MONITORING AND GIS MAPPING OF GROUNDWATER LEVEL VARIATIONS IN GULBARGA CITY

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Abstract

Gulbarga is a fast developing city in Karnataka, India. Groundwater is a major source of water supply for the city which is reflected by regular extraction of groundwater through ever increasing number of municipal, industrial and private bore wells. Monitoring groundwater levels and quality is useful to understand impact of uncontrolled drilling of bore wells, point and non point sources of pollutants. Such studies provide early indicators of changes in groundwater resource and help to understand how to protect it. A total of 55 bore wells were selected for the study with one bore well per municipal ward of the city. 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 season using manual method. The results indicate wide fluctuations in groundwater depth across the municipal wards and the groundwater flow is found to follow surface relief in the study area. GIS map showing groundwater depth and level are developed and compared with surface relief map. These maps are very useful for urban planning and sustainable groundwater usage.

Keywords: *Groundwater, GIS mapping, Surface relief map, spatial distribution map*

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1. INTRODUCTION

India is the largest groundwater user in the world. Groundwater has played a significant role in the maintenance of India's economy, environment and standard of living. Through the construction of millions of private bore wells, there has been an enormous growth in the exploitation of groundwater during the last five decades. It is reported that 56 per cent of metropolitan, class-I and class-II cities are dependent on groundwater either fully or partially [1]. As per census of India 2011, 27-35% of urban population depends on groundwater as their source of drinking water[2]. About 29% of groundwater assessment blocks in the country are classified as semi-critical, critical or overexploited categories with the situation deteriorating rapidly. The government has no direct controls over the groundwater use of millions of private bore well owners both in rural and urban areas. A study by Hector et al 2011, report that the potential social and economic consequences of continued weak or nonexistent groundwater management are serious. Aquifer depletion is concentrated in many of the densely populated and economically productive areas, and the consequences will be more severe for the poor. Widespread groundwater pollution could render the resource useless before it is exhausted. It also must be noted that indiscriminate abstraction of groundwater aggravates the quality problems and thus a more integrated management approach to quality and quantity is needed [3]. Monitoring groundwater level fluctuation data on seasonal basis can identify early indicators of changes in the groundwater resource and help to understand how to protect it [4].Present study describes economic and rapid field method of groundwater level measurement from the existing bore wells fitted with hand pumps and electric motors. Spatial attributes of the sampling bore wells and development of GIS based maps showing groundwater depth and levels are also included.

2. STUDY AREA

Gulbarga is a historical and 6th largest city of Karnataka state, spreads over an area of 65 sq. km with a population of about 541617 persons as per census of India, 2011. It is situated between longitude of 76º 47' east and 76º 52' east and latitudes of 17º17' north and 17º 22' north. The city is divided in to 55 wards based on population and municipal jurisdiction. Average annual rainfall observed in the study area is about 750 mm and the mean daily temperatures range from 19ºC in winter to over 40ºC in summer. The City is served by piped potable water supply derived from Bennithora and Bhima rivers and Bhosga reservoir located 10-25 km away from the treatment plant. There are more than 1800 municipal bore wells in the city which augments city surface water supply and contribute to over 30% of daily municipal water supply to the city [5]. In addition to this groundwater is also extracted from thousands of private bore wells and consumed for potable purposes without proper treatment. There is no record of the number of private bore wells in the city. Based on a questionnaire survey it is noted that number of private bore wells in the city exceed 20,000 [6]. Groundwater level monitoring in the city is confined to only one observation bore well under the department of mines and geology, government of Karnataka. This observation bore well is located in an isolated area and does not reflect trends of groundwater fluctuations across the city. There are no previous studies reported in literature about groundwater levels monitoring in Gulbarga city. A site plan showing Gulbarga city and location of the bore wells selected for the study is shown in Fig. 1.

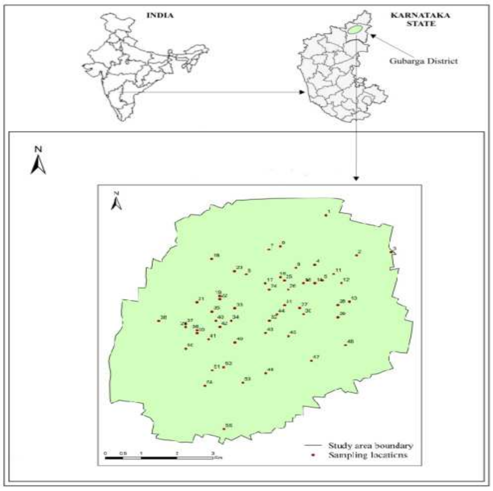

Fig.1 Study area and sampling bore well location

3. MATERIALS AND METHODS

Based on field observation 55 bore wells were selected for groundwater depth measurement. The selected bore wells are distributed throughout the city with one bore well located in each municipal ward. Spatial coordinates of the sampling bore wells were measured on site using a hand held global positioning system (GPS) instrument GARMIN GPS-60. Groundwater depth of the sampling bore wells were measured during pre monsoon season in the year 2009. Method consists of partially opening cover of the bore well/ hand pump and inserting a rope attached with a weight (spanner) at the lower end, through the casing of the bore well. This method is similar to the standard procedure described for measuring groundwater depth using a steel tape [4]. Fig. 2 shows the field measurement process. Depth to groundwater level was measured in m with the casing of the well as reference point and then deduced to exact ground level. Google earth is used to register ground level profile of the study area and ground level above mean sea level of the sampling bore wells. The groundwater level in MSL was obtained by deducting groundwater depth from the ground level in MSL.

Fig.2 Photos showing GPS instrument, and groundwater depth measurement

3.1 Variation in Groundwater Levels

Table 1 and 2 describe depth to ground water table in meter below ground level (mbgl) and groundwater level expressed in m above MSL. Fig. 3 and Fig. 4 shows graphical trend of groundwater depth and level variations across the city.

4. 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. These feature classes have been used for creating the following maps.

- Map of Gulbarga city
- Location of sampling bore wells
- Spatial distribution map(SDM) showing groundwater depth and level
- Surface relief map

The study area map is generated from the hard copy of Gulbarga city corporation map (2006) gathered from district natural resources data management system (NRDMS) centre. The map was scanned, geo-referenced and digitised for creating the spatial database. Geo-referencing means to define its real location on earth surface in terms of map projections and coordinate systems. Here the process was carried out by integrating with the maximum number of GPS points taken from different parts of the study area.

Latitude, longitude and location of all the sample bore wells of study area were obtained using GARMIN GPS-60 receiver. ArcGIS software and location data using a point feature showing the position of sampling wells is prepared (Fig 1) using the attributes given in table 1. Groundwater depth and level is stored in excel format as non spatial data and linked with the spatial data by join option in ArcMap. The spatial and the non-spatial database formed are integrated for the generation of SDM of groundwater depth (Fig 5) and levels (Fig 6). For generating the interpolation maps, inverse distance weighted (IDW) approach in GIS has been used to delineate the spatial distribution of groundwater pollutants.

Surface relief map (Fig 7) of the study area was generated from the elevation file representing the sampling locations plus additional points, falling within a grid of 1 km square, which in turn was extracted from the Google map. Using the 3D analyst extension tool in ArcGIS, location file was converted first to TIN (Triangular Irregular Network), which is the model representing a surface as a set of contiguous, non-overlapping triangles. Within each triangle the surface is represented by a plane. These triangles are used for surface representation and display. Surface relief map is created by converting TIN raster file using the 3D analyst again. The map represents northern part with red colour indicating higher levels and the southern part with blue colour indicating relatively lower levels. This indirectly reveals the surface run off direction, which is from north to south. This map is prepared to understand surface runoff and comparing the ground surface profile with the SDM of groundwater level.

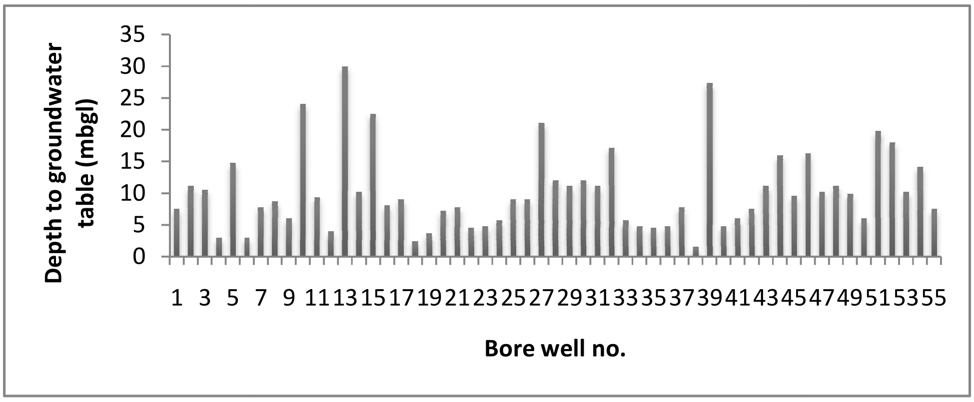

Fig.3 Variation in groundwater depth

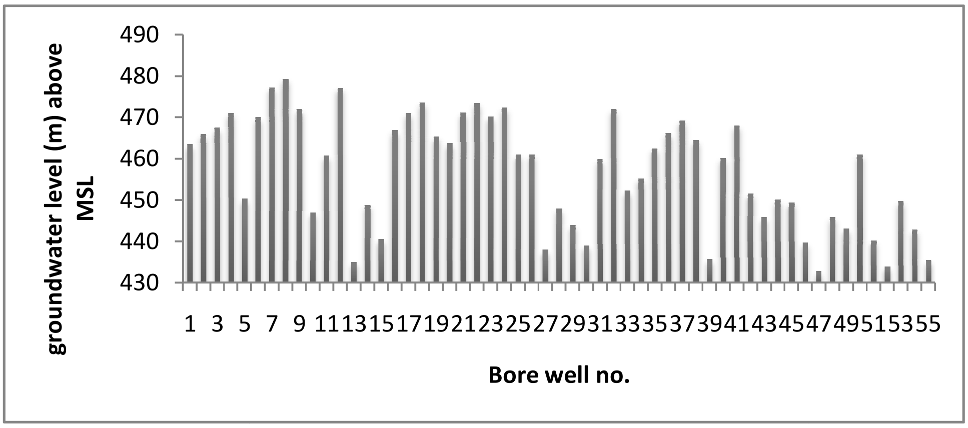

Fig.4 Variation in groundwater level

Table 1 Attributes of sampling bore wells with Groundwater depth and levels

Bore well No.	Longitude (degrees)	Latitude (degrees)	Ground level*	GW depth (mbgl)	GW level*	Bore well No.	Longitude (degrees)	Latitude (degrees)	Ground Level*	GW depth (mbgl)	GW level*
1	76.853	17.368	471	7.5	463.5	29	76.856	17.335	455	11.1	443.9
2	76.861	17.355	477	11.1	465.9	30	76.847	17.336	451	12	439
3	76.871	17.355	478	10.5	467.5	31	76.842	17.339	471	11.1	459.9
4	76.85	17.352	474	3	471	32	76.838	17.334	489	17.1	471.9
5	76.852	17.347	465	14.7	450.3	33	76.829	17.338	458	5.7	452.3
6	76.832	17.349	473	3	470	34	76.828	17.334	460	4.8	455.2
7	76.838	17.357	485	7.8	477.2	35	76.823	17.337	467	4.5	462.5
8	76.841	17.358	488	8.7	479.3	36	76.819	17.331	471	4.8	466.2
9	76.845	17.351	478	6	472	37	76.816	17.333	477	7.8	469.2
10	76.848	17.347	471	24	447	38	76.809	17.334	466	1.5	464.5
11	76.855	17.349	470	9.3	460.7	39	76.819	17.33	463	27.3	435.7
12	76.857	17.346	481	3.9	477.1	40	76.824	17.334	465	4.8	460.2
13	76.859	17.34	465	30	435	41	76.822	17.328	474	6	468
14	76.85	17.346	459	10.2	448.8	42	76.825	17.332	459	7.5	451.5
15	76.847	17.346	463	22.5	440.5	43	76.837	17.33	457	11.1	445.9
16	76.841	17.348	475	8.1	466.9	44	76.84	17.336	466	15.9	450.1
17	76.837	17.346	480	9	471	45	76.843	17.329	459	9.6	449.4
18	76.823	17.354	476	2.4	473.6	46	76.858	17.326	456	16.2	439.8
19	76.825	17.342	469	3.6	465.4	47	76.849	17.321	443	10.2	432.8
20	76.816	17.332	471	7.2	463.8	48	76.837	17.317	457	11.1	445.9
21	76.819	17.34	479	7.8	471.2	49	76.829	17.327	453	9.9	443.1
22	76.825	17.341	478	4.5	473.5	50	76.816	17.325	467	6	461
23	76.829	17.35	475	4.8	470.2	51	76.823	17.318	460	19.8	440.2
24	76.838	17.344	478	5.7	472.3	52	76.826	17.319	452	18	434
25	76.842	17.347	470	9	461	53	76.831	17.314	460	10.2	449.8
26	76.843	17.344	470	9	461	54	76.821	17.313	457	14.1	442.9
27	76.846	17.338	459	21	438	55	76.826	17.299	443	7.5	435.5
28	76.856	17.339	460	12	448						

*above mean sea level in m, mbgl- meter below ground level, GW - ground water

Table 2 Descriptive statistics for groundwater depth/level

Groundwater depth/level	Range	Minimum	Maximum	Mean	Std. Deviation
depth in m	28.50	1.50	30.00	10.22	± 6.26
Level in m above MSL	51.80	427.50	479.30	459.42	± 2.87

CONCLUSIONS

Groundwater depth varies with bore well location from 1.5 meter below ground level (mbgl) to 30 mbgl. Percent of bore wells showing water depth below 5 mbgl is 21.8% whereas the percent below 10 mbgl and 15 mbgl are found as 58.2% and 81.8% in the same order. It is observed that both the groundwater levels and ground levels are receding towards south and follow almost identical pattern across the city. Variations in groundwater levels could be attributed to hydrogeology, land use and land cover changes across the city. Another important factor effecting groundwater level is the number of bore wells and rate of extraction of groundwater in the vicinity of the sample bore well. Shallow groundwater levels are observed at bore wells located close to wetland.

Regular monitoring of groundwater levels and groundwater quality shall be undertaken by authorities to control sustainable use of groundwater. It is recommended to increase the number of observation wells to cover each ward of the city.

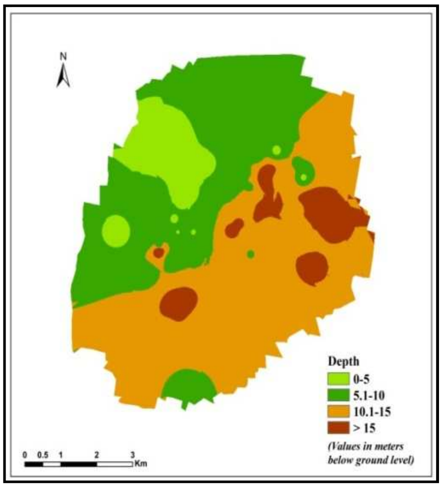

Fig 5 Depth of groundwater mbgl

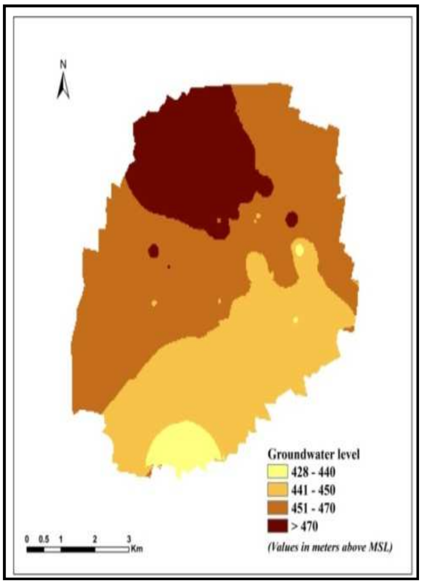

Fig 6 Groundwater level above MSL

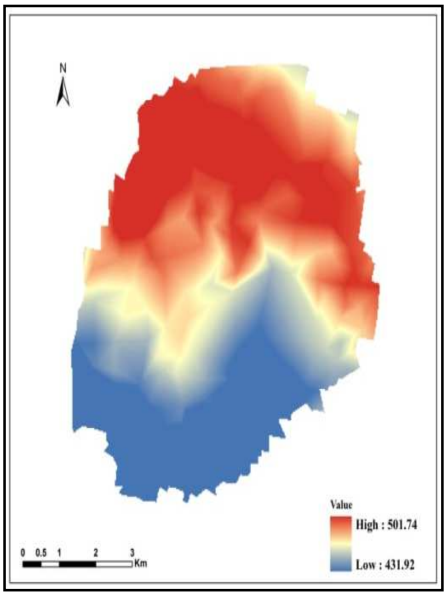

Fig 7 Surface relief map

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