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Assessment of Groundwater Potential Utilizing Gis and Estimation of Groundwater Recharge by Swat Model

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Abstract

In present situation groundwater is an essential natural resource for domestic use, industrial purpose and agricultural purpose. Due to less rainfall in monsoon it should be used in optimum manner and groundwater recharge places should be identified. Due urbanization and industrialization vegetation cover of the land decreases there will be less infiltration it is a key risk for this valuable resource. For proper management of groundwater it should be used in optimal manner. In present case an attempt is made to demarcate groundwater zones in Suryanagar watershed which comes under kaveri river basin having Latitude of 12º-47′-32″-N & Longitude of 77º-41′-59″-E, Bangalore having an area of 172.42km^2 and also to identify recharge zones of the study area. Morphometric analysis of watershed is carried out using GIS and parameters such as Linear, Areal and Relief aspects have been determined. From the drainage map it can be seen that the area is having dendritic drainage pattern. The drainage's Densities obtained of water shed obtained is 1.48km/Sq.km.Further work is carried to find groundwater potential zones and groundwater recharge zones of watershed using GIS (Geographical Information System). Different thematic have been prepared such as Geomorphology, Lithology, Slope, Rainfall, Land use and soil. Weighted overlay analysis have been made and each thematic map is given weightage based on the influence of groundwater occurrence. Five types of groundwater zones have been identified and demarcated such as poorer, just moderately to very moderate, good & very very good. Recharge estimation is carried out using SWAT and recharge varies from 170mm to 500mm and it is compared with groundwater potential map. The comparison shows that recharge is maximum where groundwater potential is maximum and vice-versa.

Key Words: Thematic map, Weight overlay, GIS, geomorphology, and lithology

Introduction

Water is one of the most precious resources. Lack of water is the main cause for delayed development. Out of 100 percent, only 3 percent of fresh water available to us and remaining 97 percent is stored underground as groundwater. More than 1500 million people relying on groundwater for drinking and domestic purposes. In arid region where rainfall is very less groundwater plays a major role for the development of that region. As the Bangalore city is expanding rapidly, it requires huge amount of groundwater for usage like Industrial purpose, Domestic purpose etc. So groundwater improvement, protection and optimum usage plays a huge role in improvement of that city. For that to happen groundwater recharge is crucial, in doing so there will be rise in the water table so that when surface water resources are dry in condition groundwater can be used. Meteoric origin contributes in greater quantity compared to juvenile and magmatic origin for groundwater recharge. The extent of water reaching the water table after recharge has commenced depends upon the saturation of the zone. If the zone is saturated the recharge quantity reaching water table is more or vice-versa. It has been reported that the success role of locating favorable sites for groundwater prospects using remote sensing techniques along with other conventional data is much more than compared to conventional methods alone. Many studies have demonstrated that the integration of thematic maps prepared through Remote Sensing & the GIS are proven to be successful w.r.t. locating groundwater zones in an area [1]

STUDY AREA

The study areas are situated b/w the Latitude of 12º47'32"N & Longitude of 77º41'59" E as displayed in the Fig. 3.1. The study areas covered an zonal area of 172.42 sq.kms & would attain a maximum. value of 950 meters & a minimum. Elevation value of 880 meters. The Suryanagar Township is actually located on the Anekal main arterial road, Chandapura nearby city Benahalli in Attibele, Bengaluru. The Suryanangar which is located at a distance of around 25 meters from Bengaluru, physiographical area being characterized by the un-dilating topographical characteristics with a number of Pedi plain,s valley hills & pediments. Their mean yearly rainfall data is about 920 millimeters. The temperature of summer and winter ranges about 18° C to 35° C and 13° C to 24° C. Therefore Bangalore has moderate climate throughout the year. Figure 3.2 shows delineated map of Suryanagar watershed using Digital Elevation Model [2].

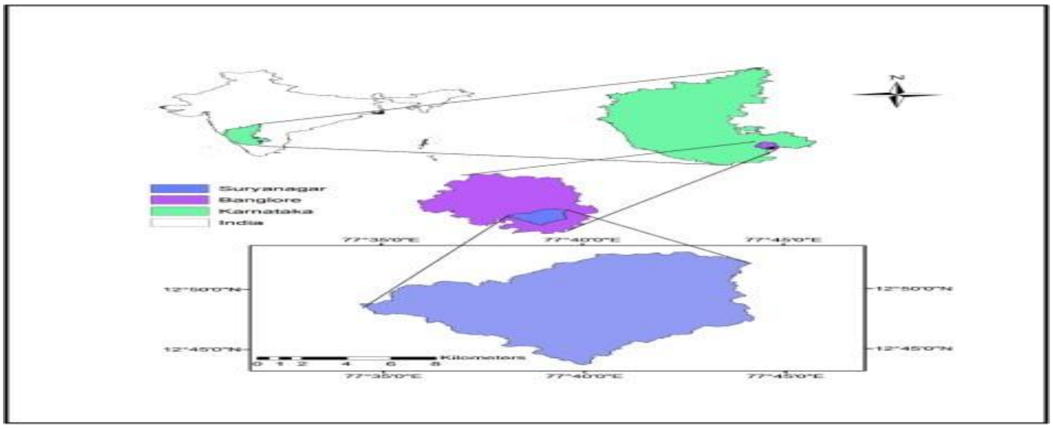


Fig-1: Location maps of their study area

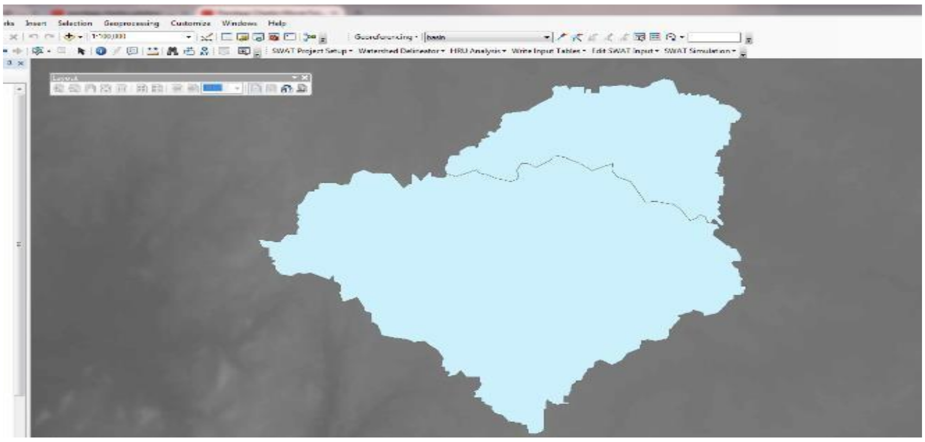


Fig-2: Delineated maps of the major study areas using DEM

The major objectives of the research study are

- Analyzing the various Morphometric parameters of the watershed.
- Generation and integration of different thematic maps.
- Generation of Groundwater potential zone Map.
- Estimation of Groundwater recharge using SWAT hydrological model.

MORPHOMETRIC ANALYSIS

It is the measurement of shape and analyzing mathematically the drainage network of the basin or watershed. The study on morphometry was first introduced by Horton (1940) and Strahler (1950). They carried out the studies of morphometry of the basin by using GIS and Remote Sensing. GIS and Remote Sensing are the effective tools for delineation of watershed as well as analysis of drainage network for assessing, monitoring and management of water resources. The first part of my paper involves morphometric analysis. The study is carried out for Suryanagar watershed. Morphometric analysis in the watershed play a major roles in understanding of their hydrologic behaviors of watershed for the analysis of hazards due to floods, geomorphological and geological structure [3] It is classified into three aspects linear aspect Areal aspect Relief aspect

LINEAR ASPECTS

This process entails assessing characteristics of the drainage system, including stream orders, stream lengths, stream length ratios, length of overland flows, and drainage pattern. Stream's orders are assigned through a hierarchical ranking of streams. The measurement of stream lengths and the statistical analysis of overland flow length represent frequently employed attributes in linear aspects of drainage system evaluation.

AREAL SPECTS

The size of the basin directly reflects the extent of drainage development within a specific watershed. The areas of the Suryanagar watersheds are of 172.42sq.km. It involves the measurement of watersheds shape factors, form factors, compactness coefficient, elongation ratios, drainage densities etc

RELIEF ASPECTS

It is an important aspect to know the amount of denudation that takes place, taking away the top surface soil of earth surface which leads to reduction in elevation of earth. It also indicates the direction of flow of water which will from higher elevation to lower elevation. It involves the measurement of basin based reliefs, relief ratios, relative relief & ruggedness numbers.

Table 1 shows formulas for linear, areal & relief

Sl.No	**Morphometric parameters**		
A	**Liner parameters**	**Formula**	**Reference**
1	Stream order (S_u)	Hierarchical rank	Strahler (1964)
2	1st order stream (S_{uf})	$S_{uf} = N_1$	Strahler (1952)
3	Stream number (N_u)	$N_u = N_1+N_2+ \ldots$	Horton (1945)
4	Stream length (L_u)	$L_u = L_1+L_2+ \ldots$	Strahler (1964)
5	Stream length ratio (L_{ur})	L_{ur}=II order /I order like wise	Strahler (1964)
6	Mean stream length ratio (L_{urm})	$L_{urm}= L_u/ L_u-1$	Horton (1945)
7	Bifurcation ratio (R_b)	$R_b=N_u/N_u+1$	Strahler (1964)
8	Mean bifurcation ratio (R_{bm})	R_{bm} = Average of R_b of all orders	Strahler (1964)
9	Rho coefficient (ρ)	$\rho = L_{ur} / R_b$	Horton (1945)
10	Mean stream length (L_{sm})	$L_{sm}= L_u/N_u$	Strahler (1964)
B	**Areal parameters**		
11	Basin shape (B_s)	$B_s=L_b^2 /A$	Schumm (1956)
12	Mean basin width (W_b)	$W_b = A / L_b$	Horton (1932)

13	Basin area (A)	GIS software analysis	Schumm (1956)
14	Basin perimeter (P)	GIS software analysis	Schumm (1956)
15	Length area relation (Lar)	Lar = 1.4 * A0.6	Hack (1957)
16	From factor (Rf)	2 Rf = A/ Lb	Horton (1932)
17	Elongation ratio (Re)	Re = 2 Lb (A / π) 0.5	Schumm (1956)
18	Texture ratio (Rt)	Rt = Nu / P	Schumm (1956)
19	Circularity ratio (Rc)	Rc = 12.57 * (A/ P2)	Miller (1968)
20	Drainage texture (Dt)	Dt = Nu / P	Horton (1945)
21	Compactness coefficient (Cc)	Cc = 0.2841 * P / A 0.5	Gravelius (1914)
22	Stream frequency (Fs)	Fs= N/ A	Horton (1932)
23	Drainage density (Dd)	Dd= Lu/Au	Horton (1932)
24	Constant of channel maintenance (C)	C = 1 / Dd	Schumm (1956)
25	Drainage intensity (Di)	Di =Rt/Dd	Faniran (1968)
26	Infiltration number (If)	If =DdFs	Faniran (1968)
27	Drainage pattern (Dp)	Based on shapes of drainage	Horton (1932)
28	Length of overland flow (Lg)	Lg = A / 2 Lu	Horton (1932)
C	Relief parameters		
29	Height of basin mouth (Zm)	GIS or DEM analysis	-
30	Maximum height of the basin (Z)	GIS or DEM analysis	-
31	Total basin relief (H)	H = Z– Zm	Strahler (1952)
32	Relief ratio (Rhl)	Rhl = Zm/ Z	Schumm (1956)
33	Relative relief ratio (Rhp)	Rhp = (H*100) / P	Melton (1957)
34	Watershed slope (Sw)	Sw=H/Lb	Schumm (1956)
35	Ruggedness number (Rn)	Rn = Dd * (h /1000)	-
37	Contour interval	GIS software analysis	-
38	Slope analysis (Sa)	GIS analysis or DEM	-

The Suryanagar watershed has trunk order of 5 & the drainage densities which are got for watershed is 1.48 kms/sq.kms that indicate that the areas are coarse in type. Figure 3 shows stream's order maps of study areas.

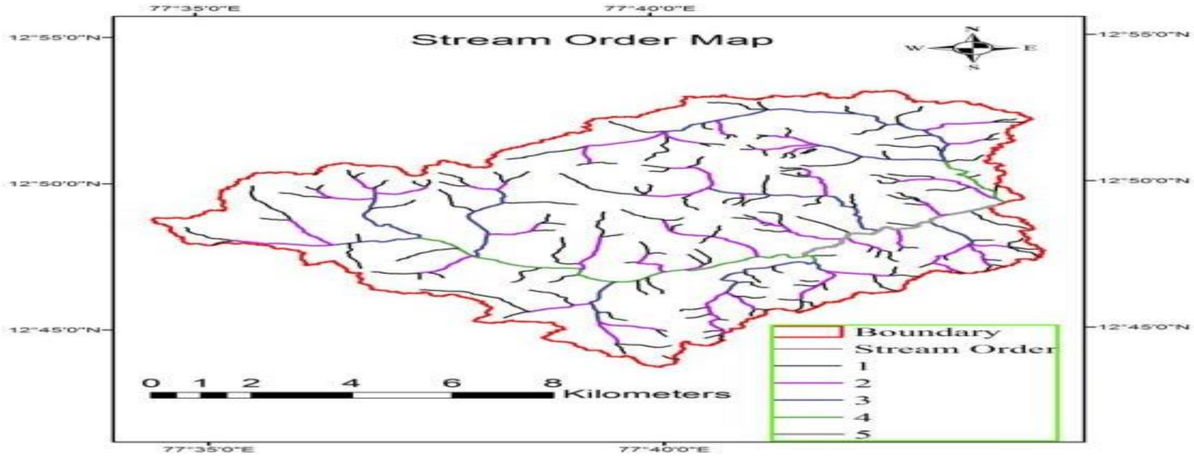


Fig- 3: The order of the steam's map of study area.

Table 2 Morphometric parameters of study area

SL No	watershed parameters	Unit	Values
1	watershed area	Sq km	172.43
2	Perimeter	km	96.9
3	stream highest order		5
4	Maximum length of watershed	km	17.27
5	Maximum width of watershed	km	17
6	Cumulative stream segments		220
7	Cumulative stream length	km	225.41
8	Length of overland flow	km	0.33
9	Drainage Density	km/km^2	1.48
10	Constant of cannel maintain	km2/km	0.67
11	Steam frequency	no/km2	1.27
12	Bifurcation ration		3.6
13	Length ration		2.37
14	Form Factor		0.98
15	Shape factor		1.72
16	circularity ration		0.23
17	elongation ratio		0.48
18	compactness coefficient		0.56
19	Total water shed relief	km	0.04
20	Relative relief		0.41
21	Ruggedness number		0.05

GROUNDWATER POTENTIAL MAPPING

Due to increase in population, urbanization and excess usage of groundwater in Bangalore the groundwater resource is depleting [CGWB, 2013]. Preserving of Groundwater becomes essential due to shortage of good quality surface water. The idea of Groundwater mapping using GIS & the remotely sensed conditions had proven to be the major operative tools for differentiation of groundwater in area, so that one can identify the recharge zones in an area and how the groundwater potentials differs w.r.t. their areas and which are the poor zones in an area [4].In present case an sincere effort is being taken to delineate the ground water potentially based zones of the of suryanagar watershed.

METHODOLOGY INVOLVED IN GROUNDWATER POTENTIAL MAPPING

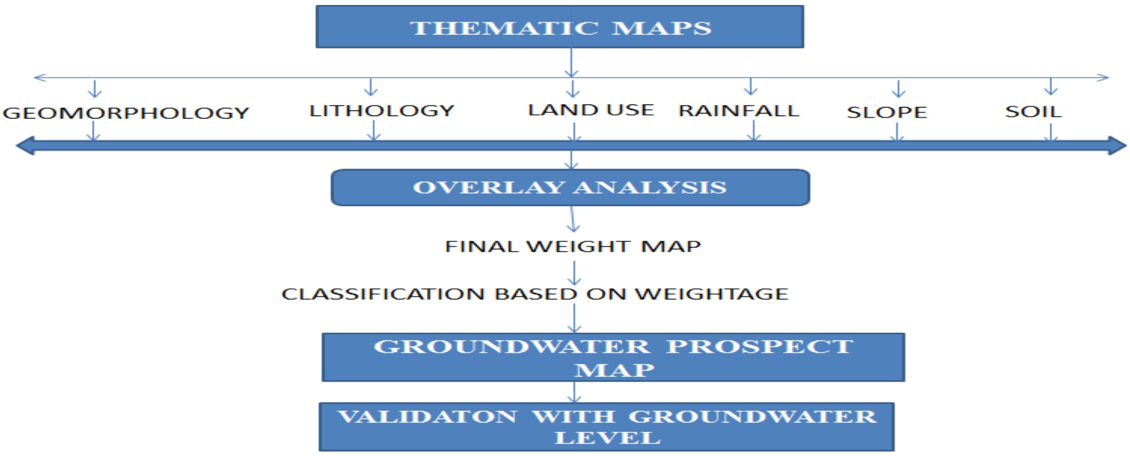


Fig: 4 Methodology of research

GEOMORPHOLOGY

Geomorphology is a learning of earth structures and also illustrates [Fig 4] the various landforms involving into the groundwater possible zones and also structural features [NRSC]. It is an areaDepends upon the structural evolution of geological development [RAMU et al, 2014]. Realizing the importance of hydro geomorphology, capability values from 1 to 5 and WCV weights of 5, 10, 15, 20 and 25 are assigned to different types of landforms [Table 3].

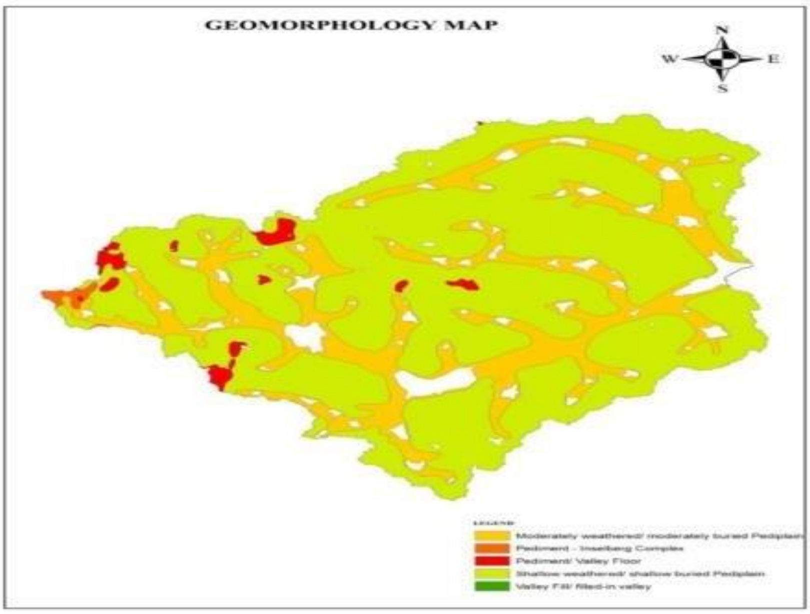


Fig -5: Geomorphological maps of the taken up study areas

LITHOLOGY

'Lithology' is the vital layer which controls the supply and presence of groundwater (RAMU *et.al*, 2014). The study areas are Suryanagar watershed in Bangalore district of the state of Karnataka.

Lithologically, this zone is consisting of a number of gneiss as shown in the Fig 5.0

Based on water holding capacity of different litho units in the watershed, capability values 3 and WCV weights of 15 is assigned [Table 3].

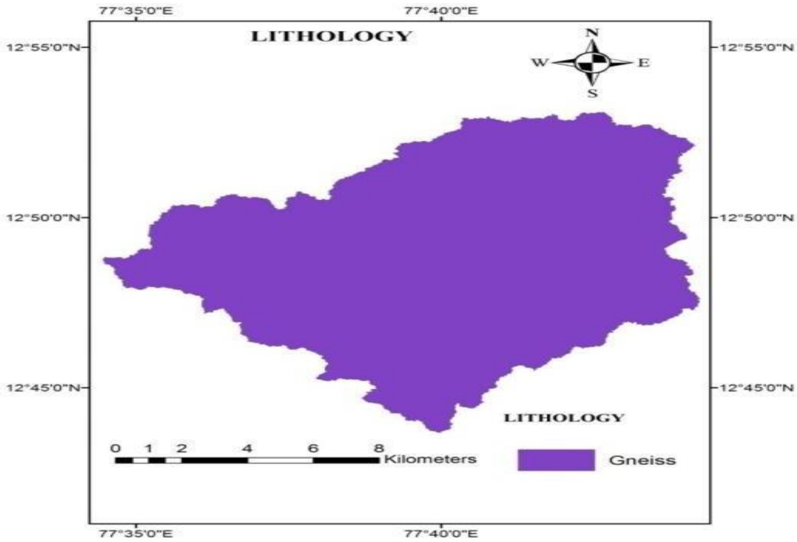


Fig-6: Lithological map of the studying zone

LAND USE

The lands used and land covered map classifying systems were prepared by Remote Sensing Agencies [NRSA], in order for classifying different type of land usage and land covered in the areas. Their present area has different categories of land use such as Built-up areas, crop land, fallow land, forest, river etc shown in [figure 6]. Tanks are in limiteduse, because their aerial are in lesser area.

The area having rivers that may flow throughout the year if rainfall is sufficient and vice-versa. Realizing the importance of land use and land cover, the capability values from 1 to 5 has been assigned and WCV weights of 5, 10, 15, 20 and 25 are assigned to various land use and land cover according to their role in capability of infiltration of water [Table 3]

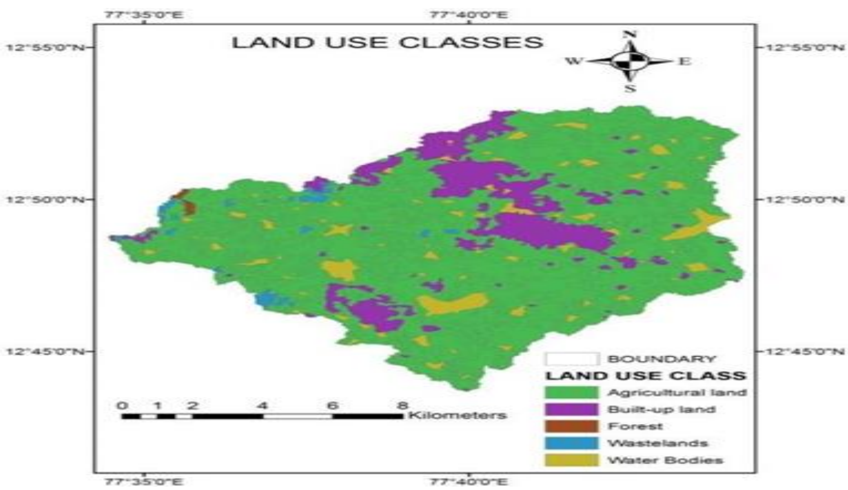


Fig-7: Land usage map of the study areas

RAINFALL

Rainfall serves as the primary origin for both surface and groundwater in the study region. Monthly rainfall data spanning 14 years [1998-2012] have been gathered from four stations located within the watershed, and an Isohyetal map has been generated. The average yearly rainfall within their study areas will range from

900 to 1100 mm, as illustrated in Figure 7. Depending upon the depth of rainfall in the study areas the capability values from 1 to 5 and WCV weights of 5, 10, 15, 20 and 25 are assigned [Table 4].

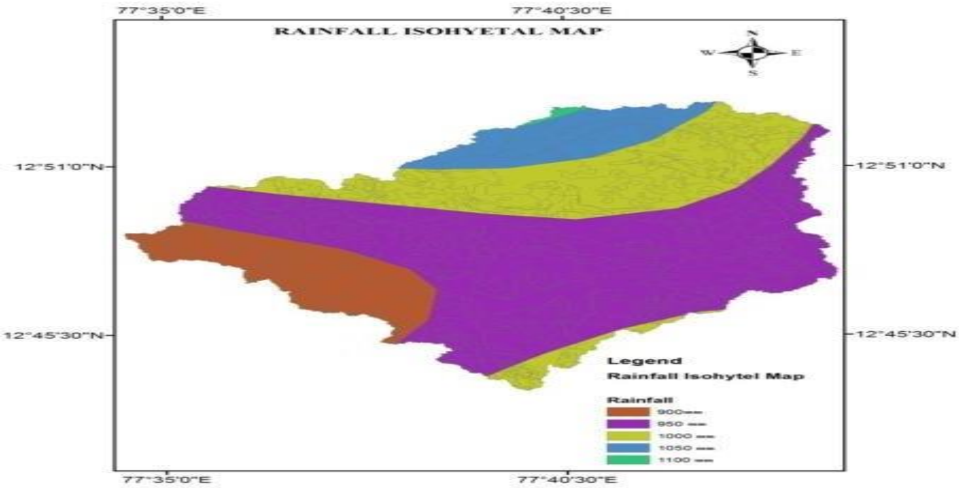


Fig-8: Rainfall Isohyet map of the study area

SLOPE

The slope classes of the study areas are shown in [figure 8]. The nearly flat and gently sloping areas facilitate infiltration and groundwater recharge, whereas moderate, steep, and very steep slopes encourage surface runoff and hinder infiltration. On the basis of infiltration capacity the capability values are assigned to individual slope categories from 1 to 5 and WCV weights of 5, 10, 15, 20 and 25 are assigned for slope classes [Table 4]

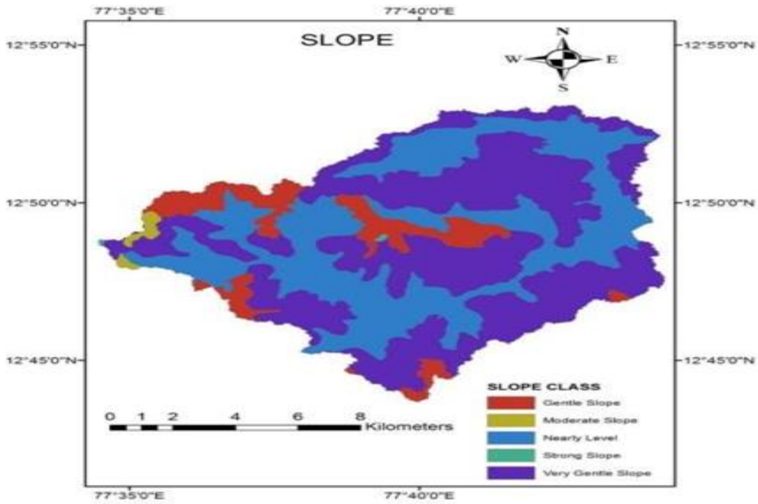


Fig-9: Slope maps of the study area

SOIL

Soil is produced due to weathering action of rocks. Soil is one of the main factor which decides the amount of infiltration of water, the study of soil helps to find the types of soil in an area and also its properties. The measure of groundwater and infiltration of surface water into ground is dependent on the porosity and permeability of soil. The study of soil is vital to decide the amount of ground water of any place [RAMU et al, 2014]. Fig shows soil classes of study area. Based on their hydrogeological properties capability values from 1 to 5 and WCV weights of 25, 20, 15, 10 and 5 are assigned [Table 5.1].

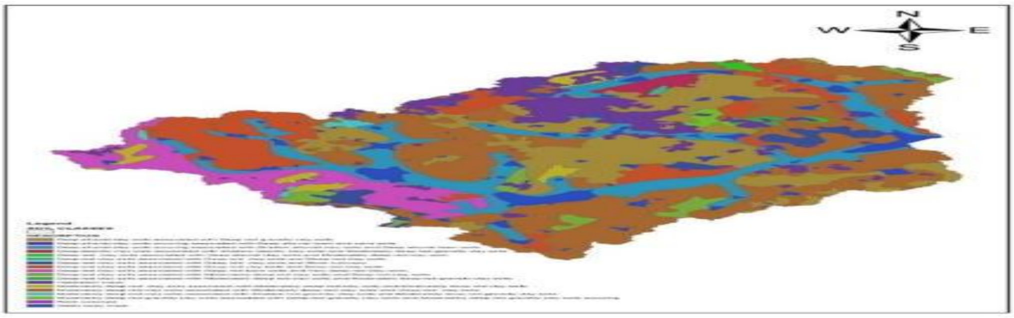


Fig-10: Soil map of study area

Utilizing integrated total weights, the study area has been classified into zones indicating Very Good, Good, Moderate, Moderate to Poor, and Poor groundwater potential, as depicted in Figure 10.

Table 3.0 weighted capability values of each layers

Thematic layers	Map weightage	categories	Capability values CV	Weighted capability values WCV
		Pediment inselberg	1	5
		Moderately weathered Pedi plan	2	10
		shallow weathered	3	15
		Reservoir	4	20
Geomorphology	5	valley fall	5	25
Geology	1	Gneiss	1	5
		Built up land	1	5
		fellow land	2	10
		Agricultural land	3	15
		Crop land	4	20
Land use land cover	5	water bodies	5	25
		700-900	1	5
		900-1000	2	10
		1000-1100	3	15
Rainfall	4	1100-1200	4	20
		0-10%	5	25
		1-3%	4	20
		3-5%	3	15
		5-10%	2	10
Slope	5	10-15%	1	5
		Habitation mask	1	5
Soil	5	Deep red soil	2	10

		moderately deep red soils	3	15
		Deep alluvial clay soil	4	20
		water body mask	5	25

Table 4 Ground water Potential categories

Sl no	Groundwater category	Area	%of the area	Higher weightage value	Lower weightage value	Ground water structures
1	Very good	10.38	6.02	125	105	Dug wells
2	Good	90.68	52.59	105	85	Dug wells
3	Moderate	63.95	37.09	85	70	dug well
4	moderate to poor	7.34	4.25	70	50	dug well
5	Poor	0.0634	0.037	50	40	not successful

VALIDATION

Validation refers to checking the model performance to replicate the reality. In this study the groundwater potential map generated overlaying various thematic maps was validated with groundwater observation well data. In this case in moderate to poor groundwater potential zone the water in the wells should be low and vice-versa in case of good potential zone. The existing observation well 1 in the study areas lies in the moderately to poor ground water potentially developed zone andthe well data is well below the ground indicating poor availability of groundwater. The existing observation well 2 in the study areas lies in good potential zones and their well data is near to ground surface indicating good availability of groundwater [Fig 5.13]. This concludes the validation of overlayanalysis [WRIS].

6.

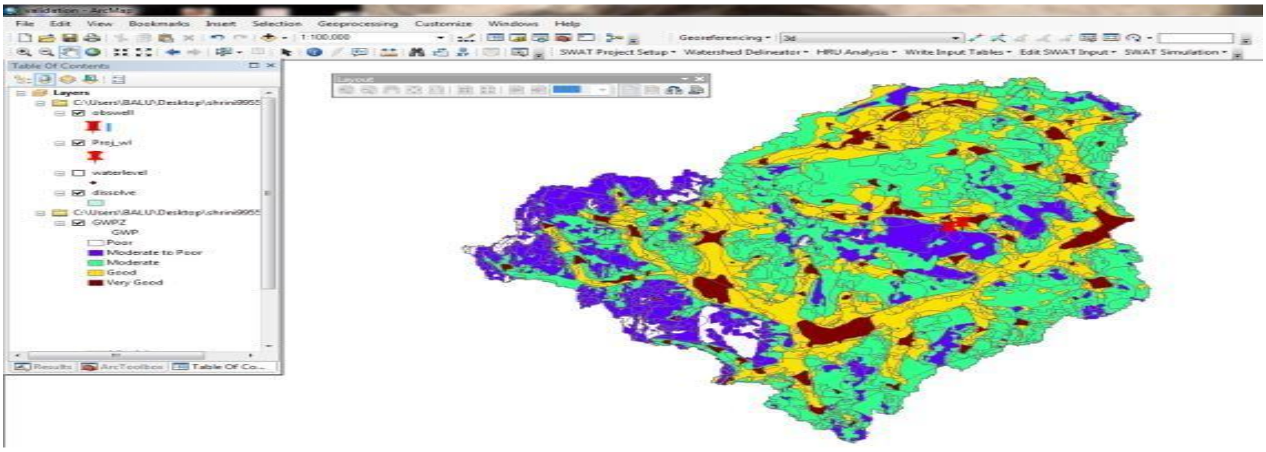


Fig 11 stimulation of recharge usingswat

SWAT MODEL DESCRIPTION: GENERAL

SWAT is a composite integrated river basin model which can be run on yearly, daily and hourly basis. This model is developed by United State Department of Agriculture [USDA] and also it has been extended. Model has the ability to predict hydrologic parameters like groundwater recharge, water quality and sediment load.The model divides the watershed into sub- watersheds based on slope of land and network of channel. It is further divides sub-watershed into hydrologic response units based on soil and land use [5].

Ground water potential map

The digital elevation models with a resolution of 90 meters for the study areas were acquired from the Shuttle Radar Topographic Missions. Fig 6.1 shows digital elevation model of Suryanagar watershed, it is having a maximum elevation of 988m and minimum elevation of 871m

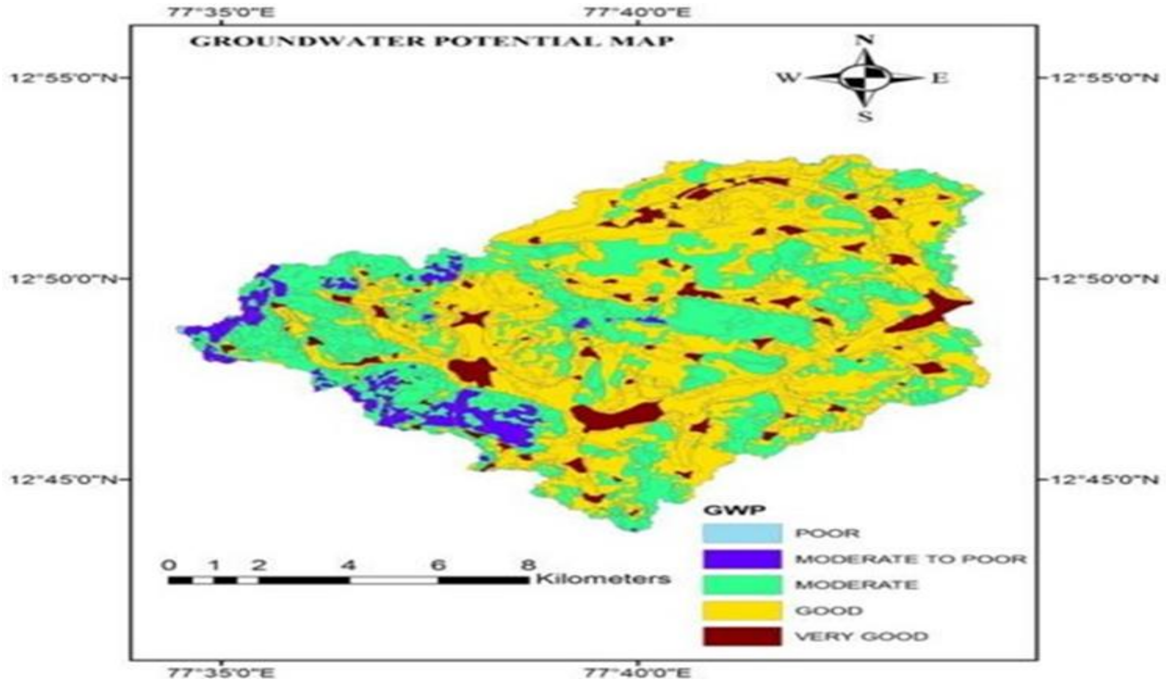


Fig-12: Groundwater potential map

POLYGONS	GW POTENTIAL	GW RECHARGE IN MM
1	65	242.67
2	63	234.18
3	103	425.24
4	120	499.92
5	61	207.04
6	93	374.161
7	90	374.22
8	55	183.02
9	53	183.01
10	56	183.055
11	83	308.05
12	51	183.29
13	55	182.15
14	51	182.82
15	62	182.92
16	98	374.52
17	55	182.99
18	58	182.90
19	62	183.05
20	64	182.92

21	57	183.24
22	85	308.40
23	60	183.03
24	81	308.45
25	85	308.45
26	87	308.31
27	81	182.97
28	85	308.412
29	87	308.62
30	89	308.27
31	82	308.344
32	84	308.358
33	86	304.258

Table 5 shows Groundwater potential andGroundwater recharge based on polygons

By using DEM, geomorphology, lithology, land use,rainfall, slope, and soil layers SWAT is runned for estimation of groundwater recharge. And groundwater recharge varies from 182mm to 500mm.

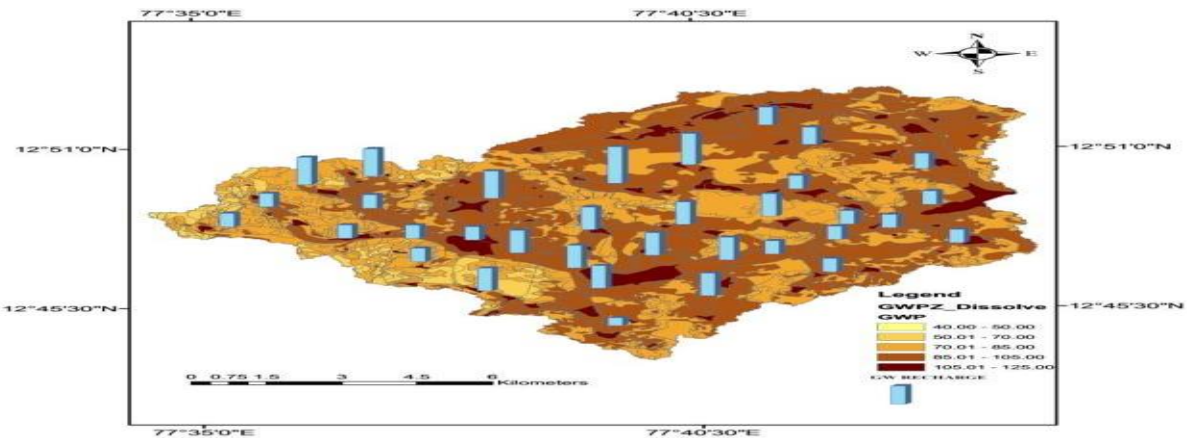
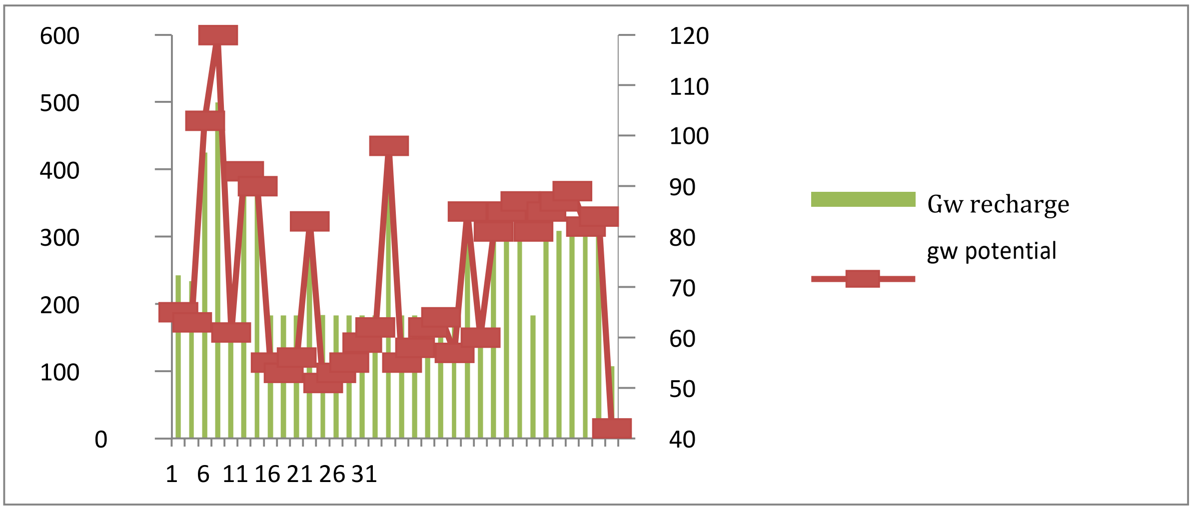


Fig-13: Comparison of groundwater potential andgroundwater recharge map

Fig-14: Comparison of groundwater potential andgroundwater recharge hyetograph



COMPARISON OF GROUNDWATER RECHARGE AND GROUNDWATER POTENTIAL

The groundwater potential obtained by overlaying thematic layers vary from 51 to 120 which is compared with groundwater recharge obtained using SWAT, groundwater recharge varies from 182mm to 500mm. Comparison shows that groundwater recharge is less in less groundwater potential region and vice-versa [figure 6.7].

From Groundwater potential map shows that Suryanagar watershed is having good groundwater prospect zone. The area is categorized into five type of groundwater potential zones [table no 5.4] and suitable groundwater feasible structures are suggested. The groundwater zone map acquired will prove beneficial for the strategic planning of surface drainage and the construction of structures aimed at groundwater recharge.

CONCLUSIONS

The drainage densities of watershed estimated is 1.48 kms/Sq.km that indicates the areas are coarser in nature. The stream's frequencies is obtained for their study will be 1.27 No/Sq.km, so it is categorized under the class of low stream frequency. The elongation ratio is evaluated as 0.48, which indicates that their watershed will be elongated in nature. In this particular scenario, the Bifurcation ratios of the watershed stand at 3.68. Furthermore, it's noteworthy that the Rb values differ as we move from one order to the next. This variation is attributed to the geological and lithological characteristics shaping the watershed, as outlined by Strahler in 1964. A lower Rb value signifies minimal structural disturbances within the watersheds, as suggested by Strahler in 1964, indicating that the drainage patterns remain undisturbed due to fewer structural disruptions, as elaborated by Nag in 1998.From SWAT model Groundwater recharge varies from 182mm to 500mm. The groundwater recharge is compared with groundwater potential map and the recharge is minimum where groundwater potential is less and vice-versa.

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