AN APPROACH TOWARDS GROUNDWATER MAPPING USING GEOGRAPHIC INFORMATION SYSTEM

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Abstract-Groundwater is attracting an ever increasing interest due to scarcity of good quality subsurface water, and growing need of water for domestic, agricultural and industrial uses. It has become crucial not only to target groundwater potential zones, but also to monitor and conserve this important resource. In this project, an attempt has been made to study the groundwater profile and to determine its suitability for human consumption (as per IS 10500 : 2009) using the various tools of Geographic Information System (GIS).A study area has been selected under Bangalore East Taluk, spanning over 100 km^2, roughly in the shape of a quadrilateral having coordinates (13º14'58.95"N , 77º40'0.06"E) , (13º5'13.12" N, 77º46'53.54"E) , (12º58'41.56" N, 77º46'47.62"E) , (12º58'56.59"N , 77º40'0.38"E).Around 160 samples of groundwater have been collected from borewells and open wells within the study area, and they have been tested for parameters such as Total Hardness, Total Alkalinity, pH, Total Dissolved Solids and Fluorides. Also, information about the depth of water in the wells and their year of construction has been collected in order to analyse the change in the profile of groundwater over the years.These data have been then fed into a GIS spatial database and suitably interpolated statistically using GIS tools and softwares, and the final output has been shown in the form of

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groundwater quality maps. These maps have proved to be very effective in discerning groundwater potential zones, and can act as a basis for planning and execution of groundwater exploration.

Keywords-Groundwater, groundwater profile, GIS, groundwater quality maps, statistical interpolation, groundwater potential zones.

I. INTRODUCTION

Groundwater is the water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations. Groundwater Hydrology is the science that deals with the occurrence, distribution and movement of water below the surface of earth. The largest available source of fresh water lies underground[2]. The total groundwater potential is estimated to be nearly one-thirds of the capacity of all the oceans
combined together.Groundwater reserves consist of water held in voids within a geologic stratum. These water bearing formations act as conduits for transmission and reservoirs for storage of groundwater[5].

There are many dissolved minerals and organic constituents present in ground waterin various concentrations. Among them the most common dissolved mineralsubstances are sodium, calcium, magnesium, potassium, chloride, bicarbonate, andsulphate. In water chemistry, these substances are called common constituents.They are not harmful if they are within permissible limits[6]. Few elements are highlytoxic and hazardous to health of both human and animals.

Basically, the quality of ground water in a given area is determined by the presenceof the contaminants and the degree of their concentration. The presence of thecontaminants and the degree of their concentration can be attributed to the in-situoriginand / or due to dispersion. The in-situ-origin of the contaminants can be eithergeo-genic and / or anthrapo-genic. Similarly, the dispersion of the contaminants canbe through a point source and / or a non-point source. Hence, variations in thequality of ground water are likely to occur both in space (horizontal as well asvertical) and time.In order to understand the dynamics of ground water quality and map its distributionin a given area, the origin and the sources of contaminants i.e data pertaining togeology, irrigation, agriculture, industry, land use, etc. have to be taken in to account[7].As the controlling parameters are many and the process is complex, the data needto be subjected to modeling based on empirical formulae to draw meaningfulconclusions and map the distribution of ground water quality[8].

A **Geographic Information System** is a computer system used for capturing, storing, analysingans displaying geographically referenced data.The acronym GIS is sometimes used for geographical information science or geospatialinformationstudies to refer to the academic discipline or career of working with geographic information systems and is a large domain within the broader academic discipline of Geoinformatics.[5]

A study by the Mines and geology department, Karnataka, India, a systematic analysis of ground water quality in Bangalore and its environs was done. A survey was carried out and ground water samples were collected in the months of March and April, 2003. The samples were analysed in the laboratory of the department for the following parameters : physical, chemical, bacteriological, pesticides and heavy metals. Totally, 918 samples were collected from the study area. A thorough comparative analysis was carried out and the relative groundwater layers were created manually using interpolation methods for spatial methods. [8]

National Remote Sensing Centre (NRSC), ISRO / Dept. of Space, Govt. of India, in collaboration with partner institutions, is preparing ground water prospects maps using remote sensing and GIS technology under Rajiv Gandhi National Drinking Water Mission (RGNDWM) project. The project is being sponsored by Department of Drinking Water Supply (DDWS), Ministry of Rural Development (MoRD). The ground water prospects maps have already been prepared for 10 states and are in final stage of preparation for another 10 states. Preparation of maps for remaining part of the country is scheduled to be taken up after completing the mapping in on-going states. The ground water prospects maps provide information on a) potential zones for the occurrence of ground water and b) site-specific recharge structures.

The maps are being used by the concerned state government departments for locating drinking water sources, and also for identifying suitable sites for constructing recharge structures to improve the sustainability of the drinking water sources. It is reported by the Nodal officers of the states that the success rate of the wells drilled using these maps has been improved by 85%-

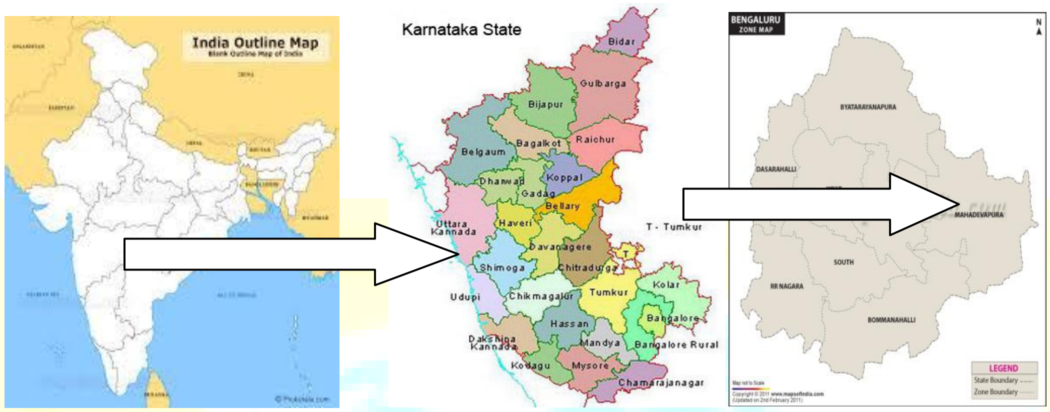
95%. It is also reported that a number of recharge structures are being constructed successfully resulting in increase of water table in the area[5].

Spatial variations in ground water quality in the corporation area of Gulbarga City located in the northern part of Karnataka State, India, have been studied using geographic information system (GIS) technique. GIS, a tool which is used for storing, analyzing and displaying spatial data is also used for investigating ground water quality information. For this study, water samples were collected from 76 of the bore wells and open wells representing the entire corporation area. The water samples were analyzed for physico-chemical parameters like TDS, TH, Cl- and NO3-, using standard techniques in the laboratory and compared with the standards. The ground water quality information maps of the entire study area have been prepared using GIS spatial interpolation technique for all the above parameters. The results obtained in this study and the spatial database established in GIS will be helpful for monitoring and managing ground water pollution in the study area. Mapping was coded for potable zones, in the absence of better alternate source and non-potable zones in the study area, in terms of water quality[6].

Mapping and management strategies for ground water resources have been studied, by Department of Applied Geophysics, by analyzing IRS LISS II multi band remote sensing data along with geological as well as geophysical resistivity sounding data carried out at places in GIS environment. Finally, based on the integrated thematic maps, weighted analysis in Arc GIS, ground water resource prospect map of the area has been prepared and discussed. The study has brought out that the high groundwater potential zones are confined along lineaments and in pediment areas[7].

II. METHODOLOGY

Study Area -Bangalore is situated at the heart of the south Deccan Plateau in Peninsular India towards the south-eastern corner of the state of Karnataka between the latitude parallels of 12°39’ N and 13°18’ N and longitudinal meridians of 77°22’ E and 77°52’ E at an average elevation of about 900 metres above MSL, covering an area of about 2191 km^2 (Bangalore rural and urban districts). Bangalore is generally considered to be a climatically well favoured district.



India Karnataka Bangalore

Figure 1 : Outline map of India, Karnataka and Bangalore

- The study area forms the pattern of a quadrilateral with its four corners having the coordinates (13º14'58.95"N , 77º40'0.06"E) , (13º5'13.12" N, 77º46'53.54"E) , (12º58'41.56" N, 77º46'47.62"E) , (12º58'56.59"N , 77º40'0.38"E).
- The study area is so considered that the Yelemmappa Shetty lake, which is one of the largest lakes of Bangalore City, falls at the centre of the area.
- The terrain spanning over about 5 kms in all the four directions from the lake has been considered. This area falls under Bangalore East Taluk. The project is done on a scale of 1:4000.

Procedure

a. Image preparation

Georeferencing - Georeferencing is the process of projecting image data onto a plane and making it conform to a map projection system. If the GCPs are collected from ground, the process is known as image-to-ground referencing; and if the GCPs are collected from an existing map, then the process is generally referred to as image-to-map georeferencing. All GIS based softwares process only georefenced images.

Mosaicking - The study area in which we are interested may span several image files. In this case, it is necessary to combine the images to create one large file (by means of spatial extent). This process is called mosaicking.

b. *Data collection*

Sample collection - A georeferenced map was used to locate the sampling points using latitudes and longitudes. The entire study area was divided into 100 grids of 1 sq. km. area each, and two groundwater samples were collected from borewells or open wells in each grid wherever possible.

Year and Depth information - Along with the sample collection, a survey was carried out to obtain information regarding the depth of water and the year of construction of the corresponding well.

c.Laboratory Tests

Laboratory tests were carried out for the groundwater samples for the following parameters :

- Total hardness (mg/l as $CaCO_3$)
- Total alkalinity (mg/l as $CaCO_3$)
- pH
- Total dissolved solids (mg/l)
- Flourides (mg/l)

The test results were divided into 3 groups for each parameter, based on the values given in table below.

***DESIRABLE AND PERMISSIBLE VALUES OF WATER QUALITY PARAMETERS AND THEIR EFFECTS** – IS 10500 : 2009*

PARAMETERS	DESIRABLE LIMIT	PERMISSIBLE LIMIT	EFFECTS
Total hardness	300 mg/l	600 mg/l	Encrustation in water supply structure and adverse effects on domestic use.
Total alkalinity	300 mg/l	600 mg/l	Embitterment and deposition of precipitates in boiler tubes.
pH	6.5 – 8.5	No relaxation	Beyond this range the water will affect the mucous membrane and/or water supply system.
Total dissolved solids	500 mg/l	1000 mg/l	Cause putrefication and reduce palatability.
Fluorides	1.0 – 1.5	No relaxation	>1.0 causes dental carries and discoloration. <1.5 causes dental and skeletal fluorosis.

d. Vector Layer Preparation

The georeferenced spatial and attribute data were finally fed into a GIS software namely ArcGIS. As the data were collected from discrete sample locations, a suitable interpolation technique known as Krigging was employed to derive individual maps of all the parameters considered for testing for the entire study area.

Finally, all these maps were integrated to form a final groundwater quality layer that gave us the suitable locations from which groundwater could be extracted efficiently for suitable human consumption.

III. OUTPUTS PREPARED

Ground water quality map corresponding to Survey of India toposheet on 1:4,000 scale in hard copy format is the main output generated under the ground water quality mapping project. However, as different steps and processes are involved in generating this output, a number of intermediate outputs are also be generated at different stages. They are –

- Organized ground water quality data in Excel table generated from raw input data.
- Ground water sample layer showing the locations of ground water samples as point features and the ground water quality data as attribute information.
- Element-wise ground water quality layers for all the elements for which the ground water quality data is available in the given study area.
- Ground water quality layer for the given study area generated based on the integration of element-wise ground water quality layers.

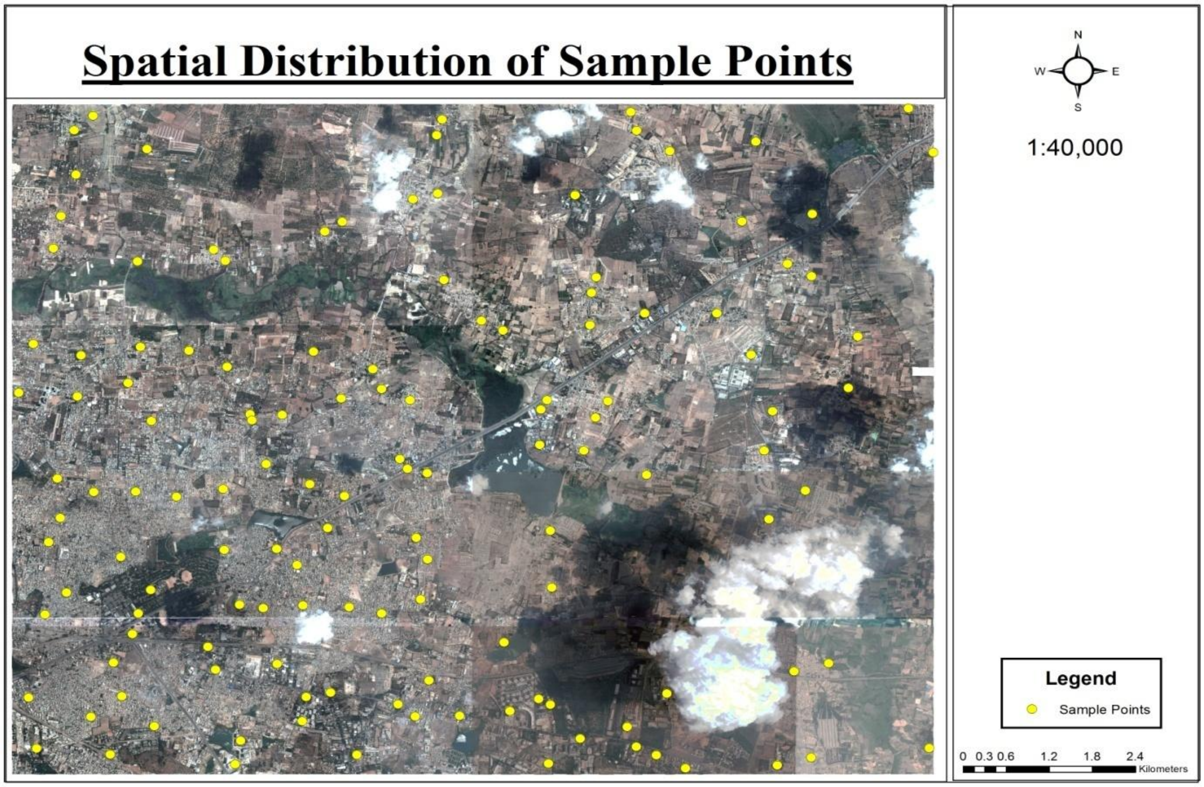


Fig 2. Spatial Distribution of Sample Points

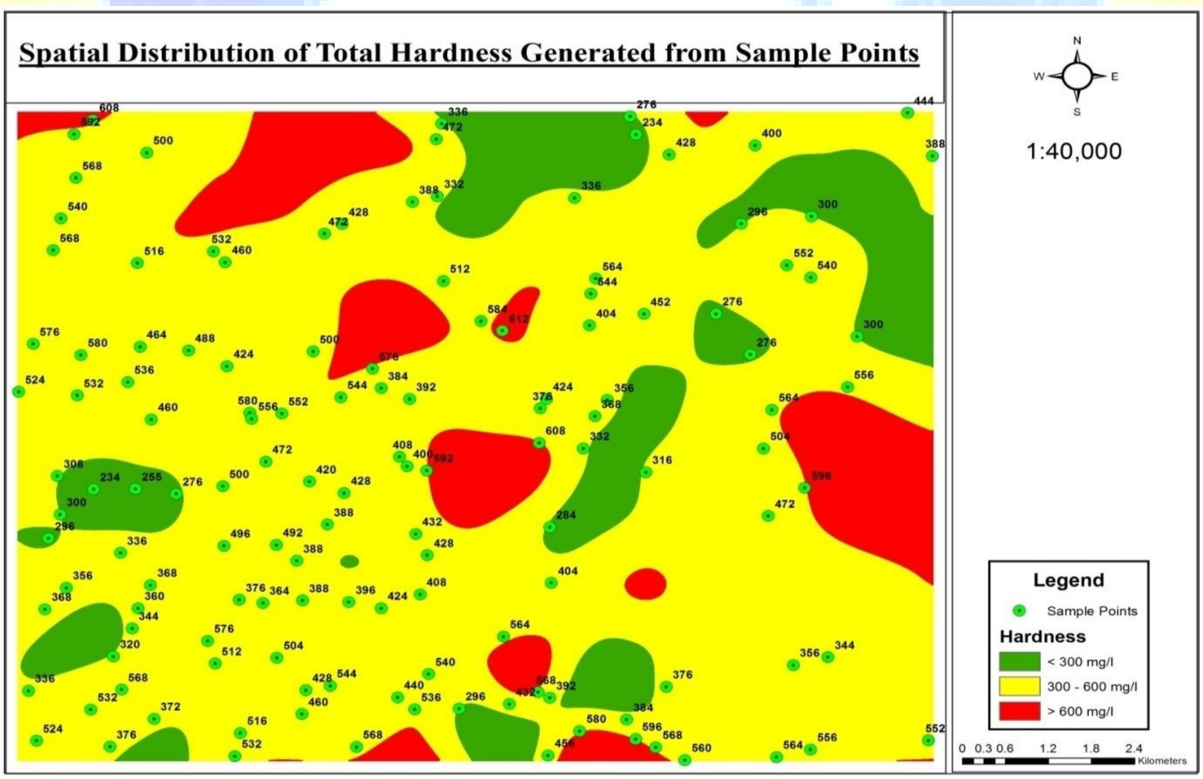


Fig 3. Spatial Distribution Of Total Hardness

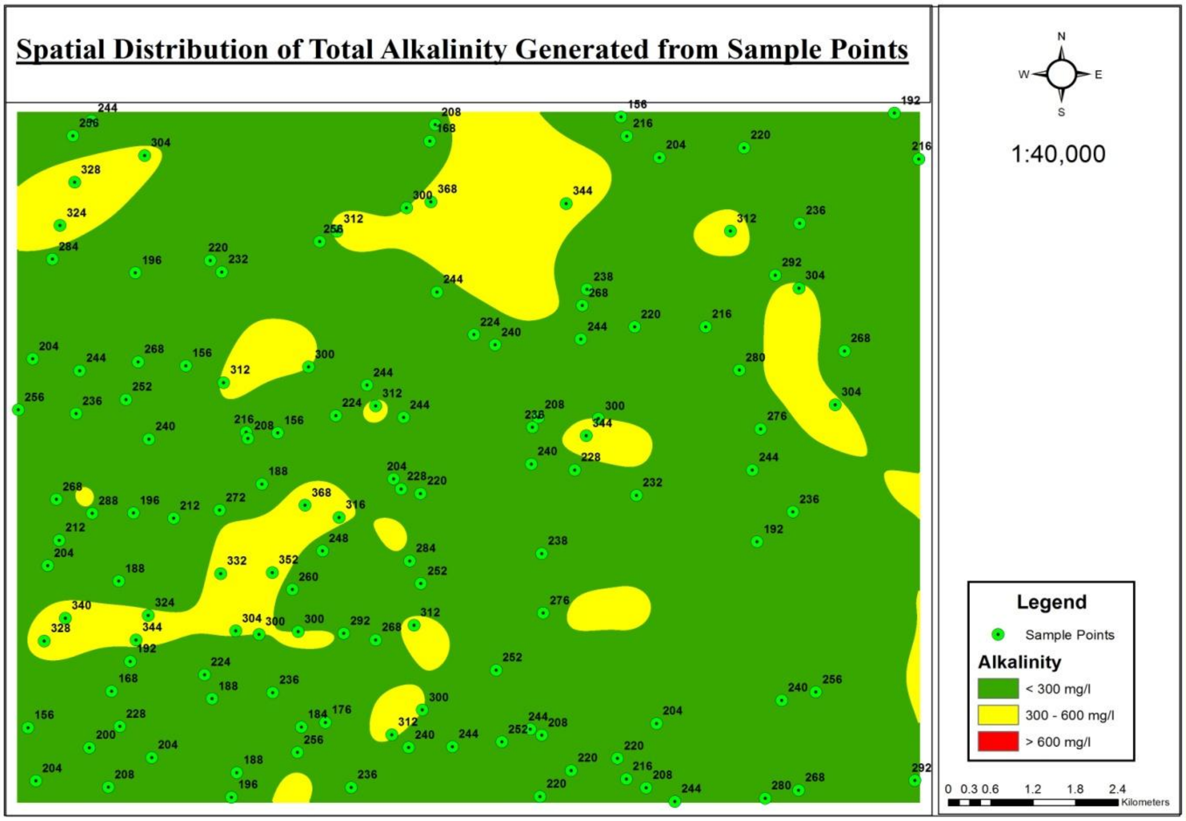


Fig 4. Spatial Distribution Of Total Alkalinity

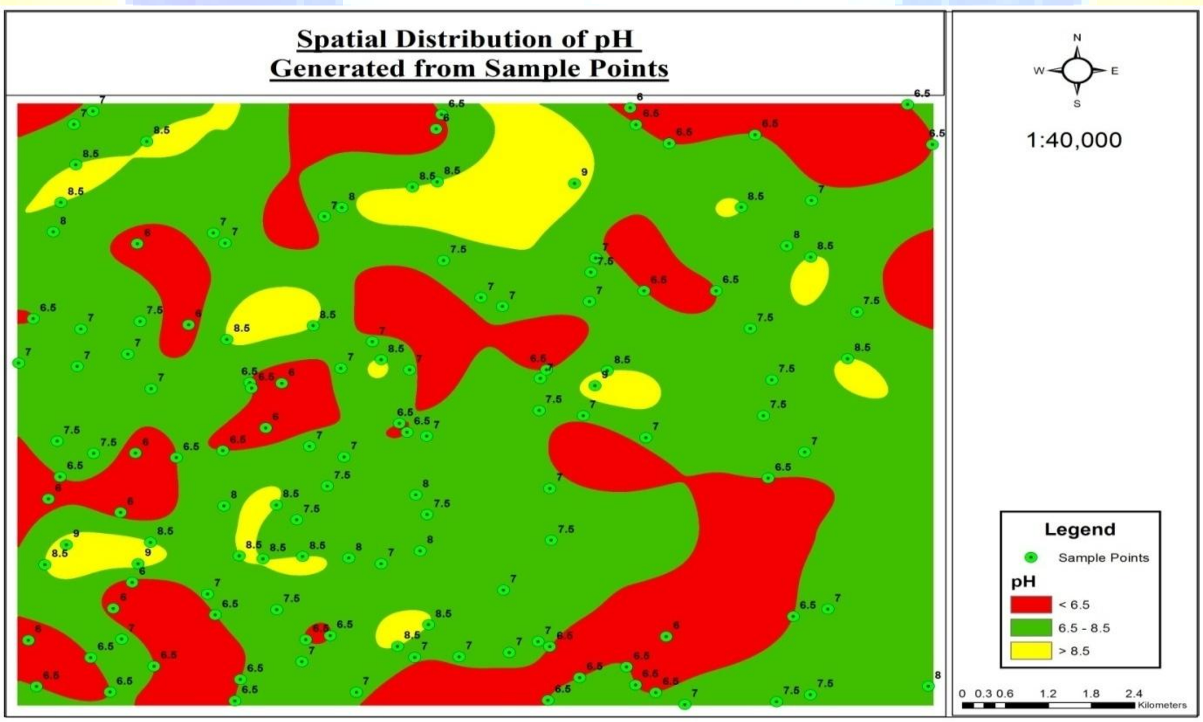


Fig 5. Spatial Distribution of pH

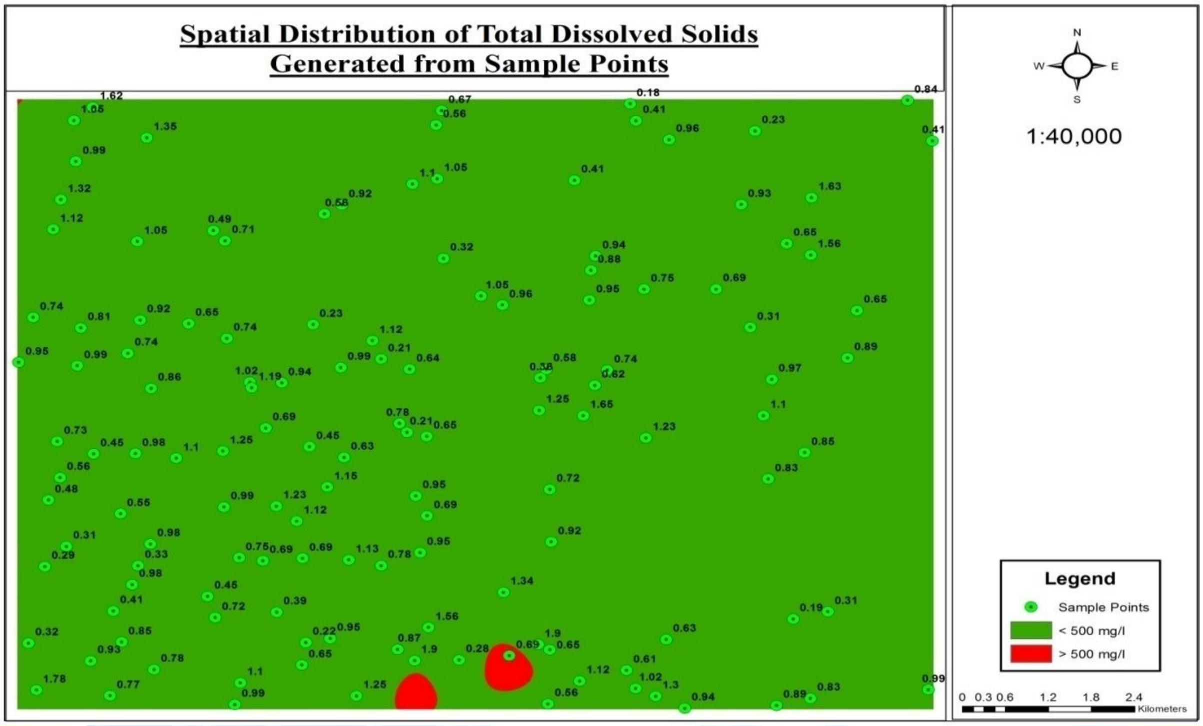


Fig 6. Spatial Distribution of Total Dissolved Solids

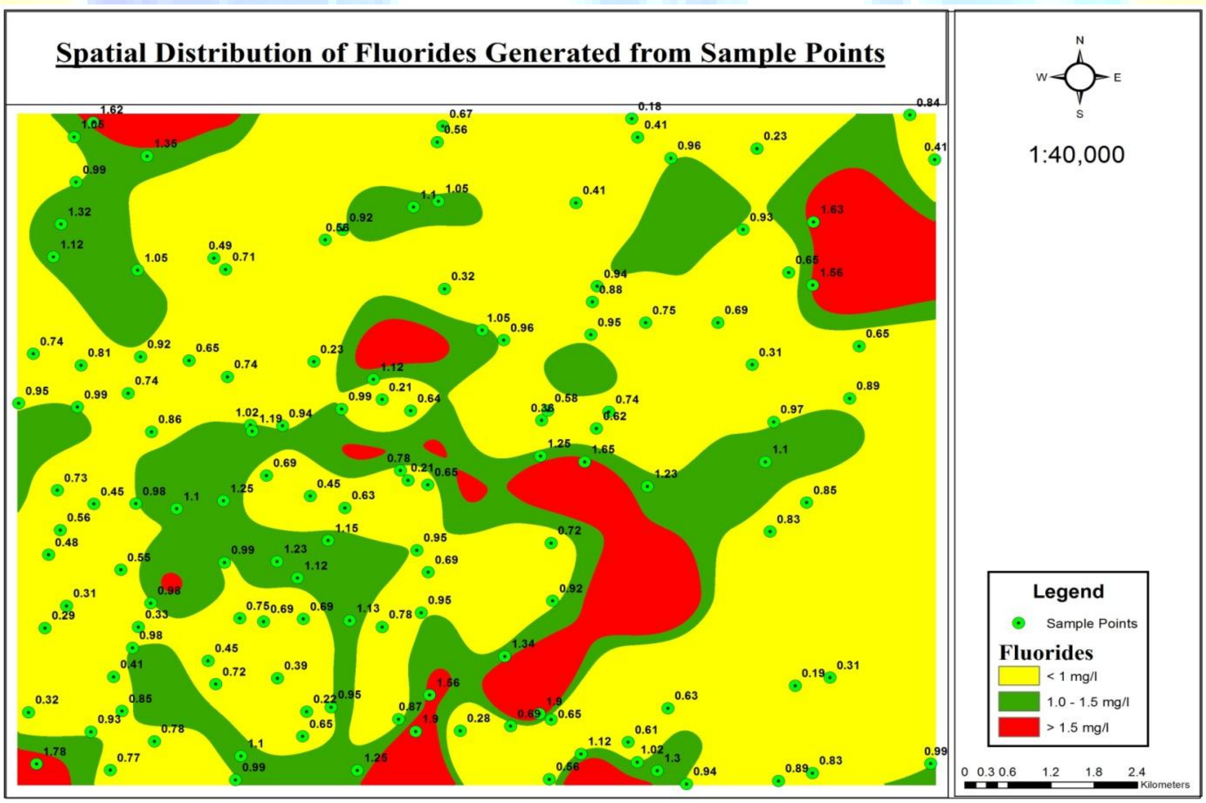


Fig 7. Spatial Distribution of Fluorides

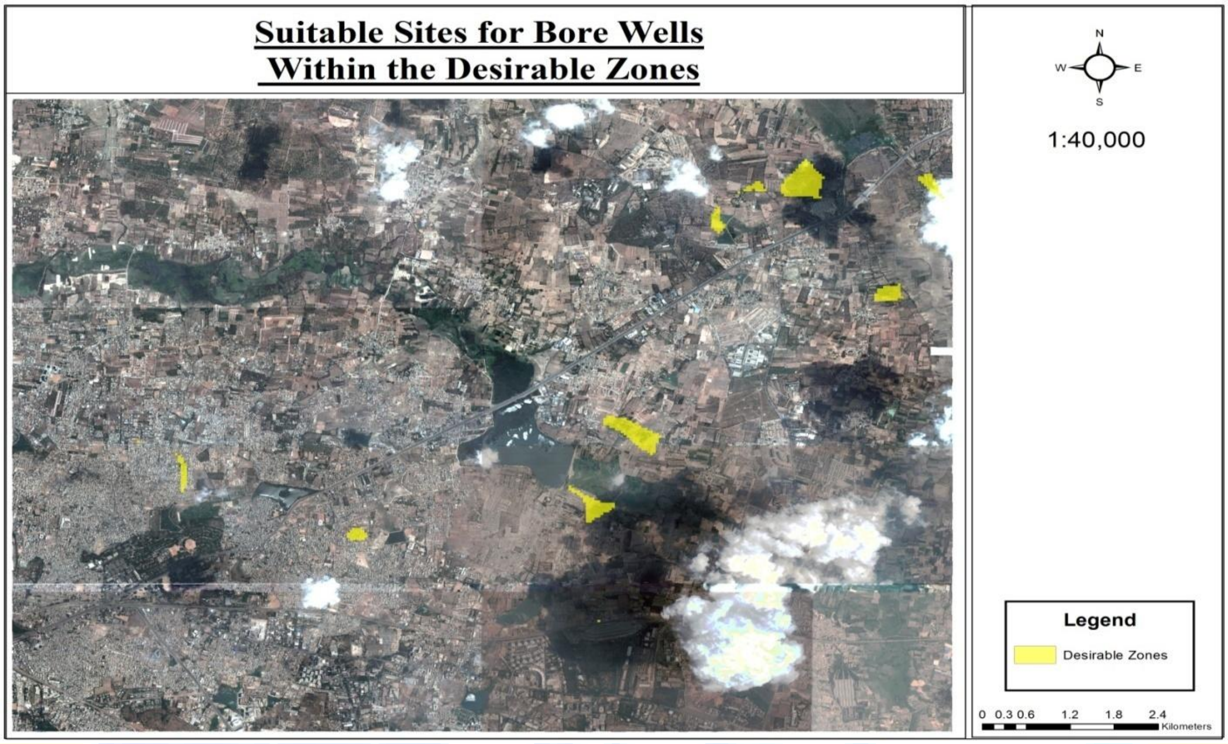


Fig 8. Suitable sites for borewells within desirable zones

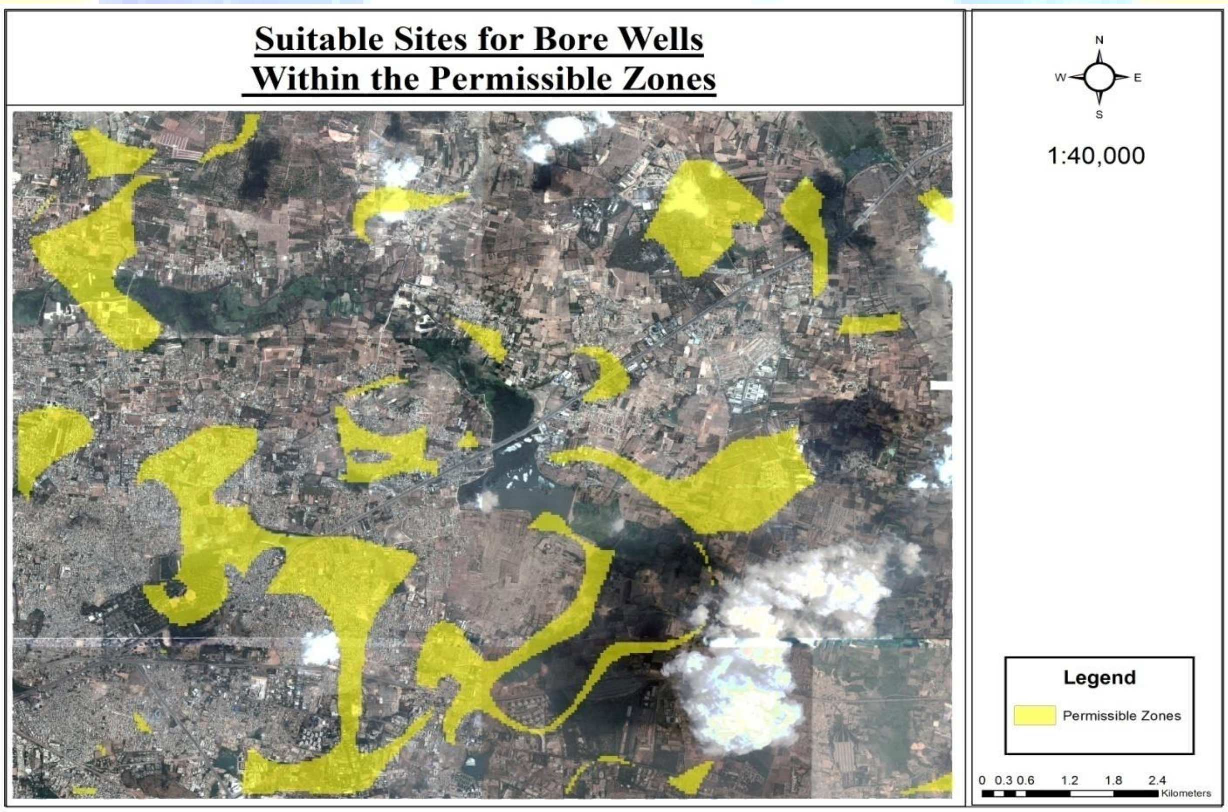


Fig 9. Suitable sites for borewells within permissible limits

IV. CONCLUSION

A total of 133 samples were collected from the entire study area as shown in fig.2.

It was observed that the hardness increased with depth. 2.26% of the samples have hardness beyond the permissible limit, with the highest value being 612 mg/l. 89.47% of the samples have hardness range between the desirable and permissible limits, and 8.27% of the samples have hardness well below the desirable limit with the lowest value being 234mg/l.

No samples were found to have alkalinity beyond the maximum permissible limit. 21.8% of the samples have alkalinity between the permissible and desirable limits, with the highest value being 368mg/l. 78.2% of the samples have alkalinity below the desirable limit, with the lowest value being 156mg/l.

3% of the samples were found to be in the alkaline range with a maximum value of 9. 87.22% of the samples have pH in the permissible range of 6.5 – 8.5. 9.78% of the samples have slightly acidic nature with the lowest value of 6.

The Total Dissolved Solids content in the water samples was found to be considerably low. Only 1 sample had a TDS value of 650mg/l, which was above the desirable limit. Rest 99.25% of the samples have TDS content well below the desirable limit.

6.02% of the samples were found to have high fluoride values, with the maximum being 1.9mg/l, which was above the permissible range of 1 – 1.5mg/l. 18.8% of the samples have values within the permissible range, while 75.08% of the samples are below the permissible range,with the lowest value being 0.18mg/l. Also, at certain points having proximity to water bodies, the fluoride content was found to be more.

Incorporating all the above details in the GIS database, individual element wise groundwater maps have been created (fig.3 –7). Integrating all the individual maps in one vector layer, it is seen that the locations meeting all the necessary desirable limits is considerably less, as shown in fig.8. However, if we take into account the permissible limits, the locations suitable for extracting groundwater for human consumption, is comparatively more, and is as shown in fig.9.

Also, it is noticed that the level of groundwater in the study area is getting depleted at an alarming rate. A 3D profile has been created to demonstrate the depletion of groundwater table with time.

V. REFERENCES

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