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Deciphering Groundwater Potential Zones in Dandavathiriver Basin of Sorab Taluk, Shivamogga District Using Remote Sensing and Gis

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Abstract* - Water is a vital resource for sustenance of life and economic development of a region. Increase in population, trade and industry have resulted in increased demand for fresh water and more than 90% of the people depend on ground water resources. In hard rock terrain, occurrence of groundwater depends on various geo-environmental parameters such as lithology, lineament, slope, hydro geomorphology, land use and land cover, water level fluctuations, rainfall, soil and drainage density. Therefore, an attempt is made to identify the ground water potential zones in Dandavathi basin of Sorab taluk in Shimoga district, Karnataka by integrating various geo-environmental limitations using multi criteria evaluation technique on GIS platform. Based on the results, the groundwater potential zones in the basin have been grouped into (a) Very Good (7.18 %) (b) Good (13.33 %) (c) Moderate (25.97 %), (d) Poor (39.49%) and (e) 14.01 % is Very Poor zones.

I. INTRODUCTION

Ground water is a dynamic and replenishable natural resource. However, in hard rock terrain, availability of groundwater is of limited and its occurrence is confined to fractured and weathered zones (Saraf and Choudhury, 1998). It is a well-established fact that in any region geology, geomorphology, lineament, soil and the terrain parameters have a direct bearing on the occurrence and movement of groundwater. Therefore, for assessing groundwater potential of an area, it is necessary to understand the landforms, soil and rock types, structures and their characteristics, normally, these details are obtained through conventional methods like ground based survey and mapping. On the other hand, in recent times, manyresearchers obtain all the spatial information from remote sensing techniques and integrating the same on GIS platform to delineate groundwater potential zones (Krishnamurthy and Srinivas, 1995, Jothiprakash, V, et al 2003, Amareshsingh, et al, 2003, Sikdar, et al, 2004, Chakraborthy et al. 2004, Deota et al, 2005 and Acharya.T, et al, 2005). In the present study, an attempt has been made to assess the groundwater potential zones of Dandavathi river Basin for future development by multi criteria techniques.

2. METHODOLOGY

The satellite data (IRS-1D, LISS–III geocoded FCC dated,16th Nov 2000, 11th Dec 2000, 08th Jan 2001 and 24th Dec 2001) at 1:50,000 scale was visually interpreted to delineate various geomorphological units based on structural trends, lineaments, soil tones, vegetative cover and relief linearity, SOI topographic maps were used to prepare slope and stream order units. The water-level fluctuation in dug wells were monitored for pre- and post-monsoon seasons from a network of 15 wells uniformly spread over the area during 1985-2006, representative wells in various lithologies were selected. Isohyets were drawn using rainfall data of 25 years (1985-2006). Lithology units were delineated using Geological map of Karnataka prepared by Geological Survey of India at 1:250,000 scales. A combined map of the features (geomorphology, soil, slope, water levels fluctuation, streams, rainfall, lithology, land use and land cover, rainfall and drainage density,) was prepared to correlate them with groundwater availability in different zones.

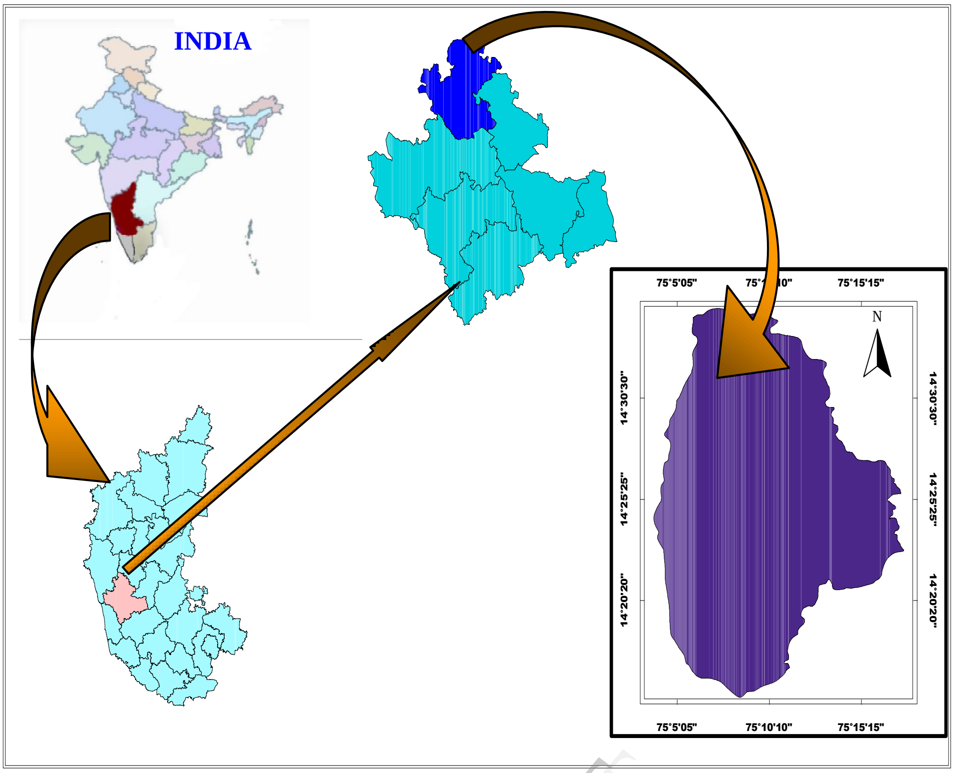

Fig.1Location Map of the study area

3. STUDY AREA

River Dandavathi, a sub tributary of River Tungabhadra, , takes its origin at Honnavali near Ulvi in Sorab taluk of Shimoga District, flowing towards north west direction before confluencing River Varada near Bankasana. Geographically the study area extends from 75^0 03' 18.62" to 75^0 18' 4.41" E longitude and 14^0 15' 25.60" to 14^0 35' 2.54" N latitude, in Survey of India (SOI) toposheet numbers 48 N/2, 48N/3, 48N/4 and 48N/7 covering about 620 sqkms. (Fig.1) the study area is characterised by a very gently undulating topography and elevation varies between 540 and 846 m above MSL. The area experiences hot and dry summer and cold winter. The annual average rainfall is 1392 mm and the major part of it occurs between early June and September.

4. RESULTS AND DISCUSSIONS
GEOLOGICAL SET UP

Geologically the area forms a part of Shimoga Schist belt of western Dharwar craton, principally comprised of greywacke, argillites, quartz-chlorite schist with orthoquarzites, ferruginous cherts and laterite (Radhakrishna and Vidyanadhan, 1994; Ramakrishna, 1994) (Fig. 2).

Gneisses are tonalitic-trondhjemite-granodioritic in composition and form a basement for the wide spread schists, phyllites and greywacke, Greywacke and argillites are one of the most important lithounits of the study area, these rocks are highly weathered, fractured and jointed to the extent of an average up to 50 – 60 feet deep from the surface, having strike of NNW-SSE to NW-SE with steep dip towards east. Joints are spaced at 2 to 3 feet intervals, are open in the upper level, but closed at depth. In this unit, the possibility for occurrence of groundwater is very moderate to good. Quartz chlorite schist is greenish in colour exhibit good schistose having strike of NW dipping 35^0 E, confined southern part of the basin. Ferruginous cherts occur as marker horizons having general strike NW-SE and dipping westerly in varying angles. In these units the possibility for occurrence of groundwater is very poor to moderate.Laterites which are insitu in nature, reddish, pervious soft, when it is fresh and hardened on exposure, these are exposed in huge pockets in the central and southern part of the basin. It is a good aquifer, because of its porous/concretionary nature, which helps in holding and transmitting water.

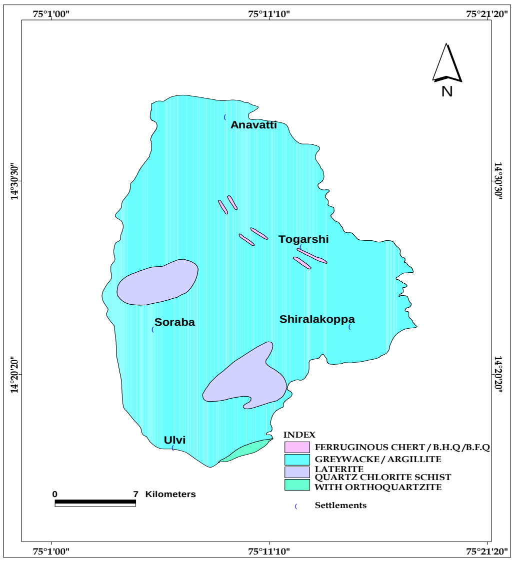

Fig.2 Lithological map of the study area

5 GEOMORPHOLOGY

The geomorphology of the area is highly influenced by the lithology and structure of the underlying formations. IRS 1D LISS III + PAN data of Nov. 2000, Dec. 2000, Jan. 2001 and Dec. 2001 are used to delineate geomorphological units in the study area. The geomorphological map of the study area was prepared based on standard interpretation techniques (Fig. 3). The different types of geomorphological units such as structural hills, residual hills, pediplain shallow weathered, pediplain moderately weathered lateritic plain shallow and valley fills are delineated. Detailed description of each unit and their ground water prospects are given below

Residual hills:Residual hills were identified along the central and south western parts of the study area where the rainfall is high. These are isolated low relief, irregular outlines standing out predominantly, and they appear as isolated hills or continuous chains of hillocks formed due to differential erosion. These regions are very poor in ground water potential due to steep gradient of the landforms where the surface runs off in more than the rate of infiltration.

Structural hills: Structural hills are the linear arcuate hills exhibiting definite trend lines structurally controlled with complex folding, faulting and crisscrossed by numerous joints/fractures. These units are found in the south western part of the study area, only along these joints/fractures, some infiltration takes place and the rest of the area act as runoff zone. The possibility of ground water occurrences is very poor.

Inselbergs:Inselbergs are theisolated regular uplands standing above the general level of the surrounding plains in tropical regions, formed due to the residual isolated hill stand above the ground level of surrounding pediplain, normally barren and rocky, the structure of inselberg is varying lithology, the ground water prospecting is poor. In this unit, the possibility of ground water occurrences is moderate, in this unit.

Pediment:Pediment are undulating or sloping rocky surface resulting from pediplanation of rocks often covered by a thin layer of soil and occurring at the transition zones found in the southern part of the study area. This unit generally acts as run off zone and recharge zone wherever fractures and their intersections are present and offer scope for ground water storage,

Pediment Inselberg Complex: Pediment/Inselberg complex are undulating plains dotted with small hills and mounds which survived by denudation process. A thick veneer of detritus generally covers this unit over pediment, which normally acts as runoff zone, possibility of ground water occurrences is moderate to good.

Pediplain moderate:Pediplain moderate units are soil/weathered material occupies gently sloping plain terrain on 5 – 10 m thick overburden of weathered mantle materials of smooth surface is classified as moderately weathered pediplain. These areas are almost covered by vegetation indicating good ground water potential zone. These units are found in the western part of the study area.

Pediplain Shallow:Pediplain shallow are gently undulating plains formed by coalescence of different pediment together, having thickness of about 0-10m. It is highly permeable zone having very good groundwater prospects.

Valley fills: Valley fills consisting of silts and clays deposited by fluvial action along the valley floor acts as a good recharging zone and forms a very good ground water potential zone. This unit covers 16.32 per cent of the area.

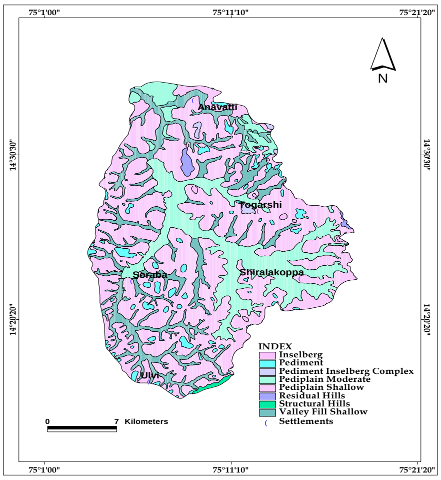

Fig 3 Geomorphological map of the study area

6 SLOPE

Slope is one of the important terrain parameter controlling the infiltration of groundwater into subsurface; hence an indicator for the suitability for groundwater prospect. In the gentle slope area the surface runoff is slow allowing more time for rainwater to percolate, whereas high slope area facilitate high runoff allowing less time for percolation of rainwater hence comparatively less infiltration. The guidelines given by NRSA (1995) have been adopted for classification of slope into different categories. The slope map was prepared using topographical and satellite data. Slope map of the area as shown in (Fig.4) indicates that it varies from 0–1 to more than 35%. The slope class have classified into seven categories, i.e. 0–1, 1–3, 3–5, 5–10, 10–15, 15– 35 and more than 35%. Most of the area belongs to gently sloping (3-5%), nearly level slope (0-1%) and very gently slope (1-3%) classes. Since, slope is also a criterion for infiltration of precipitation, most of the area has favorable slope from groundwater potential point of view.

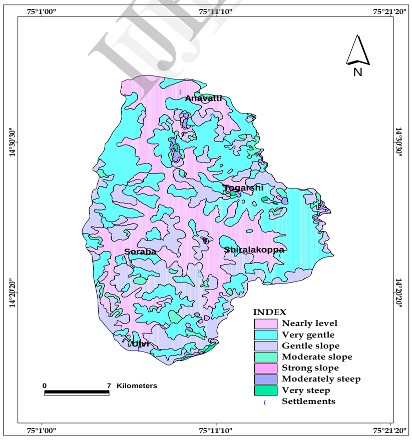

Fig.4. Slope map of the study area

7 LINEAMENTS

The lineaments are linear or curvilinear features and play a vital role particularly in geomorphic and structural analysis. Lineaments like joints, fractures etc, developing generally due to tectonic stress and strain, provide important clues on surface features and are responsible for infiltration of surface runoff to sub surface and for movement and storage of ground water. Subba Rao, N., and Prathap Reddy. R., (1999).The Dandavathi river basin is criss-crossed with a number of lineaments identified based on their association with surface features like drainages, vegetation, hills and valleys. Concentration and intersecting of lineaments are considered as good potentials for ground water targeting, as they reflect high porosity and permeability of the underlying materials. These linear features were categorized into major (more than 3 km) and minor lineaments (less than 3 km). The lineaments were found to trend in N-W, NE-SW, and NW-SE direction. Most of the lineaments are aligned along with the streamlets in the northern part of the basin and some identified in residual hills and valley fill zones in southern part of the basin (Fig. 5).

8 RAINFALL (ISOHYETAL):

Rainfall is the main recharge source of groundwater the amount of precipitation in the basin, as a function of time is highly variable and distribution in space is uneven. Mean annual rainfall of the fifteen rain gauges station located in the study area is used to generate the rainfall distribution layer through GIS interpolation (Fig.6).

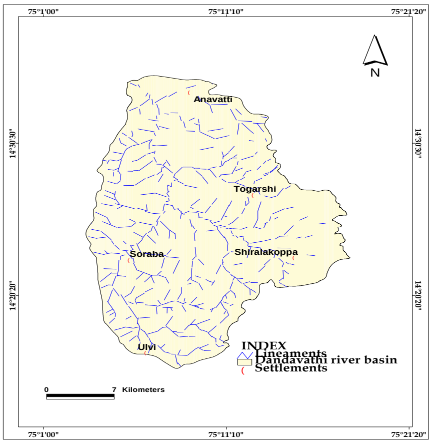

Fig.5 Lineament map of the study area

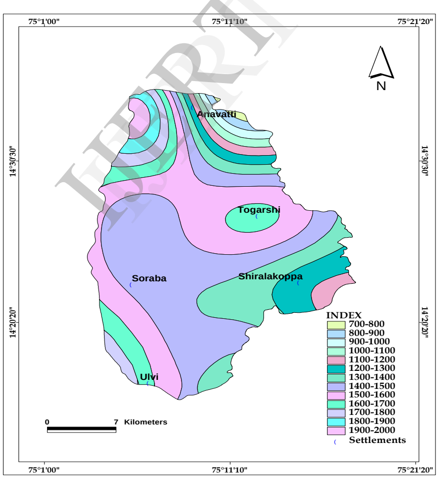

Fig.6 Rainfall map of the study area

9 BUFFERED DRAINAGES

Survey of India topomaps were used to prepare the streams units, the number of stream segments are counted and measured, Stream order designation is the first step to index the size, scale of the basin and amount of stream flow. In the present study, ranking of streams has been carried out following a method proposed by Strahler (1964). DandavathiRiver is a 5th order basin. The stream segments according to the stream orders are buffered with respect to the ground water potentials (Fig.7)

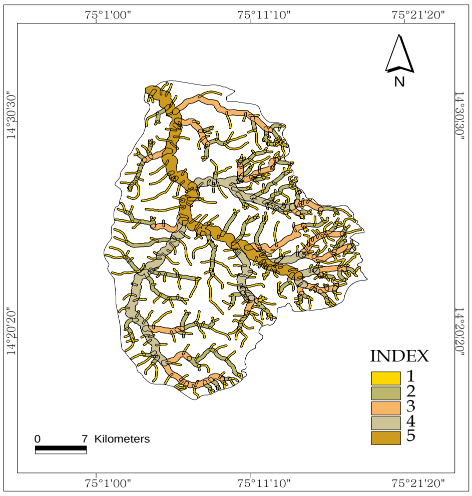

Fig.7 Buffered drainages of the study area

10 LAND USE ANDLAND COVER

Land is the most important natural resource on which all man's activities are based. Information on existing land use/land cover and pattern of their spatial distribution forms the basis for any development planning. The land use/land cover of the study area have been traced from the satellite data of IRS1D-LISS III Imagery of false colour composite (FCC) in conjunction with collateral data like topomaps. Image interpretation elements like tone, size, shape, texture, pattern, association etc were used in the identification of various land use /land cover, classes like built-up land, agricultural land (crop land), fallow land, plantation, forest (evergreen/semi-evergreen, deciduous, scrub etc.,) wastelands land, gullies/ravenous land, barren rock/stony waste etc., water bodies (rivers, streams canals, lakes etc.,) were delineated and calculated for the basin(Fig.8)

Settlements:

Settlements are the area habituated by human beings, this include villages, towns, building structures etc.,

Agricultural land

Agricultural lands are the lands primarily used for farming and for production of food, fibre, other commercial and horticultural crops. The chief indication of agricultural activity will be distinctive geometric field and road patterns on the landscape. Agriculture is mainly confined in depressions, along gentle slopes and valley sides wherever water source and soil conditions are favourable for good groundwater prospects. It includesKharif, rabi, double crop (irrigated and un-irrigated), fallow, plantations etc.

Forest

It is an area bearing an association predominantly of trees and other vegetation types capable of producingtimber and other forest products. Forest, where the vegetation density cover is 40% or more is called Dense closed forest (Evergreen, Deciduous forests) and if it is between 10-40% is called scrub and/ or open degraded forests. In the present study, forest class identified includes evergreen, deciduous, degraded forests and forest plantations, showing that the groundwater prospecting is very good to good.

Wastelands:

Wastelands are described as degraded lands, these area formed from result of inherent/imposed, disabilities such as locations, environment, chemical, and physical properties of the soil or financial management constraints (NWDB, 1987). Wastelands include marshy/swampy land, land with or without scrub and barren rocky/stony waste/sheet rock area, showing poor to very poor groundwater prospecting.

Water bodies

It is an area of impounded water in the form of ponds, lakes, and reservoirs or flowing as streams, rivers, canals, etc., it includes manmade reservoir/lakes/tanks/canals. These acts as a source for irrigation, power generation, and flood control .these area constitutes very good groundwater potential areas.

Others

These are the areas, which are of specific, or with limited areal extent in the over all context of the total land use and land cover conditions. These include grasslands/grazing land, mixed vegetation, habitat with vegetation, mixed vegetation, and tree groves. These areas constitutes good to very good potential areas.

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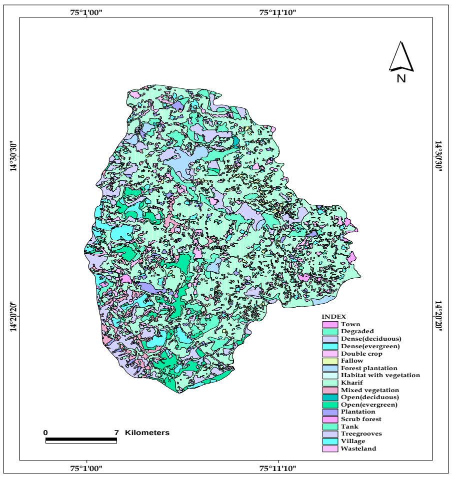

Fig. 8 land use and land cover of the study area

11 SOILS

Soil is one of the natural resource for the sustenance of vegetation on the earth surface. Soil interface between the atmosphere and lithosphere (the mantle of rocks making up the Earth's crust). It also has an interface with the hydrosphere, i.e. the sphere describing surface water, groundwater and oceans. Using satellite data (IRS-1D, LISS–III geocoded FCC dated,16th Nov 2000, 11th Dec 2000, 08th Jan 2001 and 24th Dec 2001) at 1:50,000 scale was visually interpreted to delineate soil tones, and four types of soils have been identified. Based on their hydrogeological properties they are further classified based on ICAR (Fig. 9).

Type 1 Alfisols

Alfisols are soils of the semi-arid to humid climates with light coloured surfaces and subsoil moderately rich in base cations. These soils are normally developed under deciduous forest vegetation in humid climates. They are found in regions receiving more rainfall. These soils are moderately eroded and associated with deep well drained (more than 75 ft) and gravelly clay soils with low AWC, having capacity to hold water in their interstices, indicating very good to good groundwater potential areas. These soils cover almost major part of the area constituting about 95.47 Sq. km contributing about 15.4% of the total area.

Type 2 Inceptisols

Inceptisols soils are weakly developed and are common in cool or dry climates, or in resistant or new parent material. These soils typically have a recognizable 'A' horizon, but only a weak 'B' horizon, having fine loamy, mixed, deep moderate, well drained loamy soils of valleys with shallow water table as associated with deep poorly drained (less than 50ft) clayey soils with shallow water table with very low AWC. These soils indicates poor to moderate ground water potential zones and occupy 375.29 sqkms and 60.53 per cent of the area.

Type 3 Ultisols

Ultisols are a group of soils with an argillic or kandic horizon and low base saturation in lower subsoil horizons. These soils normally developed under forest vegetation in humid climates. These soils are clayey skeletal kaolinitic, fine loamy mixed soils are very deep, well drained, gravely soils (100 – 150ft) with low available water capacity (AWC). These soils occurs on steep sloping high hill ranges associated with moderately eroded, somewhat excessively drained gravely with moderately eroded clayey soils. These soils indicate moderate ground water potential zones. They cover about 37.24 sqkms and constitutes about 6.07 per cent of the area.

Type 4 Vertisols

Vertisols soils are self-mixing swelling clays. Vertisols are rather rare on a world scale but are common in India. Vertisols are fertile but are difficult to farm because of the wide and deep cracks that form when these soils are dry. Vertisols typically have no B-horizon because these soils turn over rapidly i.e., topsoil materials fall in the cracks and end up buried in the horizon. These soils provide poor physical support for roads and buildings because they are so unstable with swelling and shrinking. Native vegetation on Vertisols is grass. In the study area these soils are found in small pockets in the northern part of the study area, these soils indicate poor groundwater potential areas, constituting about 111.94 sqkms and constituting about 18.05% of the total area.

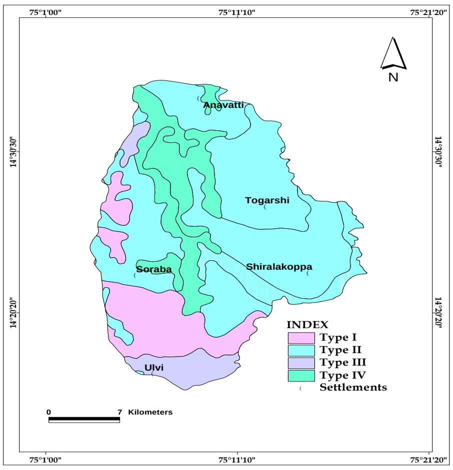

Fig. 9 Soil Map of the study area

12 DRAINAGE DENSITY

SOI toposheets were used to delineation of drainage units in the study area, to this 2x2-cm grid prepared, the total length of streams with in each grid (1 sqkms) was measured. These were plotted on the respective grid centers. These values were joined by isolines to prepare a drainage density map, classifying into 5 drainage texture classes namely very coarse, coarse, moderate, fine and very fine. (Fig. 10). Quite often, it was found that drainage density is related to infiltration of water. Low drainage density generally results in the area of permeable sub soil material, dense vegetation and low relief. High drainage density is the resultant of impermeable subsurface material, sparse vegetation and mountainous relief. (Nag 2003).

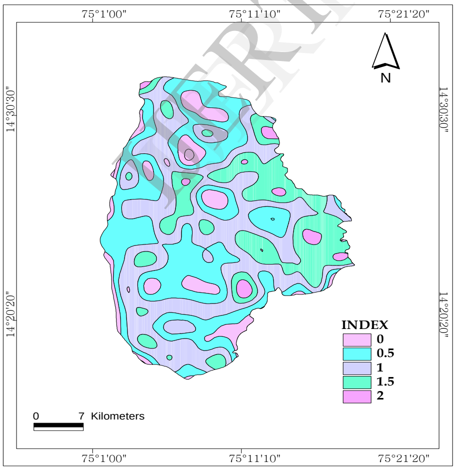

Fig.10. Drainage density map of the study area

13 GROUNDWATER FLUCTUATION

Groundwater Isohyets were drawn for the water-level fluctuation in different observations dug wells in and around was monitored for pre- and post-monsoon seasons from a network of 15 wells uniformly spread over the area during 1986–2005 classifying them into 4 classes 550 – 600, 600 – 650, 650 – 700, and 700 – 750.(Fig. 11).

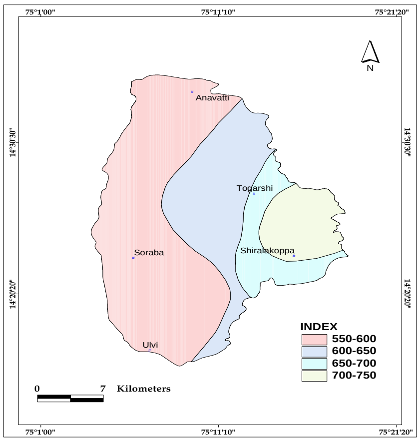

Fig.11 Groundwater fluctuation map of the study area

14 INTEGRATION OF THEMATIC MAPS

To meet the objective of the study based on multiple criteria analysis, all the thematic maps are assigned with weightage scale such as Capability values (CV) and Weighed capability values (WCV) with respect to the values depending upon their suitability to hold ground water (Table 1). These capability values (CV) are then multiplied with the respective probability weight of each thematic map to arrive at the final weight map during overlay analysis. Summation of these values indicates the probable ground water potential zones in the Dandavathi river basin.

15 Simple Additive Weighing Method (SAW):

Simple additive method is one of the simplest and most often used as Multi-Criteria Evaluation technique (MCET) of several methods available for determining interclass/ intermap dependency. The 07 map layers, each of which defines a criterion necessary to be considered in landfill site selection are prepared. A probability weighted approach has been adopted that allows a linear combination of probability weights of each thematic map (W) with the individual capability value (CV). Different categories of derived thematic maps have been assigned scores in a numeric scale of 0 to 5 depending upon their suitability to landfill location. These scores are converted to capability values using Bayesian statistics. Because the scores of the criteria are given on different scales, they must be standardized to a common dimensionless unit. Using Arithmetic overlay procedure, these capability values (CVi) are then multiplied with the respective probability weight of each thematic map (Table.2). An aggregation of these product values leads to the final weight map. (Eastman et al., 1995 and Eastman, 1996). Mathematically, this can be defined as:

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GWP = f (Lu, Li, Sl, Ra, Ge, St, So, Gw, Lm, Dd)(where GWP is Groundwater potential, Lu is Land use and land cover,Li is Lithology, Sl is Slope, Ra is Rainfall, Ge is Geomorphology, St is streams, So is Soil,Gw is Groundwater level, Lm is Lineament,Dd is Stream density)

$LF = \Sigma\ W_i\ CV_i$, with $\Sigma W_i = 1$. Where: GWP is the Ground water potential map value, Wi is the probability value of each thematic map, CVi is the individual capability value. The above equation can be written as a summation of: (0.18181818 x CV Lu) + (0.163636363 x CV Li) + (0.145454545 x CV Sl) + (0.127272727 x CV Ra) + (0.109090909 x CV Ge) + (0.090909090 x CV St) + (0.072727272 x CV So + (0.054545454 x CV Gw+ (0.036363636 x CV Lm+ (0.018181818 x CV Dd).

The resultant final weight map indicates potentiality of groundwater potentials in vicinity of Dandavathi basin. This map has then been classified into five designated zones are introduced indicating Very good, Good, Medium, poor and very poor (Fig.12).

Table 1: Thematic layers CVand WCV

Thematic layers		Map Weight (Wi)	Categories	Capability Values (Cv)	Weighted Capabilities Values (WCV)
L1	Land use and land cover	05	Highly dense forest	05	25
			Moderately dense forest , agricultural land	04	20
			Scattered forest, mixed vegetation	03	15
			Fallow land	02	10
			Barren land	01	05
L2	Rainfall	04	1900-2000	07	35
			1700-1900	06	30
			1500- 1700	05	25
			1300-1500	04	20
			1100-1300	03	15
			900-1100	02	10
			700 - 900	01	05
L3	Groundwater level	4	550 – 600	04	20
			600 – 650	03	15
			650 - 700	02	10
			700 - 750	01	05
L4	Streams	06	5th Order	05	25
			4th Order	04	20
			3th Order	06	15
			2th Order	02	10
			1th Order	01	05
L5	Soil	11	Type 1	04	20
			Type 2	03	15
			Type 3	02	10
			Type 4	01	05
L6	Lithology	04	Laterite	04	20
			Greywackes and argillites	03	15
			Ferruginous Chert/BHQ/BFQ	02	10
			Quartz chlorite Schist with Orthoquartzites	01	05
L7	Lineaments	01	Around 100 mts	01	10
L8	Slope	07	1 - 2	05	25
			3	04	20
			4	03	15
			5	02	10
			6 - 7	01	05
L9	Drainage Density	02	Very High density	05	25
			High density	04	20
			Medium density	03	15
			Low density	02	10
			Very low density	01	05
L10	Hydrogeomorphology	05	Valley floor	06	30
			Pediment shallow weathered	05	25
			Pediment Moderately weathered	04	20
			Pediment , PIC	03	15
			Inselberg complex	02	10
			Residual hill, Structural hill	01	5

Table 2: The Summary of the Input Layers used in the Analysis

Sl.No	Data Layer	Weight	Normalized Weights
1	Land use and land cover	10	0.18181818
2	Lithology	9	0.163636363
3	Slope	8	0.145454545
4	Rainfall	7	0.127272727
5	Geomorphology	6	0.109090909
6	Streams	5	0.090909090
7	Soils	4	0.072727272
8	Ground water level	3	0.054545454
9	Lineaments	2	0.036363636
10	Drainage Density	1	0.018181818

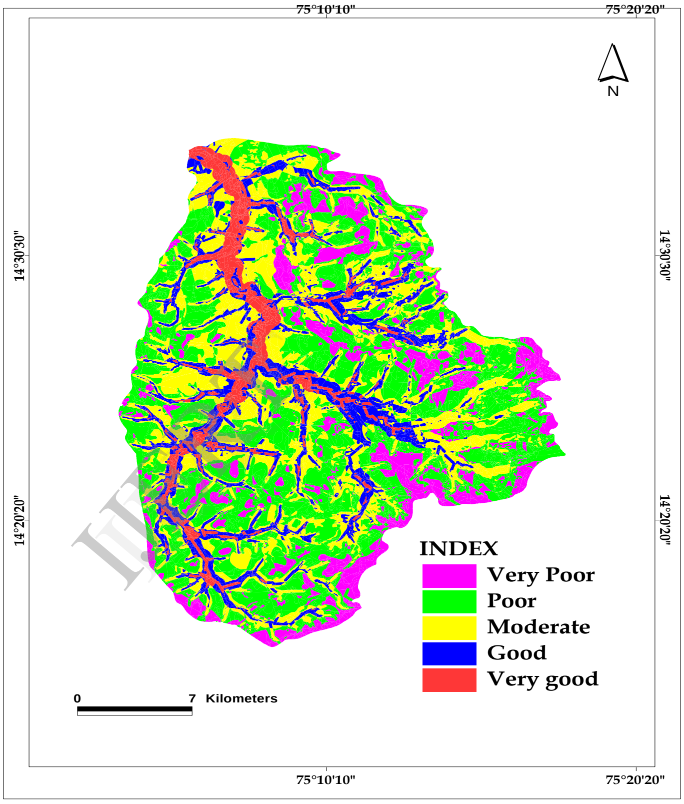

Fig12. Groundwater Potential Zone S Of Dandavathi River Basin

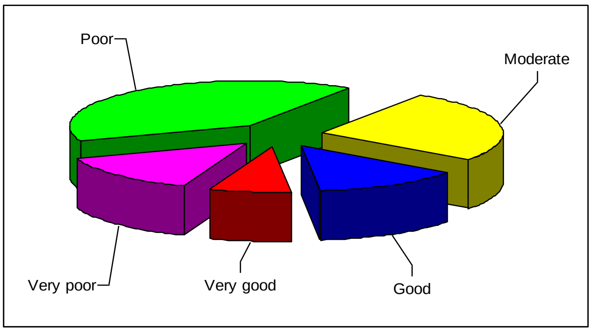

Fig13. Area percentage of ground water potential zone map of Dandavathi river basin

Table 3. Groundwater potential zones of Dandavathi river Basin

Sl.No.	Groundwater category	Area (sqkm)	Percentage of the total area
1	Very good	44.70	7.18
2	Good	83.01	13.33
3	Moderate	161.68	25.97
4	Poor	245.82	39.49
5	Very poor	87.25	14.01

DISCUSSION:

Superposing all the layers like Land use and land cover, Lithology, Slope, Rainfall, Geomorphology, Streams, Soil, Groundwater level, Lineaments, and Drainage density the final zoning of Very good, good, Moderate, Poor and very poor zones have been identified. Considering relative priority of all criteria, a specific weight is designated to each criterion according to their total influence on the whole process of decision making.

According to the final weight of each criteria in combination with different selected zones, Central and northern part of the having Good groundwater potential zones, North eastern and a part of central are found to be good potential zones, western part of the study areof moderate groundwater potential zones, and a part of northern and eastern part are consider to be poor and very poor groundwater potential zones.

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