

**ASSESSMENT OF GEOHYDROLOGIC PARAMETERS FOR GROUNDWATER
POTENTIAL OF SARASWATI BASIN IN NORTH GUJARAT, INDIA**

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ABSTRACT

The present study revealed the picture of physiographic characteristics of surface and subsurface natural resources of a Saraswati basin of North Gujarat, India. The important basin parameters viz., geomorphology, soil types, topographic elevation and land slope along with status of groundwater resources were assessed during 1995 to 2012 for groundwater potential. The factors influencing the occurrence of groundwater and rainfall distribution were also studied. The remote sensing and GIS technique was employed to assess the basin characteristics and status of the geohydrological resources. The Digital Elevation Model (DEM) and satellite images were used. Hydrological module of ARC GIS 10.3 software was utilized for calculation and analysis of geohydrological basin characteristics. The components of each basin parameters were categorized for the assessment of groundwater potential. In geomorphology, alluvial plains cover 46.78 per cent of the basin area having good groundwater potential. Other components such as flood plains, river and water body also possess very good groundwater potential, however area covered under these components were very limited. The study area reveals six main soil categories with more than 45.12 per cent of area covered by fine loam soil considered good for groundwater buildup. The fine loam area is distributed all along the basin right from the foot hill (upper reach) to lower reach. The slope class in the basin indicated that 84.02 per cent of the study area comprises the moderate slope (< 3%). in conjunction with fine to coarse loam soils, favourable for rain water infiltration and groundwater built up. The topographic elevation was found ≤ 50 m to ≥ 300 m. The rainfall was varying from ≤ 550 mm to ≥ 700 mm, accordingly considered moderate to good for groundwater potential. The status of groundwater resources were found according to rainfall and exploitation pattern besides types of physiographic characteristics. The Pre- and post monsoon groundwater levels were varied from ≤ 7 m to ≥ 22 m, hence the most shallow were considered excellent and the deepest were considered as poor groundwater potential. Despite favorable physiographic characteristics for groundwater resources, the area is considered water scarce more due to over exploitation than erratic and scanty rainfall.

KEY WORDS: Geohydrologic, groundwater, Saraswati

INTRODUCTION

The growing world population has put a lot of strain on natural resources. Water as one of these resources has an absolute importance in regard to the health and economy of all countries (UNCSD, 1997). In India, high inhabitant expansion,

fast urbanization and climate change along with the irregular frequency and intensity of rainfall make the task of water management and storage plans much complex. The demand for groundwater resources has increased tremendously from year to year, causing a drastic decline of

groundwater levels. It is necessary to maintain the groundwater reservoir of a basin in dynamic equilibrium over a period of time and the water level fluctuations have to be kept within a particular range over the monsoon and non-monsoon seasons. It is, therefore, more emphasis is given to increase the recharge of the basin for the water management programme at watershed level (Eyquem, 2007; Rao, 2008; Ellis and Revitt, 2010). It is imperative to evaluate water resources, as they play a crucial role in the sustainability of livelihood economics throughout the world. Watershed characterization and management requires detail information for soil, topography, slope, water divide, geomorphology along with hydrogeological parameters (Sreedevi *et al.*, 2013). The characterization of geohydrologic attributes enable us to understand the relationship among different aspects of the basins recharge pattern and also enables a comparative evaluation of different basins developed in various geologic and climatic regimes. Identification and assessment of ground features such as soil, topography, slope and geomorphic features and their link to hydro-geological characteristics may serve as direct or indirect indicators of surface and groundwater potential of an area. The surface and sub surface hydrological indications are one of the potential scientific tools for assessment and management of water resources.

The remote sensing (RS) technique provides organized and quick coverage of the earth's features in different windows of the electromagnetic spectrum, offers a distinctive and commanding tool for obtaining spatio-temporal information of large areas in a stipulated time. The geographical information system (GIS) provides an excellent framework for efficiently handling large and complex spatial data for natural resources management. Consequently, RS and GIS have been proved to be useful tools for groundwater studies (Shahid and Nath,

2002; Rao and Jugran, 2003; Jha and Peiffer, 2006; Jha *et al.*, 2007; Madrucci *et al.*, 2008; Chowdhury *et al.*, 2009, Chenini *et al.*, 2010; Chowdhury *et al.*, 2010; Jha *et al.*, 2010). Digital elevation models (DEMs), from the Shuttle Radar Topography Mission (SRTM) have been used to extract different parameters of the basins, including soil types, catchment divides, slope gradient, topographic elevation and upstream flow contributing areas (Mark, 1984; Tarboton, 1997).

The present study comes under the semi-arid region and receives principal component of recharge through rainfall. The area requires integrated approach of analysis to understand the status of the basin parameters. The hydrological analysis of basin parameters and their evaluation for the Saraswati basin in North Gujarat were carried out for assessment of groundwater potential through SRTM DEM, satellite images and GIS analysis. Digital elevation models (DEMs) were used to extract diverse geomorphological parameters of basins, soil, land slope and topographic elevation (Mark, 1984; Tarboton, 1997). GIS based assessment using Shuttle Radar Topographic Mission (SRTM) data have given a precise, fast and an in expensive way to analyze hydrologic system (Grohmann *et al.*, 2007; Panhalkar, 2014). The results observed in present work can be used as the scientific data base for further detailed hydrological investigation and find out the urgency of need to manage both surface and groundwater resources in sustainable manner.

MATERIALS AND METHODS

Study area

The study on assessment of ground water potential was carried out in Saraswati river basin, located between 72°03' and 72°53' East longitude and 23°50' and 24°22' North latitude, in North Gujarat, India. The river Saraswati originates from Northern Part of the Banaskantha district near Ambaji of North Gujarat and flows through the

Banaskantha and Patan Districts, finally dissipates beyond Sami block. The basins cover an area of 1725.26 sq.km. The major sources of water for the region are groundwater which is extracted through the open-dug wells and tube wells. The study area falls in the almost centre of the North Gujarat. The North Gujarat experiences excessive withdrawal of groundwater for irrigation and leading in alarming rate of in groundwater level reduction [Kumar, 2002], with the rate of decline in water levels ranging from 0.91 m to 6.0 m/annum [CGWB,1997]. Going by Falkenmark's indicator of physical scarcity, North Gujarat is an "absolute water scare" region [IRMA, 2001]. North Gujarat alone contributes about 40 per cent (3822 MCM) of the total groundwater draft in the state (Anonymous, 1999). Nearly 89.5 per cent of the water used up in the region is for crop production.

Data collection

The district resource maps comprising the basin area under Banaskantha, Mehsana and Patan were procured from Geological Survey of India, Gandhinagar at the scale of 1:50,000 to extract extent and geo-morphological, soil and elevation features of the basin. The calculation and assessment of different physiographic characteristics were done using the facility of Bhaskaracharya Institute of Space Application and Geo-informatics (BISAG), Gandhinagar. Remote sensing data such as Digital Elevation Model (DEM) and LISS-III images required for the study were also collected from BISAG. The DEM data of CARTOSAT-1 and ArcGIS 10.3 software was used for the study.

Assessment and calculation of basin parameters

The assessment and calculation of basin parameters were carried out using the remote sensing and GIS techniques. The information on different physiographic characters such as geomorphology, soil, topographic elevation and land slope for the basin were

generated and calculated using ArcGIS 10.3. The daily rainfall data were used in the ArcGIS 10.3 software to calculate area of a polygon under respective rain gauge station (Figure 1). The point data of groundwater with their location (longitude and latitude) in text format were imported into the ArcGIS 10.3 to calculate area under different groundwater contours.

RESULTS AND DISCUSSION

Geomorphology

On the basis of the physiographic characteristics, the landforms of the study area was classified into nine different classes viz., alluvial plain, built up land, denudation hill, eolian plain, flood plain, pediplain, river, structural hill and water body. The geomorphology explains important geomorphic units, landforms and underlying geology so as to provide an understanding of the processes, materials/lithology and structures relating to groundwater occurrence as well as groundwater prospects. In Table.1, the area covered by different geomorphological classes is presented. Alluvial plains cover 878.02 sq. km of study area are loose unconsolidated soil eroded and reshaped by water in some form and redeposited formations. It is typically made of variety of materials including small particles of silt and clay and large particles of sand and gravel. These formations are considered with very good potential of groundwater, covers 50.89 per cent portion of the study area. The denudational hills are long term sum of processes that cause the wearing away of the earth's surface by moving water, winds and several other weathering agents which lead to reduction in elevation and relief of landforms and landscapes. It contains highly fractured, folded, faulted and jointed structure formations. The denudational hill comprises 4.29 sq.km of area. The prospects of the groundwater in denudation hill formations are poor (Sahai *et al.*, 1991). The area covered by the eolian plains is 347.56 sq. km. These plains are land forms consists of migrated

sand dunes from the dry river bed or resulted due to deposition of sand carried by the wind in the desert prone areas. These areas under severe to very severe wind erosion, deposition hazards, low in rainfall and poor moisture regime considered as poor in groundwater potential, cover 20.15 per cent of study area. The flood plain covers 47.37 sq. km physiographic formation comprises the flood prone area of the river. It is well sorted, unconsolidated fluvial sediments. The wet course of the riverine channel, well sorted fluvial material serves as good aquifer. The groundwater prospects of the flood plains are considered very well (Sahai *et al.*, 1991). The pediplains are the extensive plains formed by the coalescence of pediments. A considerable area 207.57 sq. km. (12.03%) is covered by the pediplains. It allows high infiltration and have good groundwater potential, hence more importance in building groundwater resources. The structural hills cover 188.23 sq. km (10.91%) of the basin area. These formations are linear to arcuate hills showing definite trend-lines with varying lithology associated with folding and faulting. The structural hills are considered as very low groundwater potential as they are fractured rock and have low infiltration (Rammaiah *et al.*, 2012).

Soil

The study area reveals six main soil categories viz., coarse loam, fine loam, loamy skeletal, mixed coarse to fine loam, river and rocky outcrop. It is apparent from Table 2 that majority of the area (45.12%) is covered by fine loam soil. The area covered by fine loam is 778.43 sq.km followed by mixed coarse to fine loam 409.29 sq.km and coarse loam 265.20 sq. km. The fine loam area is distributed all along the basin right from the foot hill area (north east) to lower reach (south west) portion, while mix coarse to fine loam is distributed at trunk of the basin. The coarse loam area is to be found mainly at central portion and stretches up to lower reach. The upper portion of the study area

(north eastern part) is covered by the rocky formations. A little portion, about 6 per cent area is covered by loamy skeletal (at eastern portion) and other soil types (including river bed soils) located throughout the basin.

Topographic elevation

The study area is divided into seven topographic elevation classes. The lowest topographic elevations of < 50 m and highest topographic elevations of > 300 m found in the basin area. The study area dominated by topographic elevations of 200–300 m is 597.07 sq. km (34.61%) followed by 150–200 m in 399.12 sq. km (23.13%) and 100–150 m in 267.87 sq. km (15.53%) (Table 3). They altogether cover majority of the basin study area. The topography of the basin appeared suitable for groundwater build up.

Basin land Slope

It is seen from the figure that maximum study area comprises the moderate slope conditions. It is seen from Table 4 that 738.54 sq.km areas has below 1 per cent slope and 711.04 sq. km area is having 1 to 3 per cent slope, which altogether covers 84.02 per cent area of the basin (Table 4.). The area under the slope class below 1 per cent is densely distributed at lower (south west) portion, whereas the area under the slope class 1-3 per cent is closely distributed at the trunk of the basin. The slope class of 3-10 per cent comprises an area of 149.36 sq. km, while the area under hilly terrain (> 10 per cent slope) was 126.32 sq. km. comprises hillocks of Aravalli range.

Rainfall

The study area represents five different classes of seasonal rainfall over the years of study period (1981 to 2012) (Table 5). The highest seasonal rainfall zone (> 700 mm) comprises 23.68 per cent of the area was located at the windward side of the Aravalli hills. The moderate rainfall zone (550 to 700) comprises 54.91 per cent of the basin area. Remaining area is covered by the low rainfall zone (< 500 mm). As per prevailing rainfall conditions

and the area covered under different rainfall class, the basin area was categorized poor, moderate, good and very good for groundwater potential (Table 5).

Groundwater status

In the present study the groundwater level of the area refers to the depth of water level below ground surface/level measured in the monitoring wells present in the area of respective rain gauge station. In Danta and Ambaji covering upper most (north eastern) portion, the effect of seasonal rainfall was observed beneficial with augmented or maintained groundwater levels. Conversely, the post monsoon groundwater levels of the Kanodar, Palanpur and Siddhapur stations were found declined in some years (in early years of study period), where the groundwater levels were comparatively deeper than the rest of the areas. The groundwater levels declined generally and observed up to 40.03 m (bgl) in some area. The pre-monsoon groundwater level class 13 – 16 m covered more area (25.02%) as compared to other classes (Table 6). The groundwater levels (both pre- and post) were found less than 7 m (shallow) near the out let of basin followed by the 7-10 m in upper most portion of the basin. In the central part of the area, pre-monsoon groundwater levels were observed deeper than 22 m covering 20.25 per cent of area. Further, towards the lower reach also the pre-monsoon groundwater levels were found rising. Considering the most shallow groundwater level as excellent and the deepest as poor, the basin area under different groundwater classes are categorized and presented in Table 6.

The major portion (22 % of the area) having 13 to 16 m ground water levels were found in central-north western part of the area. In the central north part of the area, post-monsoon groundwater level also observed deeper than 22 m, pattern almost similar to the pre-monsoon groundwater levels. However, the area under shallow groundwater levels

increased in post monsoon period obviously due to recharge during monsoon. The shallow groundwater levels were recorded at the lower reach (south west portion) of the basin. It was found that the pre- and post-monsoon groundwater levels were varying in similar fashion. Despite seasonal rainfall more than 600 mm, the central north portion of the study area covering Ratanpur, Palanpur and Kanodar stations (west of Patan and North of Siddhapur stations) were observed with declining groundwater levels, reflected higher groundwater exploitation than rest of the areas. Similar findings were reported by Tianming and Zhonghe, 2013 for groundwater exploiting areas. In several pockets the post monsoon groundwater fluctuations were observed negative, may be due to lagging effect of non monsoon exploitation in deep unconfined aquifer. Similar findings were reported by Rimon *et al.*, 2007 and Ferenc, 2014.

It clearly reveals that majority of the physiographic characteristics appear favourable for groundwater recharge potential. However, the detailed analysis revealed that the post monsoon groundwater level below 16 m covered only 30.21 per cent of the basin area, suggest the poor groundwater status of the area. The effect of seasonal rainfall on groundwater was observed negative in some of the pockets. It implicates that due to deeper groundwater levels recharge did not realized till the beginning of the irrigation for *rabi* season. The fall of groundwater was blamed to over exploitation for irrigation during non-monsoon seasons (Shah *et al.*, 2003). As the livelihood of the farmers in the region is predominantly agriculture-based, hence intensive agriculture is being practiced during the non-monsoon seasons and farmers normally adopt traditional (surface) methods for irrigation. The partnership wells are one of the main reasons which restrict farmers in adoption of the micro irrigation systems (MIS). As a

result, the uncontrolled and inefficient use of groundwater for irrigation remains continues through the traditional methods which make the groundwater resources susceptible. As the irrigation is the main user of the groundwater, it is essential to raise water productivity through water saving technologies to arrest groundwater depletion.

CONCLUSION

The geomorphologic characteristics considered good for groundwater potential were identified as alluvial plain and pediplain cover sizable basin area (62.92 %). Similarly, the majority of the area under soil is covered by fine loam (45.12%) followed by mixed coarse to fine loam (23.72%) and coarse loam (15.37%) in all considered favourable for groundwater build up. The topographic elevations covered by 200–300 m, followed by 150-200 m and 100–150 m altogether cover majority (73.27%) of the of the basin area appear suitable for groundwater build up. The basin slope ≤ 3 per cent covers 84.02 per cent area of the basin may also be considered good for buildup of the groundwater potential. The distribution of the seasonal rainfall in the study area indicated the typical semi-arid characteristics (≤ 550 mm to ≥ 700 mm) of the region and represents the rainfall characteristics of the whole north Gujarat region. The assessment of the basin parameters for their physiographic characteristics reveals the favourable characteristics for groundwater build up. Even though, the rainfall and groundwater exploitation pattern suggest the poor status of the groundwater resources. The majority of the area (69.79 %) is having the deeper groundwater levels reveal the grim picture of the basin groundwater resources. In several pockets, the recharge due to rainfall didn't realize due to very deep groundwater levels implicate the exhaustive exploitation of groundwater. Despite, favourable fundamental basin characteristic, the poor status of groundwater suggest the urgency of

rainwater conservation and judicious use of groundwater through the micro irrigation technologies for irrigation.

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Table 1: Area covered by different geomorphological classes

Sr. No.	Geomorphology	Area (Sq.km)	Groundwater Potential
1.	Alluvial Plain	878.02	Very good
2.	Built up Land	1.63	Poor
3.	Denudational Hill	4.29	Poor
4.	Eolian Plain	347.56	Poor
5.	Flood Plain	47.37	Very good
6.	Pediplain	207.57	Good
7.	River	49.06	Very good
8.	Structural Hill	188.23	Poor
9.	Water Body	1.53	Very good
Total		1725.26	

Table 2: Area covered under different soil classes

Sr. No.	Geomorphology	Area (Sq.km)	Groundwater Potential
1.	Course Loam	265.21	Very good
2.	Fine Loam	778.43	Good
3.	Loamy Skeletal	26.03	Good
4.	Mixed Course to Fine Loam	409.29	Very good
5.	River	66.23	Very Good
6.	Rocky Outcrop	180.07	Poor
Total		1725.26	

Table 3: The topographic elevation distribution of the study area

Sr. No.	Geomorphology	Area (Sq.km)	Area (%)	Groundwater Potential
1.	< 50m	120.96	7.00	Very good
2.	50 –75m	123.96	7.00	Very good
3.	75 – 100m	77.81	4.51	Good
4.	100 – 150m	267.87	15.53	Good
5.	150 – 200m	399.13	23.13	Moderate
6.	200 – 300m	597.07	34.61	Poor
7.	>300m	138.46	8.03	Very poor
Total		1725.26	100.00	

Table 4: The slope distribution of the study area

No.	Slope Class	Area (Sq.km)	Area (%)	Groundwater Potential
1.	< 1%	738.54	42.81	Very good
2.	1 - 3%	711.04	41.21	Good
3.	3 - 10%	149.36	8.66	Moderate
4.	> 10%	126.32	7.32	Poor
Total		1725.26	100.00	

Table 5: Area covered under different rainfall classes

Sr. No.	Rainfall Class (mm)	Area (Sq.km)	Groundwater Potential
1.	< 550	369.38	Moderate to poor
2.	550 - 600	162.71	Moderate
3.	600 - 650	628.30	Good
4.	650 - 700	156.25	Moderate
5.	> 700	408.62	Very good
Total		1725.26	

Table 6: Pre- and post-monsoon groundwater levels (bgl) of the study area

Sr. No.	Groundwater Level (m)	Area (Sq. km)		Groundwater Potential
		Pre-monsoon	Post- monsoon	
1.	< 7 m	54.25	88.98	Excellent
2.	7 - 10 m	79.74	197.93	Very good
3.	10 - 13 m	201.00	234.28	Very good
4.	13 - 16 m	431.66	380.44	Good
5.	16 - 19 m	349.44	250.34	Good
6.	19 - 22 m	310.13	262.38	Moderate
7.	> 22 m	299.04	310.90	Poor
Total		1725.26	1725.26	

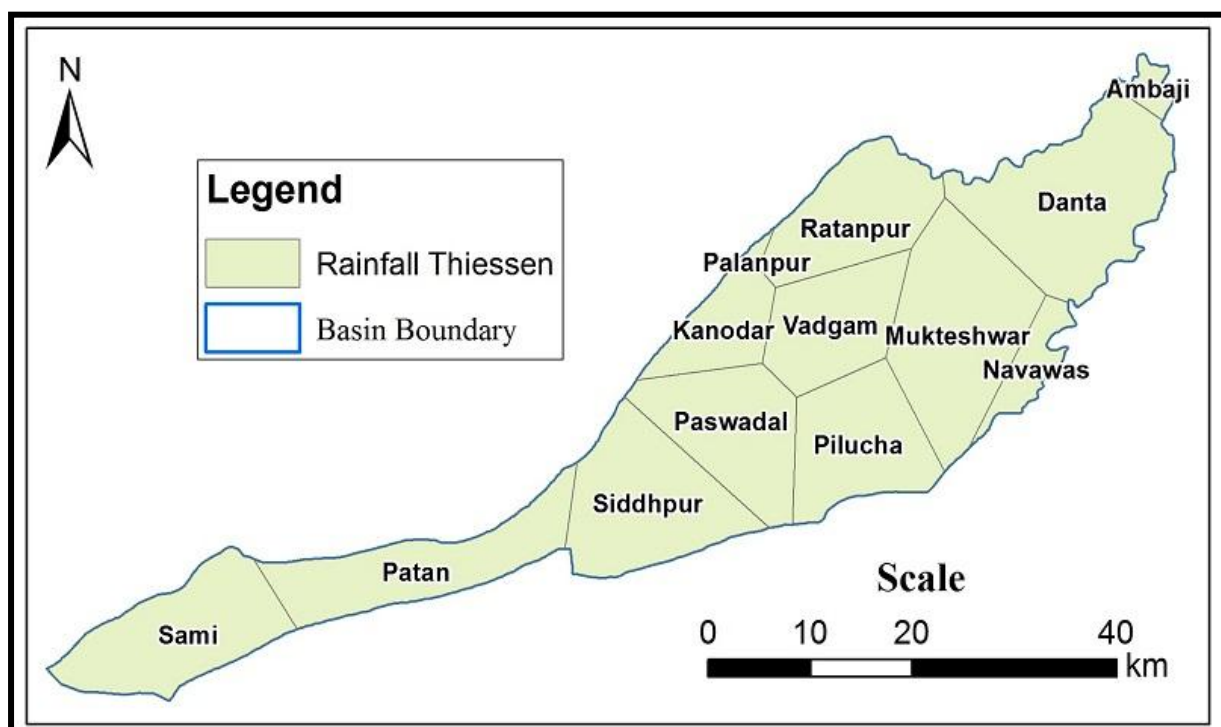


Fig. 1 : Thiessen polygons represented by the different rain gauge stations of the study area

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