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Original Research Paper

Geomorphological Mapping for Identification of Ground Water Potential Zones in Hard Rock Areas Using Geo-spatial Information – A Case Study in Malur Taluk, Kolar District, Karnataka, India

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ABSTRACT

The search for new groundwater resources is essential to sustained economic development in arid environment. The study area is part of Ponnaiyar river basin falling between N latitude of 12°48'24" to 13°07'06' and E longitude of 77°50'30" to 78°08'15" falls in Survey of India toposheets 57 G/16, 57 H/13, 57 K/4 and 57 L/1 covering an area of 645 km^2 in Kolar District, which is highly drought prone in Karnataka State, India. In the present paper, by a methodological approach based on remote sensing and GIS, drainage and hydrogeomorphological maps were prepared using the IRS-1 C & 1 D LISS-III and PAN merged satellite data and geomorphic units. Denudational hill, residual hill, inselberg, pediment inselberg complex, pediment, shallow weathered pediplain, moderately weathered pediplain and valley fill shallow were identified. The area is characterised by undulating terrain interspersed by low ranges of rocky hills. The elevation ranges from 860 m to 1127 m above MSL. The mean annual rainfall of Malur is 722.0mm. The River Dhakshina Pinakini and Markarda Halla drain the area. The streams exhibit dendritic to sub dendritic type of drainage pattern and comprise of granite and gneissic rock formations of Achaean age. On the basis of different geomorphic units, four categories of groundwater potential zones were delineated as (i) very good to good (ii) good to moderate (iii) moderate to poor, and (iv) poor to very poor.

INTRODUCTION

Groundwater is attracting an ever increasing interest due to scarcity of good quality water and growing need for domestic, agricultural and industrial uses. It has become crucial not only for targeting the groundwater potential zones, but also monitoring and conserving this important resource (CGWB 1985). The groundwater prospecting especially in hard rock terrains requires thorough understanding of geology, geomorphology and lineaments of an area, which are directly or indirectly controlled by the terrain characteristics like weathering grade, fracture extent, permeability, slope, drainage pattern, landforms, land use/land cover and climate (Jaiswal et al 2003, Surrete et al. 2008, Yeh et al. 2008, Ravindran & Jayaram 1997, Lokesh et al. 2005 and 2007, Sidle & Onda 2004, Bisson & Lehr 2004, Babar 2005, Kudrna & Sindelarova 2006, Jaiswal et al. 2003, Surrete et al. 2008, Yeh et al. 2008). In hard rock terrains, availability of groundwater is of limited extent. Occurrence of groundwater in such rocks is essentially confined to fractured and weathered horizons (Uday Kumar & Binay Kumar 2010).

More recently, some interesting works stressed the importance of the relationships between geomorphology and groundwater approaches with other emerging scientific domains, such as hydroecology or hydrogeoecology (Loague et al. 2006, Hancock et al. 2009). Efficient management and planning of groundwater in high grade terrains is of the utmost importance (Anuradha et al. 2010). A systematic integration of these data with follow-up of hydrogeological investigation provides rapid and cost-effective delineation of groundwater potential zones. Hence, integrated approach for groundwater targeting is needed.

Geospatial technology is a rapid and cost-effective tool in producing valuable data on geology, geomorphology, lineaments, slope, etc. that help in deciphering groundwater potential. Integrated remote sensing and GIS techniques have provided the appropriate platform for convergent analysis of diverse data sets for decision making in groundwater resource identification, mapping and planning. Many workers such as El-Kadi et al. (1994), Kamaraju et al. (1995), Krishnamurthy et al. (1996), Gogu et al. (2001), Sikdar et al. (2004), Dawoud et al. (2005), Lokesh et al. 2005, 2007, Solomon & Quiel (2006), Leblanc et al. (2007), Münch & Conrad (2007), Vijith (2007), Chatterjee & Bhattacharya (1995), Teeuw (1995), Shahid & Nath (1999), Goyal et al. (1999), Saraf & Choudhary (1998), Jaiswal et al. (2003) and Vittala et al. (2005) have used the approach of remote sensing and GIS for groundwater exploration.

In the present work geomorphological mapping has been carried out in order to delineate the potential groundwater areas in Malur taluk of Kolar district, Karnataka by a methodological integrated approach based on remote sensing and GIS.

STUDY AREA

Malur Taluk is a part of Ponnaiyar river basin, which falls between N latitude of 12°48'24" to 13°07'06" and E longitude of 77°50'30" to 78°08'15". The area falls in Survey of India toposheets 57 G/16, 57 H/13, 57 K/4 and 57 L/1 covering an area of 645 km^2 in Kolar district in Karnataka State, India (Fig. 1). Physiographically, the area is characterised by undulating terrain interspersed by low ranges of rocky hills. The elevation ranges from 860m to 1127m above MSL. The mean annual rainfall for Malur is 722.0mm.

Drainage system and soils: The River Dhakshina Pinakini and Markarda Halla drain the area. A large number of streams join these rivers. All these streams exhibit dendritic to sub dendrite type of drainage. A large number of minor irrigation as well as percolation tanks exist in the area, which are constructed across streams and rivers (Fig. 1). The area is covered mainly by two types of soils viz., red soil and lateritic soils. The red soil is comprised mainly of red loam and is very easy for cultivation purposes and responds to good manure and other treatments. This soil is particularly suited for growing vegetables. Patches of laterite soil are found all over the area.

Geology and hydrogeology: The area comprises of granite and gneissic rock formations of Achaean age. The Peninsular gneiss forms the oldest rock formation of the area and has given rise to barren hilltops with steep to gentle slopes and flat valleys. At places these rock formations are intruded by basic dykes, pegmatites and quartz veins. The granites occupy northern, north eastern and eastern parts of the study area. They are grey in colour and medium to coarse grained. Two diagonal sets of joints and horizontal set (sheet joints) are common in them. Weathered fractured and jointed granite and gneiss serve as potential aquifers in the area. Recent alluvium is found along the banks of streams and river courses, and is not much significant from the groundwater point of view in the area. The thickness of weathered zone in the area ranges from 5.00 to 42.00 m. Groundwater occurs under water table and semiconfined condition.

Slope: The area is characterised by undulating terrain interspersed by low ranges of rocky hills. Intermittent parallel chains of low hills running NEE to SWW found towards north east of the area and south east of Tekal village. Numerous boulders of granites with various shapes and sizes are piled one upon the other are very characteristic of the granite hills in this area. Isolated patches of hillocks are found all over the area i.e., north of Malur, east and south east of Malur town and also in the adjoining area of Masti village. Pediment with steep and gentle slopes is found adjacent to all low range hills. Pediplains of shallow depth is dominant over the area, more predominant around Malur, north and north east of Malur and in the adjoining area of Chukka Tirupathi. Pediplain of moderate depth is restricted to a small area in northern part of Malur taluk. Valley fills of shallow depth are found all along and adjacent of drainage course.

MATERIALS AND METHODS

Different thematic maps viz., drainage, hydrogeomorphology and lineament maps have been prepared through standard visual interpretation techniques (Lillesand & Kiefer 2002) using IRS 1C and 1D Geocoded FCC of LISS III and PAN fused satellite data and their corresponding topographic maps (57 G/16, 57 H/13, 57 K/4 and 57 L/1) on 1:50,000 scale. The drainages have been delineated using merged satellite data of Geocoded FCC of bands-2 3 4 on 1:50,000 scale and SOI toposheets have been used as a reference. The various hydrogeomorphic units have been delineated by following the Standard Technical Guidelines (NRSA 2000). The ground verification of interpreted data was checked out in the field and necessary modifications were made in the thematic maps. The lineament map has been prepared through the analysis of satellite data considering mainly the drainage lineaments and vegetation anomaly. All the prepared primary input drainage, hydrogeomorphology and lineament details were scanned and digitized using AutoCAD Map 2000 software. The GIS software Arc Info was used for analysis and Arc View software was used to create layouts for output generation.

RESULTS AND DISCUSSION

Hydrogeomorphological mapping: Hydrogeomorphological investigations include the delineation and mapping of various landforms, drainage characteristics and structural features that could have a direct control on the occurrence and flow of groundwater (NRSA 2000, Soman 2002). Many of these features are favourable for the occurrence of groundwater and are classified in terms of groundwater potentiality. In the present study, the geomorphological map was prepared based on specific tone, texture, size, shape and association characteristics of remotely sensed data and significant geomorphic units were identified and delineated viz., denudational hill, residual hill, inselberg, pediment inselberg complex, pediment, shallow weathered pediplain, moderately weathered pediplain and valley fill shallow (Fig. 2). The occurrence of groundwater, based on the geomorphological units and its characteristics and area statistics in sq.km and in % has been given in Tables 1 and 2 respectively.

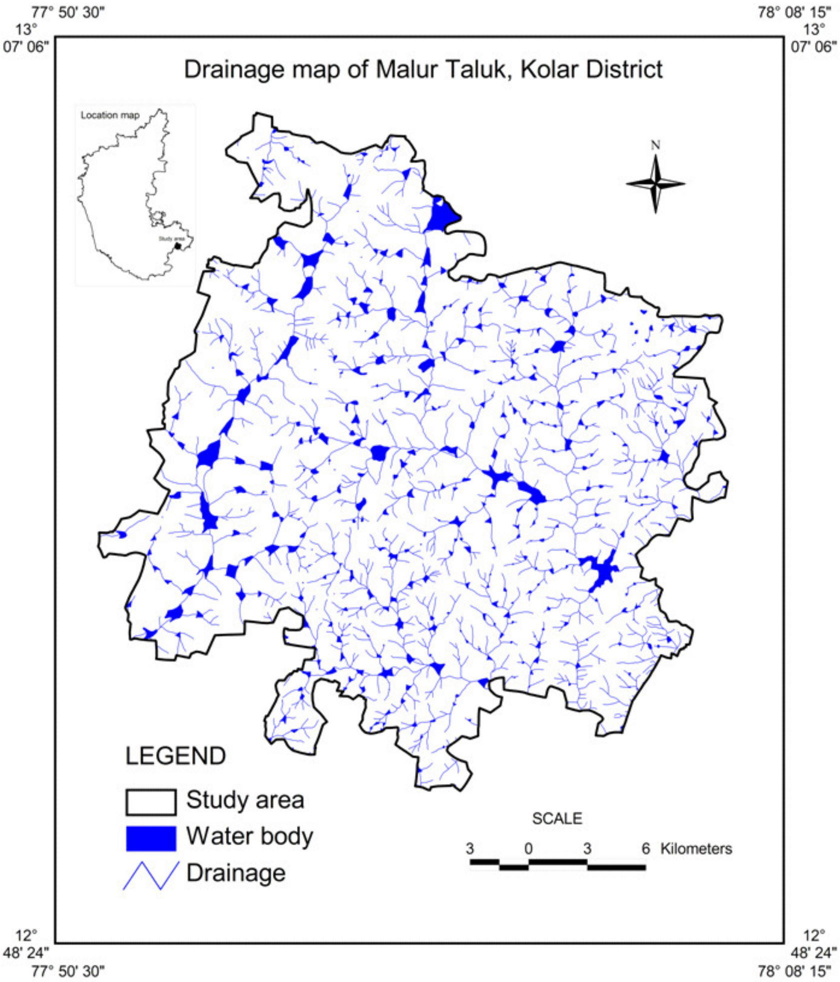

Fig. 1: Drainage map of Malur taluk, Kolar district.

Denudational hills consist of highly fractured gneisses covered with big boulders and sparse vegetation occurring due to the accumulation of weathered material. These hills are marked by sharp to blunt crest lines, rugged tops and light grey in colour. These occur as a group of massive hills with resistant rock bodies that are formed due to differential erosion and weathering and observed in only in south-eastern part of the study area comprising of 5 sq.km. Residual hills are generally resulted from the end product of pediplanation, which reduces the original mountains into a series of scattered knolls standing on the pediplains (Thornbury 1990). These units are considered as poor potential zones, as they have unfractured rock material, low infiltration and behave largely as runoff zone. In the present study, these type of residual hills features have been observed in the north-western part of the study area constituting about 9 sq.km. Inselbergs are with moderate steep to very steep slope and occur as smooth and rounded isolated hills abruptly rising above surrounding plains. They are very negligible (1 sq.km) and observed in the northwestern part of the study area. Pediment inselbergs complex are pediments dotted with a number of inselbergs which cannot be separated and mapped as individual units. They have very low potential of groundwater occurrence. These features are observed in southeastern part of the study area (17 sq.km). Pediments occur as gently undulating plains with moderate slope dotted with outcrops and are often covered with thin layers of soil in the study area. They are mostly confined to base of the various hills. Many small pockets of pediment formations (35 sq.km) were observed throughout the study area. These units are characterized by the presence of relatively thicker weathered material. These units consist of fairly thick weathered zones underlined by granites and gneisses. Depending upon the depth and thickness of weathered materials, these are broadly classified as shallow and moderately weathered pediplains (415 and 18 sq.km respectively) which

Table 1: The occurrence of groundwater, based on the geomorphological units and its characteristics in Malur taluk, Kolar district.

Sl. No.	Geomorphic Unit	Characteristics	Hydrogeology	Groundwater potential
1	Denudational hill	Small hills or heaps of angular boulders raising abruptly from surrounding.	Runoff zone	Poor-Very Poor
2	Residual hill	A group of hills occupying comparatively smaller area than composite hills.	Runoff zone	Poor-Very Poor
3	Inselberg	Isolated, very steep conical hill	Runoff zone	Poor-Very Poor
4	Pediment inselberg complex	Pediment dotted with a number of inselbergs which cannot be separated and mapped as individual units.	Inselbergs form runoff zones. Pediment contributes for limited to moderate recharge.	Moderate to Poor
5	Pediment	Pediments occur as gentlyundulating plains with moderate slope	Contributes for limited to moderate recharge.	Moderate to Poor
6	Shallow weathrered pediplain	Gently undulating plain of large areal extent often dotted with inselbergs formed by the coalescence of several pediments.	Pediplains form good aquifers depending on their composition. In hard rocks, they form very good recharge and storage zones depending upon the thickness of weathering/accumulated material, its composition and recharge conditions.	Good to Moderate
7	Moderately weathrered pediplain	It is shallow depressed low relief area with good drainage net works.	Moderate infiltration to good, recharge by hydrological feature, Storage complemented by secondary features.	Very good to good depending upon type of lithology and thickness of the material deposited
8	Valley fill shallow	Valleys of different shapes and sizes occupied by valley fill material (partly detrital and partly weathered material).	Form moderately productive shallow aquifers, subject to thickness of valley fill material, its composition and recharge conditions. The unconsolidated sediment deposited to fill a valley. Sometime controlled by fracture forming linear depression	Very good to good depending upon type of lithology and thickness of the material deposited

Table 2: Different hydrogeomorphological units (km^2 and %) delineated in Malur taluk, Kolar district.

Sl.No	Geomorphic Units	Area (sq.km)	Area (%)
	Run-off zones		
1	Denudational Hills	5	1
2	Residual Hills	9	1
3	Inselberg	1	0
4	Pediment Inselberg Complex	17	3
5	Pediment	35	5
	Infiltration zones		
6	Pediplain Shallow	415	64
7	Pediplain Moderate	18	3
8	Valley Fill Shallow	145	22
	Total	645	100

are spread in almost all direction of the study area sub-watersheds occupying the areas between the pediments and valley fills and varying from nearly level to gentle slope. Shallow valley fill zones are located adjacent to pediments/

Table 3: Area showing various groundwater potential zones in Malur taluk, Kolar district.

Sl.No	Groundwater prospects	Area (sq.km)	Area (%)
1	Poor to Very poor	14	2
2	Moderate to Poor	52	8
3	Good to Moderate	415	64
4	Very good to Good	163	25
	Total	645	100

pediplains. They vary in shape and extent. Wide and extensive valley fills are formed within the faulted lines. These occupy all along the major lineaments in the study area. Minor and narrow valley fills are located along the pediplains. The valley fill zones are mostly occupied by major and minor streams. They have been demarcated on the basis of their reddish tone on satellite images. In the present study, the shallow valley fills comprised of 145 sq.km, which is spread over in all the directions.

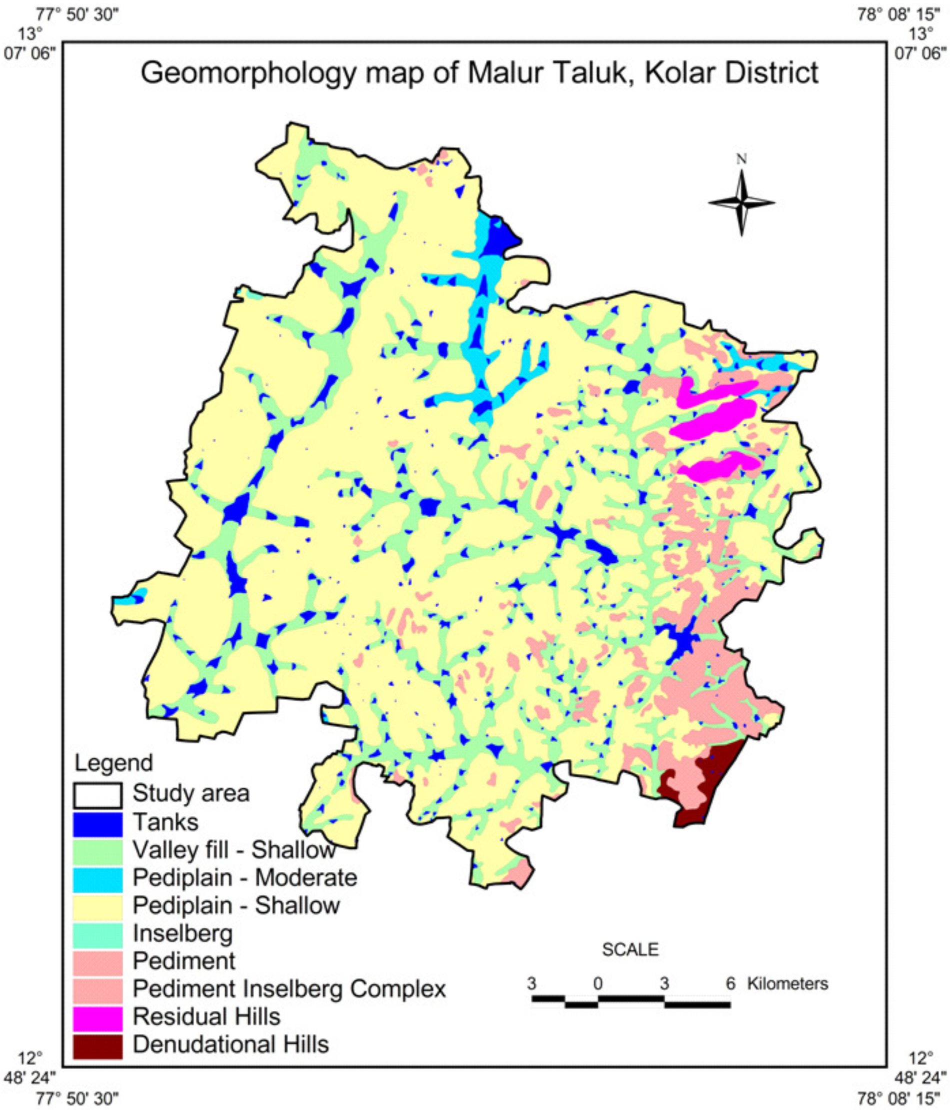

Fig. 2: Hydrogeomorphological map of Malur taluk, Kolar district.

Groundwater potential zone mapping: The full potential of remote sensing and GIS can be utilized when an integrated approach is adopted. Integration of the two technologies has proven to be an efficient tool in groundwater studies (Krishnamurthy et al. 1996). In the present study, the groundwater favourable zone of the study area has been analysed using geomorphological map. On the basis of various geomorphological units of the study area, the ground water favourable zones are delineated and given in Table 3 and Fig. 3. On the basis of different geomorphic units, there are four categories of groundwater potential zones delineated as (i) very good to good (ii) good to moderate (iii) moderate to poor and (iv) poor to very poor (Fig. 3). The geomorphological units such as valley fill shallow and pediplain moderate are very good to good ground water potential zones and considered most favourable zones for groundwater exploration while pediplain shallow areas are good to moderate, pediment inselberg complex and pediment zones are moderate to poor and denudational hills, residual hills and inselbergs are considered as poor to very poor groundwater potential zones in the study area.

During field study data pertaining to the bore wells drilled for water supply to the towns and villages by Panchayatraj Engineering Department, Government of Karnataka, which is taking care of water supply needs of the public in Malur taluk, were collected. A total number of 796 bore wells were drilled out of which 636 bore wells are fitted with hand pumps as the discharge of these wells is less than 1.5 l.p.s.,

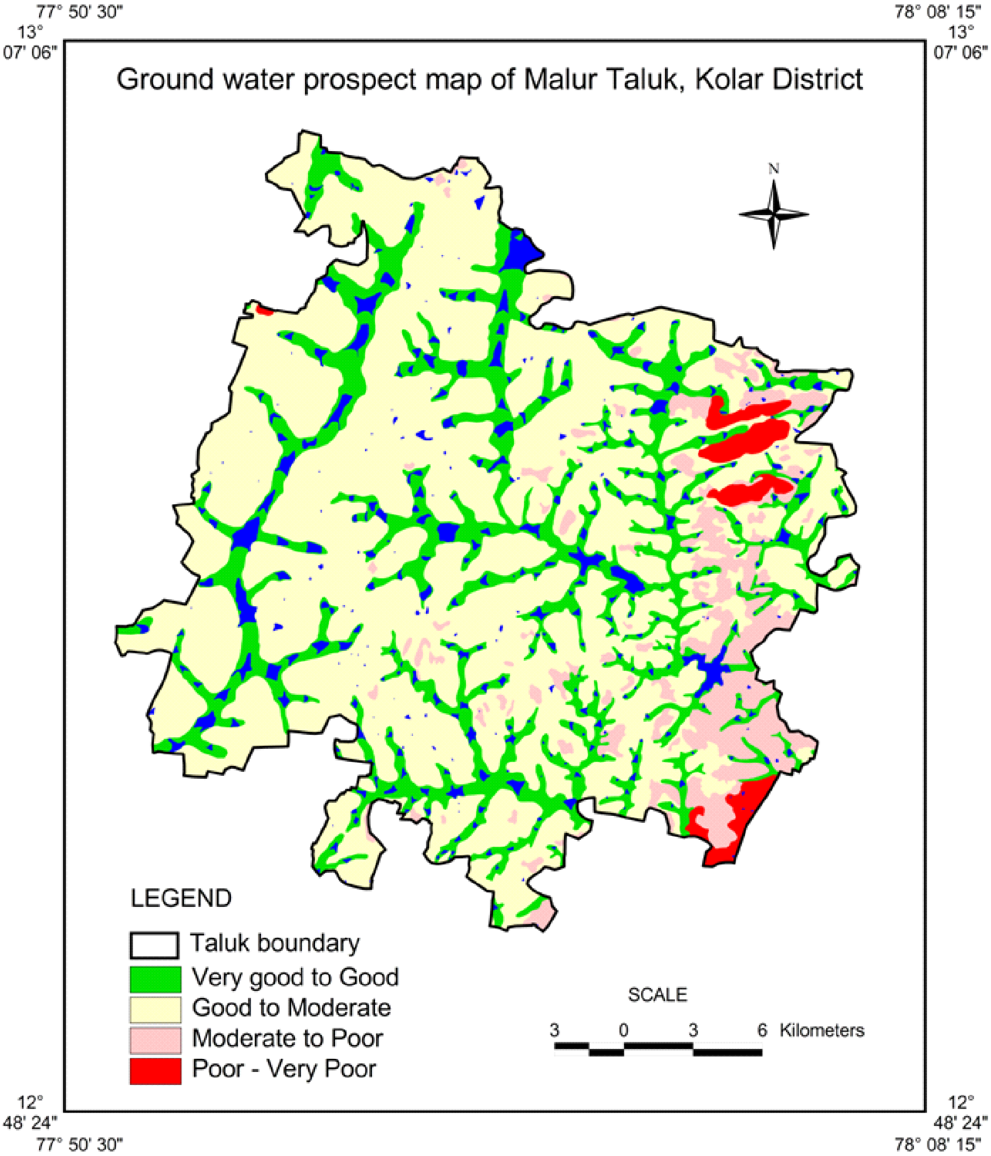

Fig. 3: Delineation of groundwater potential zone in Malur taluk, Kolar district.

which are located in the zones marked as moderate to poor yield zones. One hundred fifteen bore wells are fitted with submersible pumps for mini water supply schemes and 45 bore wells fitted with submersible pumps for piped water supply schemes for big villages and Malur town in the area. Observation made during the survey clearly indicates that the bore wells located in the zones marked as very good to good mostly in the area occupied by valley fills shallow, are having very good discharge ranging from 3.15 to more than 8.00 l.p.s. It is also evident from the bore wells drilled for water supply to Malur town in the vicinity of the tank bed, which are high yielding. Geomorphological mapping with methodological integrated approach, based on remote sensing and GIS techniques coupled with ground truth investigation, will definitely be helpful in demarcating potential groundwater zones in hard rock areas.

CONCLUSIONS

Hydrogeomorphological analysis supported by GIS mapping technique is very useful tool in the assessment of infiltration potential. The geomorphological features of these areas provides a simple and efficient way to identify the groundwater potential zones and to contribute to the decision-making process. On the basis of different geomorphic units, there are four categories of groundwater potential zones were delineated as (i) very good to good (ii) good to moderate (iii) moderate to poor and (iv) poor to very poor. The geomorphological units such as valley fill shallow and pediplain moderate are very good to good ground water potential zones and considered most favourable zones for groundwater exploration while pediplain shallow areas are good to moderate, pediment inselberg complex and pediment zones are moderate to poor and denudational hills, residual hills and inselbergs are considered as poor to very poor ground water potential zones in the study area.

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