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Groundwater Potential of a Fastly Urbanizing Watershed in Kerala, India: A Geospatial Approach

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Abstract: The 6th order watershed, which hosts Thiruvananthapuram, the capitol city of Kerala State, India, has been studied in terms of groundwater potential, employing Geospatial Technologies. The watershed receives an average annual rainfall of 2600 mm. Geologically, the major part of the watershed is characterized by Khondalites, Charnockites and Migmatites of Archaean age, and the remaining by Tertiary sedimentaries, Miocene and Holocene formations. All these rocks are extensively lateritised. Geomorphology, geology, drainage, fracture systems in hard rocks and the slope of the terrain play a significant role on the accumulation and movement of groundwater in the watershed. The integration of these datasets has been accomplished through Geospatial technology. The basin area has been categorised into four zones, namely, Very high, High, Moderate and Low in terms of groundwater potential. It is estimated that about 35% of the watershed, comes under the very high to high category in terms of groundwater potential and is confined to the less inhabited upstream reaches. Low groundwater potential category dominates in the watershed which covers 40% of the area characterized by Built up Area, evidently due to the urbanization.

Key words: Watershed, Groundwater potential, Spatial Information Systems, Urbanization

I. INTRODUCTION

Owing to the rapid economic growth and consequent development, the need for developing water resources has become more pressing than ever before. Water is going to be one of the major issues confronting humanity in the coming decades. The state of Kerala is known for its lush green landscape, evergreen forests, serene water bodies, ponds, springs and wells. The major freshwater resources are surface runoff (mainly river discharges) and groundwater (wells or springs). Despite all these facts, the condition of Kerala is precarious with regard to drinking water potential. Even though the state receives heavy rainfall, the shortage of drinking water is alarming during summer months, and then the only source is groundwater. Dug wells are the major ground water extraction structures in Kerala. Almost every household has a dug well on which people are dependent for drinking and other domestic purposes (CWRDM, 1995).

The watersheds or drainage basins should be the unit for better understanding of the hydrologic system as well as accurate assessment of the available resources (Narasimha Prasad et al., 2013, Arun et al., 2014). Over the past three decades, remotely sensed data have been increasingly used in groundwater studies (Jackson and Mason 1986, Star and Estes 1990, Baker and Panciera 1990, Sreedevi et al. 2005, Dinesh Kumar et al. 2007; Narasimha Prasad et al., 2013; Arun et al., 2014, Sreeja et al., 2015). For groundwater prospecting it is necessary to integrate data on various characteristics like topography, lithology, geology, lineaments, structures, depth of weathering, extent of fractures, slope, drainage patterns, etc.The use of remote sensing techniques in combination with geospatial systems aid in integrating these data sets in a very convenient manner, thereby facilitating quick decision support. In this context, the present study has been taken up with catchment as the unit in the watershed of the Thiruvananthapuram City, the capital of Kerala.

II. MATERIALS AND METHODS

The available data on geology, hydrogeology, geomorphology, landuse/landcover, borehole lithologs, water level fluctuation, pumping test results, rainfall and other related and relevant data were collected from different agencies/publications and were suitably processed using modern statistical and spatial analysis tools. Survey of India toposheets, satellite imageries, ASTER Digital Elevation Model (DEM) and aerial photographs have been used to demarcate various geomorphological units and distribution of lineaments in the basin. Thematic map layers like drainage, geology, watersheds, geomorphology, land use and lineaments were prepared using SOI toposheets, IRS LISS III Imagery, Landsat Imagery and ASTER DEM. Derived map layers like slope, drainage density and lineament density were prepared using the spatial analysis tools in GIS environment. All the maps were geo-referenced to the Universal Transverse Mercator (UTM) plane co-ordinate system. The entire base maps were transformed to a common format for further analysis and identification of groundwater prospect zones (Dinesh Kumar et al, 2007, Arun et al, 2014). This output map is correlated with the groundwater data collected in the field. Details of aquifer parameters have been taken from the publications of Central Ground Water Board (CGWB) and CWRDM. Datasets collected from the Ground Water Department (GWD), Government of Kerala, were also used for this study. All of this information has been integrated in GIS environment by assigning weights and ranks to understand the characteristics to demarcate groundwater potential zones. The above results have been integrated to determine the conditions in the watershed in terms of groundwater potential and development prospects. The resultant composite coverage was classified into four groundwater prospect categories such as (i) very high (ii) high (iii) moderate and (iv) low.

III SALIENT FEATURES OF THE AREA

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Study area, the watershed hosts Thiruvananthapuram City. is in the Karamana river basin, and is located between north latitudes 8°26' and 8°40' and east longitudes 76°56' and 77°03' (Fig.1) with a drainage area of 97 km^2.

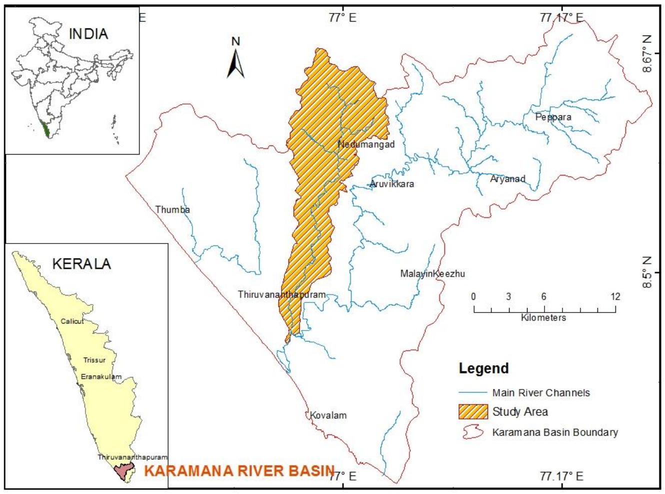

Fig.1 Location map of the Study area

The watershed is oriented North-South from the origin to the confluence with Karamana river. Physiographically the watershed is characterized by, lowland in the south (between MSL and 7.5 m AMSL), The midland region (7.5 – 75 m AMSL), mostly covered by laterite, in the central portion and the highland in the north (>75 m AMSL), comprising the foot hills of Western Ghats, covered by crystalline hard rocks (Arun, 2006).

The watershed receives an average annual rainfall of 2600 mm. While the southern part of the basin receives less than 1400 mm of rainfall, the northern portion receives rainfall of about 3000 mm. The study area receives rain in all the seasons (Eapen et al., 2000).

The basin is characterized by dendritic to sub-dendritic drainage pattern with variable density. Angular joint/fracture controlled drainage is also observed. The densest dendritic pattern is developed on the hard crystalline rocks (Strahler, 1957). The main channel is a 6th order stream. The morphometric analysis carried out under this study has revealed that the drainage density varies between 0.002 to 5.2 km/sq.km depending on the geological and geomorphological setup at different locations within the watershed.

IV TERRAIN CHARACTERISTICS

Geologically, nearly 90% of the study area is composed of garnetiferous-biotite-sillimanite gneiss with or without graphite (khondalite). The remaining area is composed of garnet-biotite gneiss with associated migmatites, quartzo-feldspathic-hypersthene granulite and garnetiferous granite gneiss. These rocks are intruded at many places by acidic (pegmatites and quartz vein) and, basic (gabbro and dolerite) rocks (GSI, 1995). In addition to these, a few patches of Quaternary sediments represented by pebble beds, sand and clay deposits are also reported. A peat sample collected from a sand mining pit at Changa at a depth of 2.5 m below ground level is C14 dated at 3300±90 years before present (ybp) (Arun, 2006). This is clear evidence for the occurrence of Late Quaternary (Holocene) sediments in the study area. Subsurface lithological details were gleaned from the already available data on bore wells and from the observations made in the field from existing dug wells in the study area. . The alluvial deposits are followed by laterites, lithomargic clay, weathered rock followed by hard rocks. In the midland region lateritic soil tops the sequence and in the highland region, brown soil tops the same sequence with variable thickness. The depth to bedrock varies between 4 to 28 m below ground level.

Most of the lineaments are found to follow linearly arranged valleys and hence hold potential for groundwater development. The major direction of lineaments is N-S and other directions are NW-SE and to a lesser extent NE-SW. It is observed in some places that the lineaments intersect each other and such areas are expected to be more favourable for groundwater development (Sekhar, 1966; Narasimha Prasad et al., 2013).

Through remote sensing, various hydrogeomorphological features within the basin have been identified. Based on the relationship among topography, lithology and drainage, the study area has been classified into different hydro-geomorphological units such as lateritic uplands, buried pediments, alluvial plains, and flood plains. In the structural hills, the chances of occurrence of groundwater depend on the fracture system. Valley fills are considered as potential zones for groundwater exploration (Arun et al., 2014).

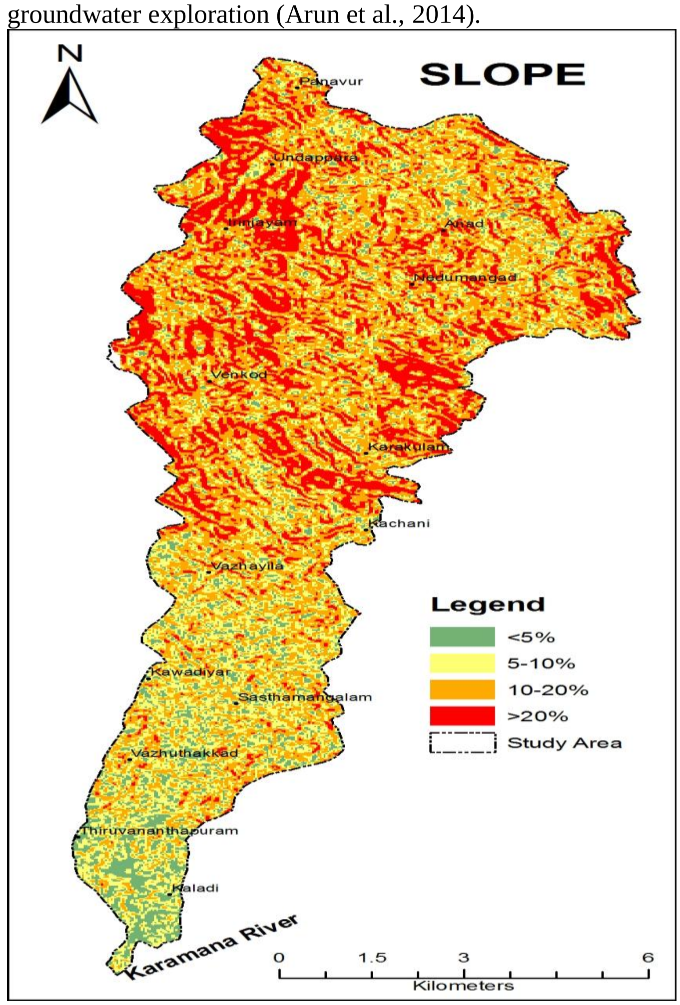

Fig. 2 Slope of the study area.

Using the DEM of 30 m ASTER data, it was found that the areas with a slope of >20% covers 23% of the watershed (Fig. 2). In the preparation of groundwater prospecting maps, more weight is given to gentle slopes since slope plays a significant role in infiltration verses runoff (Sarkar et al., 2001). As infiltration is inversely related to slope, a break in the slope (i.e. steep slope followed by gentler slope) promotes appreciable groundwater infiltration.

Landuse/landcover describes how a parcel of land is used for agriculture, settlements industry etc., or refers to the material on land surface such as vegetation, rocks or water bodies (Anderson et al. 1976) and it plays a significant role in the development of groundwater resources as well as the replenishment of groundwater. In this study, the landuse map is taken as one of the thematic layers for preparing groundwater potential zones. Least ranking is given to the mining, built-up and industrial areas, whereas the highest is given to river sand, river channel and water body.

V HYDROGEOLOGICAL CONDITIONS

Observation wells were established in such a way that different physiographic regions are represented and wells are equally distributed. Based on these criteria, 20 wells were established in the study area and the depth to water level seasonally monitored for almost two consecutive years. The water level fluctuation between post-monsoon and pre-monsoon periods is more important than the annual water level fluctuation for groundwater development and management purposes, as these values reflect the effective groundwater recharge due to rainfall.

The ground water in the watershed mainly occurs under phreatic semi-confined and confined conditions. In the alluvium, laterite, weathered and fractured rock, groundwater occurs under phreatic condition and in deep seated fractured crystalline rocks, it occurs under phreatic or semi-confined or confined conditions depending on the overlying lithomargic clay formation.

In alluvium, dug wells and filter point wells are used to extract groundwater. The dug wells are usually pumped at discharges between 30 and 265 lpm, but, it sustains for 30 to 60 minutes only during summer. Laterites are highly porous but the permeability depends on the texture and clay content. Large diameter dugwell is the typical groundwater extraction structure in this terrain and discharges between 110 and 200 lpm and sustain pumping for 30 to 60 minutes during summer. In most cases, the full recovery takes place within 12 hours. In weathered rocks, usually large diameter dugwells are the typical groundwater extraction structures. In the semi-confined to confined aquifers bore wells are the typical groundwater extraction structures. Yield ranges of majority of the established borewells are between 1000 and 3000 lpm and the depth ranges between 30 and 120 m below ground level.

VI GROUNDWATER POTENTIAL ZONES

Integrating all the above information into a spatial information system with geology, geomorphology, land use, drainage, slope, lineament intensity, aquifer parameters, ground water level fluctuation and saturated thickness, the watershed hosts Thiruvananthapuram City has been classified into different groundwater potential areas, viz VERY HIGH, HIGH, MODERATE and LOW using overlay analysis tools in Geographical Information System (Fig.3). This can form the basemap for the concerned authorities to take necessary decisions as well as actions for the development of groundwater in this basin in the future.

7. CONCLUSIONS

The present study establishes the significance of spatial data integration in identifying groundwater potential zones and thus the use of remote sensing as well as spatial information systems to achieve the data integration effectively. Valley fills and pediments of the basin are found to be favourable geomorphic units for groundwater exploration and development, whereas structural hills, residual hills, residual mounds, and linear ridges are of poor groundwater potential. Hydrogeomorphology, lineament and slope play vital roles in the occurrence and movement of groundwater in the study area. Landuse plays an important role in the case of groundwater recharge and potential. Based on these parameters, the basin area has been categorised into four zones, namely, Very high, High, Moderate and Low in terms of groundwater potential. The downstream portion of the watershed is dominated by Low to Moderate groundwater potential zones whereas the Middle and Northern portion of the basin is dominated by High to Moderate groundwater potential zones. It is estimated that about 35% of the basin, which belongs to the cultivated and inhabited land use, come under the very high to high category in terms of groundwater potential. Low groundwater potential area is dominant, covering 40% of the area. This unit is dominated by Builtup Area. The moderate category covers about 20% represented mainly by plantations. This suggests that the urbanization causes an increase in impervious surface area, which in turn, decreases the ground water recharge as well as groundwater potential.

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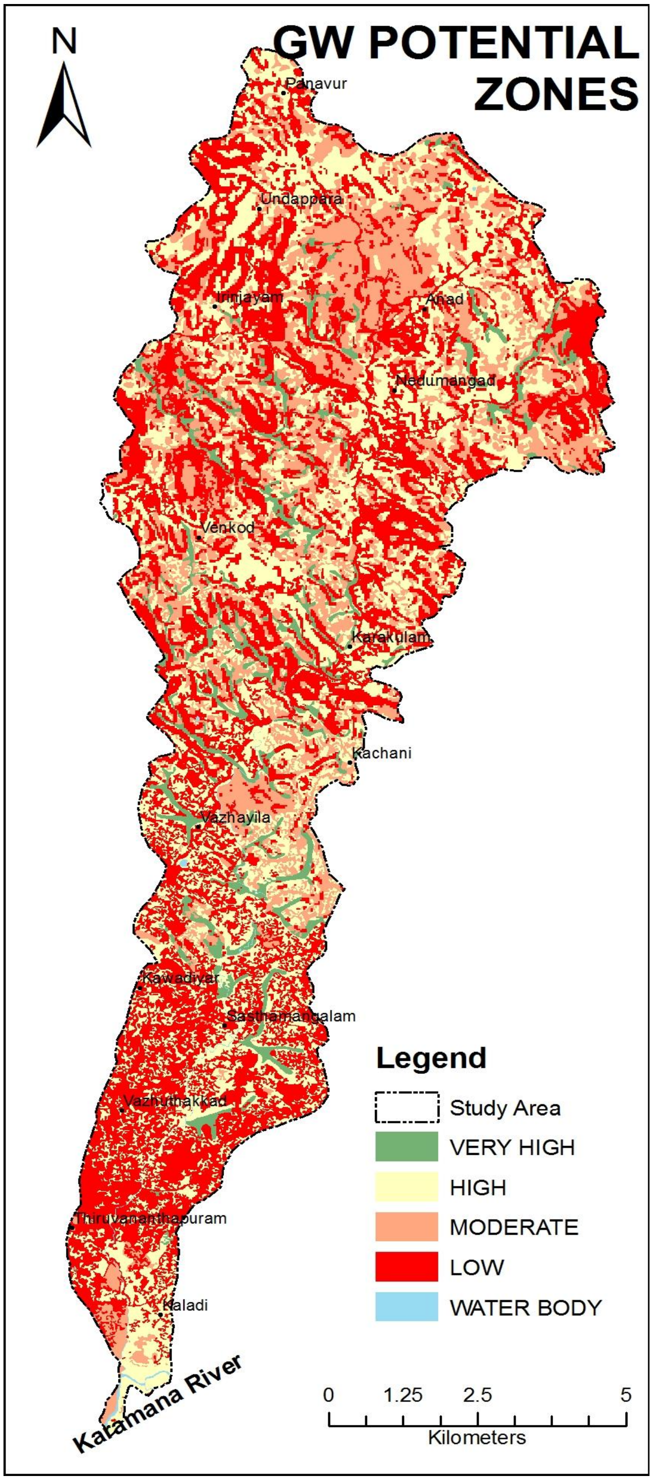

Fig. 3 Groundwater potential zones

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