water and air. Water contained in saturated zones is important for engineering works, geologic studies, and water supply developments. Unsaturated zones are usually found above saturated zones and extend upward to the ground surface; because water here includes soil moisture within the root zone, it is a major concern of agriculture, botany, and soil science (pedology).

Ever-growing population, high production agriculture practices, development of industries and various other domestic and recreational water uses has resulted in the overexploitation of the groundwater resources. Groundwater is the only dependable source for irrigation and domestic purposes during post-monsoon months in semi-arid zone. Many places in Madhya Pradesh face acute water crisis especially during the summer months. The groundwater table is depletes at an alarming rate and the wells dried up in the summer months. The fluctuation in the water table reflects the combined effect of precipitation, infiltration, transpiration, evapotranspiration withdrawal of water through bore wells and discharge of groundwater into streams and lakes. The groundwater exploitation increases during droughts, due to deficiency of rainfall more dependence comes on the groundwater storages and due to the higher rate of transpiration and evapotranspiration, the irrigation demand gets enhanced thereby causing sharp decline in the groundwater table.

Bhopal, the capital city of Madhya Pradesh is also known as the City of Lakes. Upper Lake, Lower Lake, Shahpura Lake are the ones contributing to being as the chief sources of water bodies besides their contribution to recreational needs. Amongst these, Upper Lake is the chief source of potable water for the people of Bhopal city. It has a catchment area of 361 km and a water area of 30.7 km at full tank level. It meets 40% of the drinking water demand for the city's growing population.

II. STUDY AREA

Bhopal district, spanning over an area of about 2772 km^2, lies in the central part of the state of Madhya Pradesh. 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°05' and 23°54' and east longitude 77°10' and 77°40', falling in Survey of India Topo sheet No. 55 E. As per 2011 census, the population of Bhopal district is about 1,798,218. 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.

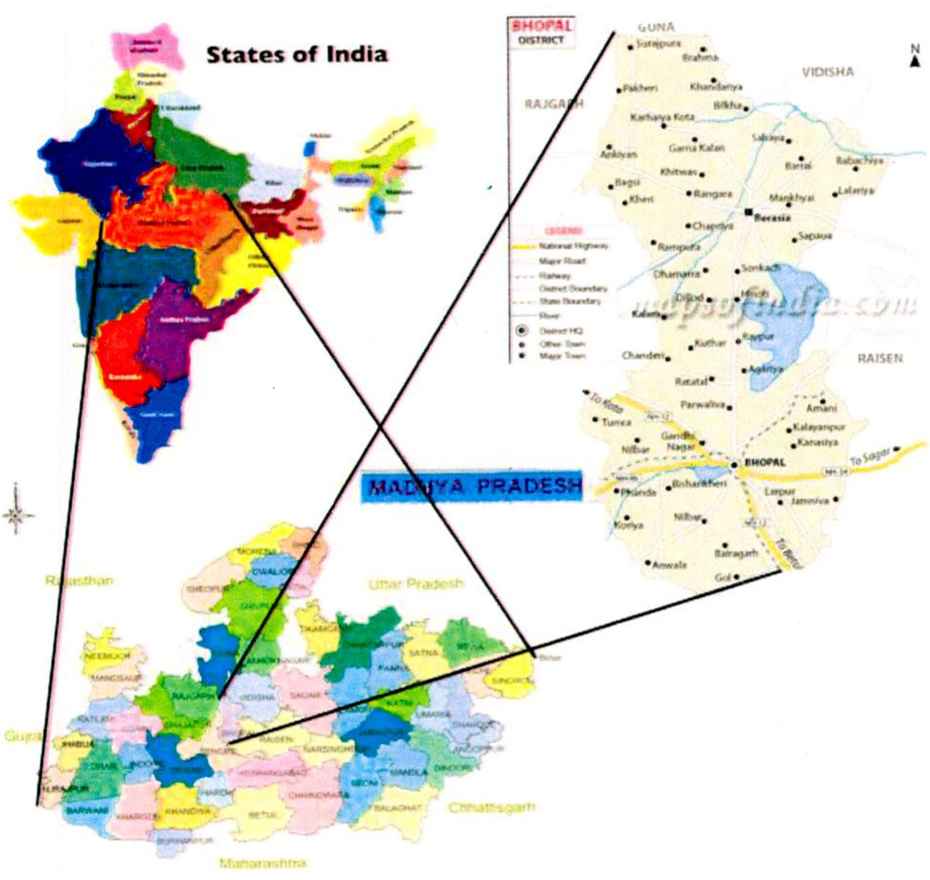

Fig. 1 Index map showing Bhopal district, M.P.

1.1 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.

1.2 Objectives Of The Study

Groundwater is a precious and most widely distributed notable resource of the earth. Spatial and temporal behavior of groundwater is of utmost importance for its proper management. Over growing population, high production agricultural practices, development of industrial and other domestic uses have resulted the over exploitation of groundwater resources. Thus, analysis of the groundwater fluctuations is the immediate need, as it an important area of hydrological cycle. The Bhopal district of Madhya Pradesh is facing such alarming situation for which it has been selected to study the groundwater fluctuations.

The main objectives of the study are:-

- Create the groundwater database for the study area
- GIS mapping of groundwater fluctuation of Bhopal district

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

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

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.

2.1 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 and constitute the pre-monsoon in middle of May. 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 annual precipitation of the district is 1146 mm (46 inches), 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°C and daily mean minimum temperature is 25.3°C. The individual day maximum temperature in May goes up to 44°C. The individual day minimum temperature is recorded 10.2°C in the month of January.

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. 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.

2.2 *Physiography*

Bhopal city forms a part of Malwa plateau and the topography is generally undulating. Vindhyan hill ranges occupies the eastern part of Phanda block which cover a major part and Deccan Trap basalts occupy the valleys. There are several hills scattered around Upper Lake and the highest of them is Singarcholi near Lalghati, which has an elevation of 625 m above (Mean Sea Level) MSL. There are several hills scattered around Upper Lake and the elevation of Bhopal city generally varies from 490 to 601 m MSL and the average elevation is 523 m above MSL. The southern part is drained by river Kaliasot, a small drainage course. It is an outlet of Upper Lake and becomes a tributary of Betwa River in the downstream. A limited area in the western side is drained by Kolans River. Patra tank, which receives overflow of Lower Lake drains the central and northern parts of the city.

The district covers part of two river sub-basins. Betwa River sub basin covers 82% of the area and lower Chambal basin in northwest covers 18 % area of district. The district is drained by River Betwa with its main tributaries like Kaliasot, Kerwa, Ajnal, Bah, Halali and Kolans .Betwa River (earlier known as Betravati River) originates from Barkhera in Raisen district of Madhya Pradesh state in India. Both the Rivers Chambal and Betwa are the southern tributary of the Yamuna River which in turn is a tributary of the Ganga River.

2.3 Soil and Crops

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. On getting wet the soil becomes extremely sticky and expands greatly due to high absorption of water, on drying up the soil contracts again and develops cracks on the surface. However, it has very high fertility status. The main crop grown in Kharif season Soyabeen, Urad and paddy and main crop grown in Rabi season are wheat, red gram. Other staple crops like linseed, chickpeas, sorghum, oilseeds and grown are also grown in the study area.

2.4 Geology

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.

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

Table-2: General geological successions of Bhopal district.

2.5 *Hydrogeology*

The general hydrogeological conditions of the district is discussed below on the basis of their formation settings.

2.5.1 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. 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. 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.

2.5.2 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 Bhadhada. 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.

2.5.3 *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 (gravel). 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.

2.6 *Groundwater Quality*

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 temperature was found to range between 21.1 °C and 34.7°C. A general trend of an increase in the Dissolved Oxygen (DO) value was observed in the post-monsoon season, as rainfalls favor the solubility of oxygen in water. The hardness of water is a measure of the amounts of minerals, primarily calcium and magnesium, it contains. It is often referred to as the soap consuming property of water. It is generally categorized as carbonate and non-carbonate hardness.

III. DATA AVAILABILITY

The groundwater level data for different stations was collected from the State Data Center (SDC), Bhopal. The selected bore wells are distributed throughout the Phanda and Berasia block in Bhopal district. Spatial coordinates of the sampling bore wells and depth to ground water table in meter below ground level (mbgl) and groundwater level expressed in m above MSL (Table-3).

Table-3: Attributes of sampling bore wells with Groundwater depth and levels

Well No.	Latitude	Longitude	Ground level above MSL	Pre-monsoon water level 2003 (m)	Post-monsoon water level 2003 (m)	Pre-monsoon water level 2004 (m)	Post-monsoon water level 2004 (m)
BPL-PZ-01	23°18'00"	77°25'00"	491.73	17.90	11.10	17.49	11
BPL-PZ-02	23°14'50"	77°24'00"	483.60	09.25	05.73	08.90	05.80
BPL-PZ-03	23°16'50"	77°20'00"	507.44	09.85	04.53	10.04	04.41
BPL-PZ-04	23°14'10"	77°15'10"	510.57	18.32	05	18.10	09.60
BPL-PZ-05	23°19'20"	77°11'00"	477.30	15.81	05.35	13.34	06.59
BPL-PZ-06	23°22'10"	77°23'15"	479.90	18.41	05.12	18.23	08.25
BPL-PZ-07	23°48'00"	77°16'00"	428.68	29.90	18.95	29.85	14.95
BPL-PZ-08	23°08'00"	77°28'00"	478.96	05.23	01.62	05.20	01.65
BPL-PZ-09	23°16'30"	77°35'10"	420.00	11.90	03.10	12.30	05.22
BPL-PZ-10	23°15'00"	77°26'00"	492.55	17.97	11.09	17.47	11.12

Pre-monsoon water level 2005 (m)	Post-monsoon water level 2005 (m)	Pre-monsoon water level 2006 (m)	Post-monsoon water level 2006 (m)	Pre-monsoon water level 2007 (m)	Post-monsoon water level 2007 (m)	Pre-monsoon water level 2008 (m)	Post-monsoon water level 2008 (m)	Pre-monsoon water level 2009 (m)
17.60	12	17.75	11.50	17.85	12.45	17.90	12.40	18
09	05.85	09.15	05.75	08.80	06.65	09.23	05.85	09.85
10.62	03.46	10.80	03.14	09.13	03.40	10.20	04.65	09.70
17.95	07.50	18.33	07.65	18.42	11.20	18.16	11.65	18.35
17.40	05.71	17.30	05.95	16.96	06.10	15.90	08.95	16
18.10	06.34	18.05	06.30	18	11.20	18.35	14.45	18.40
29.90	18.30	29.75	14.65	29.85	14.90	29.70	15.45	35
05.23	01.59	05.20	01.62	05.25	01.70	05.50	03.40	05.75
12.90	03.15	12.33	05.29	12.27	05.25	12.38	06.35	12.60
17.62	12.10	17.76	11.50	17.80	11.40	17.83	12.65	18.15

Post-monsoon water level 2009 (m)	Pre-monsoon water level 2010 (m)	Post-monsoon water level 2010 (m)	Pre-monsoon water level 2011 (m)	Post-monsoon water level 2011 (m)	Pre-monsoon water level 2012 (m)	Post-monsoon water level 2012 (m)	Pre-monsoon water level 2013 (m)	Post-monsoon water level 2013 (m)
12.60	18	13.90	18.05	13.95	18.15	14.05	18	14
05.05	09.50	05.90	09.75	05.60	09.85	06.08	09.73	05.50
03.50	10.10	08.05	10.60	05.60	08.20	06.10	08.60	05.60
11.55	18.10	12.65	18.80	10.80	18.50	10.30	19.20	08.50
07	16.60	10.43	17.45	08.90	23.70	08.50	12.10	07.50
14.35	18.70	14.90	19	12.80	15.40	13.10	15.90	10.30
15.40	29	15.60	29.55	15.10	27.10	14.20	17.70	13.60
04	06	04.30	06.60	04.20	07.45	05.40	10.10	04.30
06.30	12.70	09.15	12.75	07.85	17.10	09.10	12.20	08.30
12	18.35	12.35	19	11.40	18.40	11.50	15.80	11.90

IV. GIS DATA BASE AND GIS MAPPING

In the present study, a spatial database has been created to store relevant GIS data for groundwater depth analyses with the coordinate system, Universal Transverse Mercator (UTM) zone 43N. The feature classes include, location point file generated using GPS, boundary line and polygon files generated from the ward map after geo-referencing with accurate GPS control point. Attributes like groundwater depth, groundwater level were then integrated to the location point file generated using GPS, boundary line and polygon files generated from the ward map after geo-referencing with accurate GPS control point. Attributes like groundwater depth, groundwater level were then integrated to the location point file. These feature classes have been used for creating the following maps:-

- Map of Bhopal district
- Location of sampling bore wells
- Spatial distribution map(SDM) showing groundwater fluctuation

Latitude, longitude and location of all the sample bore wells of study area were obtained using GPS receiver. ArcGIS software and location data using a point feature showing the position of sampling wells is prepared using the attributes given in table 3. Ground level and pre-monsoon and post-monsoon water level depth is stored in excel format as non-spatial data and linked with the spatial data by join option ArcMap. The spatial and the non-spatial database formed are integrated for the generation of SDM of groundwater depth and levels.

V. METHODOLOGY

The evaluation of groundwater resources requires an estimation of various inputs to the groundwater body, the output from it and the resulting change in storage. The various inputs (sources of recharge) are rainfall infiltration, seepage from canals, tanks (surface water bodies), return flow from surface and groundwater irrigation. The main output factors include the withdrawal through groundwater structures (groundwater draft) and outflow from the aquifer. The total replenishable resource for an area remains unchanged, whereas the draft is, normally, ever increasing thereby reducing the available groundwater resource for future use year by year. The resultant change in storage is reflected in the groundwater levels. Measurement of groundwater level at each and every point is not possible, therefore it is necessary to interpolate the available data at fixed points.

5.1 Point Interpolation Method

There are different methods of numerical interpolation of irregularly distributed data to a regular N-dimensional array (Thiebaux and Pedder (1987). Bussieres and Hogg (1989) studied the error of spatial interpolation using four different objective methods. For application to the specific project grid, the statistical optimal interpolation technique displayed the lowest root mean square errors. This technique and kriging interpolates a surface from points data base and would be useful for areal average computations. These regular points are then averaged to provide area mean, annual water level depth on choosable grid cells.

5.1.1 Kriging Method

Kriging is named after D.G. Krige, a South African mining engineer and pioneer in the application of statistical techniques to mine evaluation. The kriging technique is derived from the theory of regionalized variables (Krige, 1966; Matheron, 1963). An advantage of Kriging (above other moving averages like in verse distance) is that it provides a measure of the probable error associated with the estimates. Kriging can be seen as a point interpolation, which requires a point map as input and returns a raster map with estimations and optionally an error map. The estimated or predicted values (Z) is thus a linear combination known input point values (zi) and have a minimum estimation error. Thus,

$$Z = \sum (w_i \times z_i) \tag{1}$$

Where, w_i is weight factors.

In case the value of an output pixel would only depend on three input points, this would read:

$$Z = w_1 \times z_1 - w_2 \times z_2 + w_3 \times z_3 \tag{2}$$

Thus, to calculate one output pixel value Z, first, three weight factors w_1, w_2 ,w_3 have to be found (one for each input point value z_1, z_2, z_3), then, these weight factors can be multiplied with the corresponding input point values, and summed.

In Kriging, the weight factors are calculated by finding the semi- variance values for all distances between input points and by finding semi- variance values for all distances between an output pixel and all input points; then a set of simultaneous equations has to be solved. The weight factors are calculated in such a way that the estimation error in each output pixel is minimized. All semi-variance values are calculated by using a user-specified semi-variogram model. The model describes the expected variance in value between pairs of samples with a given relative orientation. One of the best semi-variogram model like Spherical, Exponential, Gaussian etc. is selected and values for the sill, range and nugget are chosen for best fit. Thus, the semi-variogram model and values for sill, range and nugget have been finalized, and the Kriging operation has been continued.By using kriging interpolation technique the statistical values for groundwater level/depth of Bhopal station have been carried out in the form of Minimum, Maximum, Mean and standard deviation of past 11 years (2003-2011).

VI. RESULTS AND CONCLUSIONS

Groundwater depth shows variation (fluctuation) over the period of 11 years (2003-2011) in selected bore wells location from 1.72 meter below ground level (mbgl) to 19.45 mbgl. Percent of bore wells showing water depth below 5 mbgl is 16.6% whereas the percent below 10 mbgl and 15 mbgl are found as 41.66% and 41.66% in the same order. In general, the results show that the district is facing the problem of declining groundwater table in recent past. The groundwater fluctuation maps also show that groundwater in the agricultural/plain area is declining fast due to over exploitation. The groundwater table maps of different years have been used to calculate the changes in groundwater table during that period by subtracting the prior year map from the later year. Variations in groundwater levels could be attributed to hydrogeology, land use and land cover changes across the district. The percolation tanks and farm ponds may be constructed in the lower most corner of the agricultural fields to increase the natural recharge of rain water during monsoon period and the stored water can be used for life saving irrigation during dry spells and so wing of wheat crops.

Year	Minimum (m)	Maximum (m)	Mean (m)	Std. deviation
2003	3.69	13.55	9.34	± 1.02
2004	3.25	14.85	10.40	± 2.63
2005	3.79	13.37	9.21	± 1.58
2006	3.99	14.63	11.31	± 2.49
2007	2.39	14.89	10.34	± 2.78
2008	2.11	14.16	8.80	± 2.79
2009	1.78	19.45	10.51	± 3.98
2010	1.72	13.31	7.76	± 2.74
2011	2.43	14.35	8.95	± 2.48
2012	2.09	14.91	7.11	± 1.89
2013	3.32	10.00	5.08	± 0.45

Table-4: Descriptive statistics for groundwater depth/level

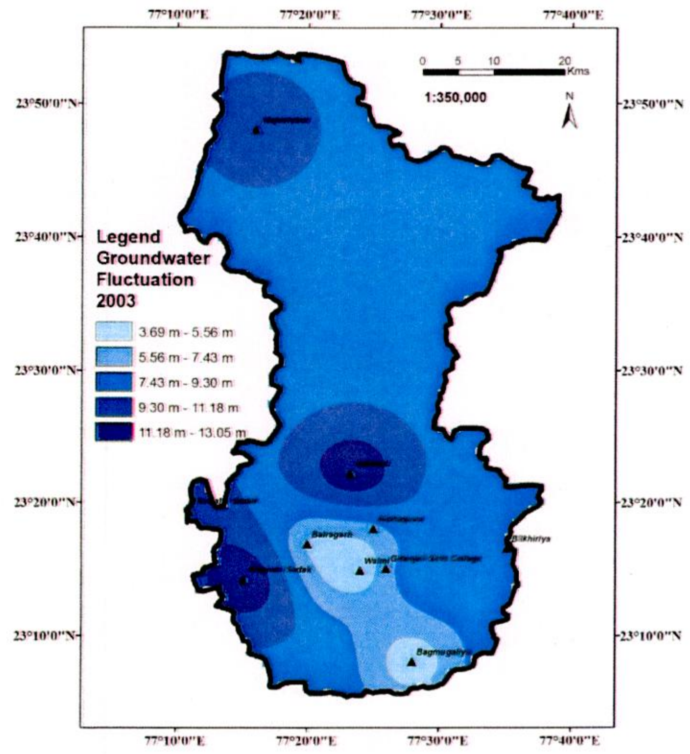

Fig. 2 Groundwater Fluctuation Map, Year 2003

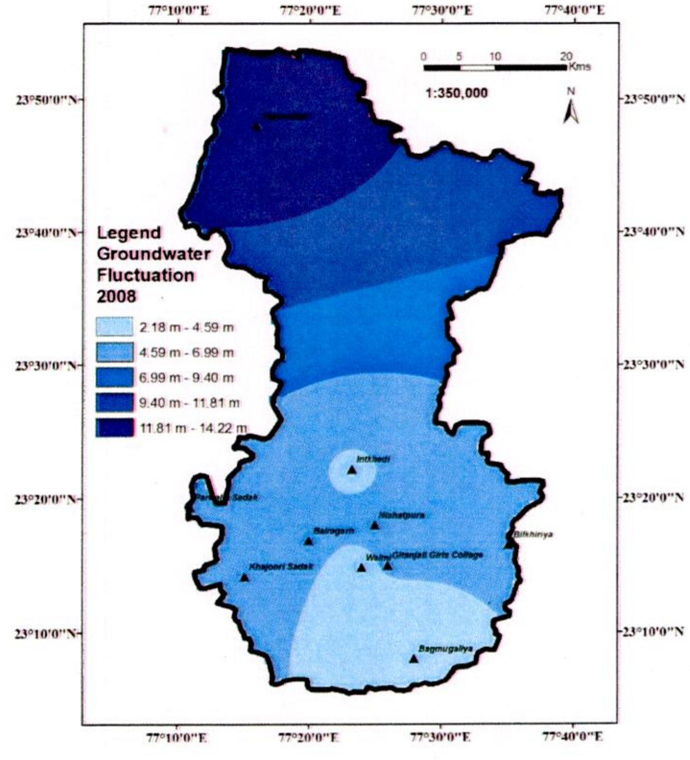

Fig. 3 Groundwater Fluctuation Map, Year 2008

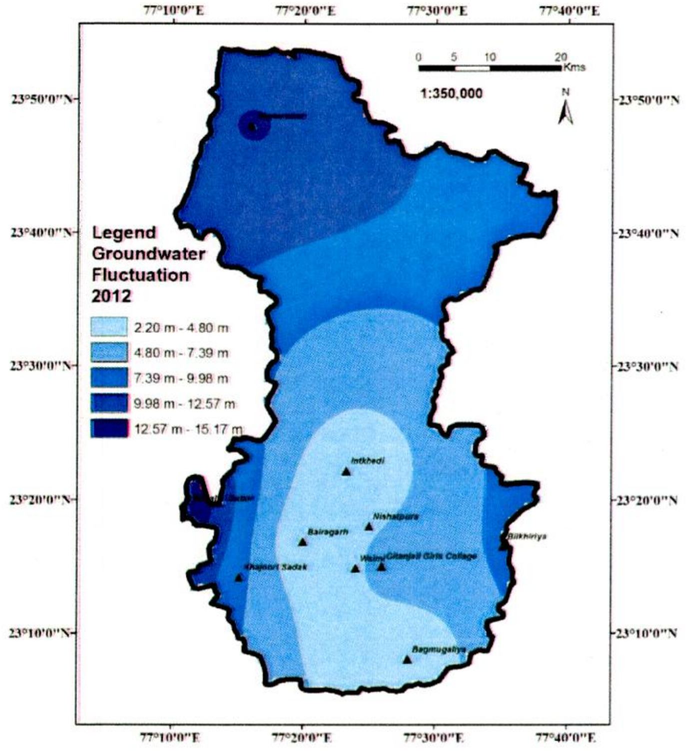

Fig. 4 Groundwater Fluctuation Map, Year 2012

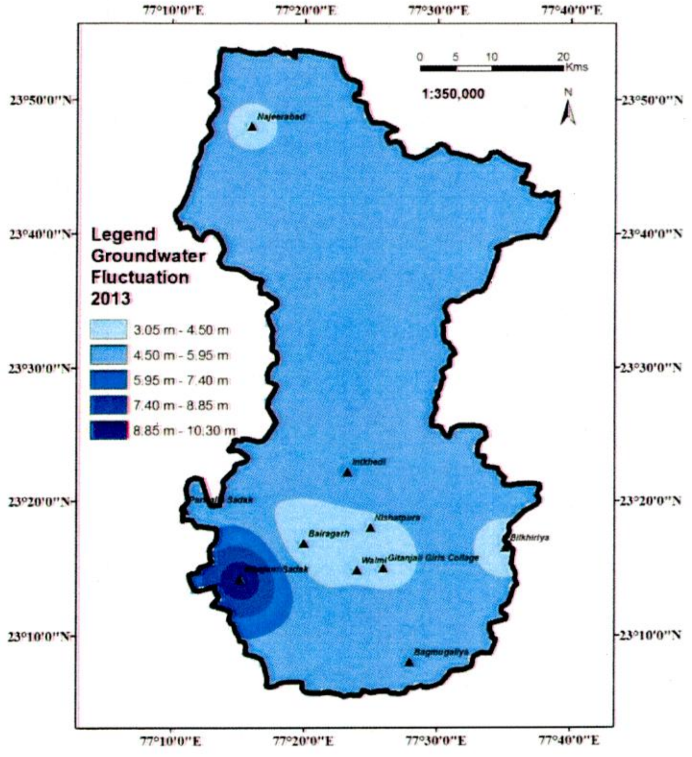

Fig. 5 Groundwater Fluctuation Map, Year 2013

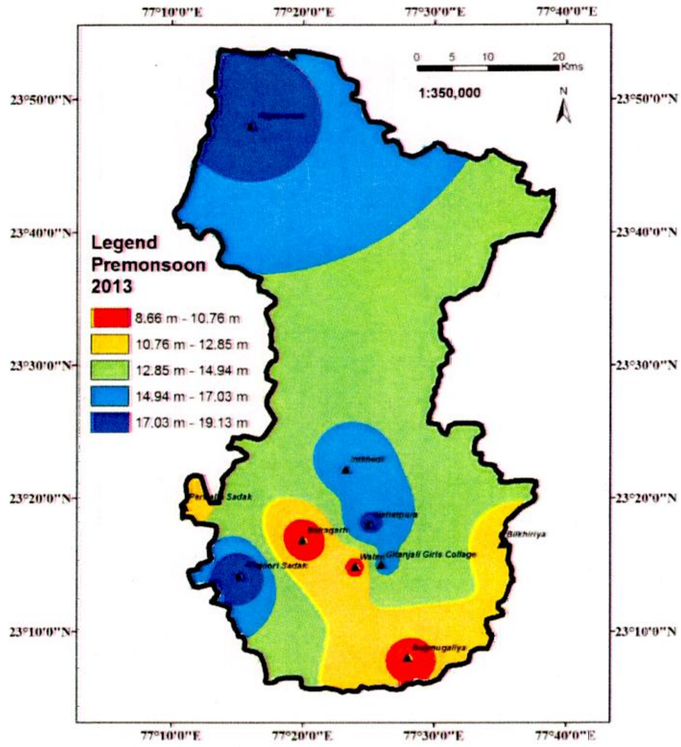

Fig. 6 Pre-Monsoon Groundwater table, Year 2013

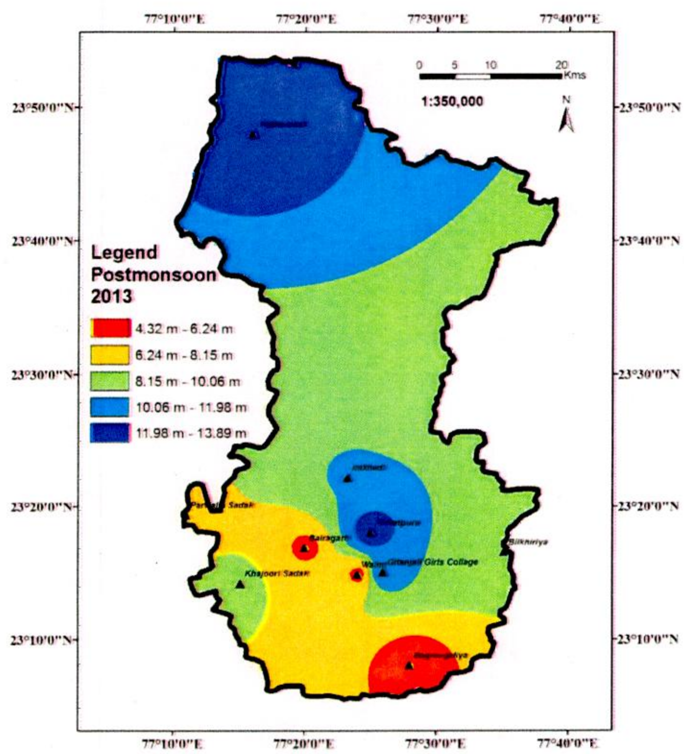

Fig. 7 Post-Monsoon Groundwater table, Year 2013

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