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Evaluation of Ground Water Potential Zones Using Remote Sensing Data - A Case Study of Gaimukh Watershed, Bhandara District, Maharashtra

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ABSTRACT

In the present study efforts have been made to evaluate ground water potential zones for ground water targeting using IRS-IC LISS-III geo-coded data on 1:50,000 scale. The drainage, geology, geomorpholgoy and lineament information has been generated and integrated to evaluate hydro-geomorphological characteristics of the Gaimukh watershed, Bhandara district, Maharashtra for delineation of ground water potential zones. The analysis reveals that the deep valley fills with thick alluvium have excellent, shallow valley fills and deeply weathered pediplains with thin alluvium have very good and moderately weathered pediplains in the geological formations of Tirodi Gneiss and Sausar Groups have god ground water potential and these units are highly favourable for ground water exploration and development. Shallow weathered pediments in geological formations of Tirodi Gnesis and Sausar Groups are marked under moderate ground water potential zone. Shallow weathered pediplains in geological formations of Tiridi Gneiss and Sausor Groups are grouped under limited ground water potential category, except along the fractures/lineaments. Structural hills in geological formations of Tirodi Gneiss and Sausar Groups have poor ground water prospects. Inselbergs and Linear ridges in geological formations of Tirodi Gneiss are grouped under very poor ground water prospects zone. The good inter-relationship was found among the geological units, geomorphological units, lineament density, hydro-geomorphological zones and ground water yield data.

Introduction

Ground water occurrence, being subsurface phenomenon, its identification and location is based on indirect analysis of some directly observable terrain features like lithology, geological structures, geomorphic features and their hydrologic characters. Ground water is a dynamic and replenish able natural resource but in hard rock terrains availability of ground water

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is of limited extent and its occurrence is essentially confined to fractured and weathered zones (Saraf and Choudhury, 1998). Satellite remote sensing provides an opportunity for better observation and more systematic analysis of various geomorphic units/landforms/lineaments due to the synoptic and multi-spectral coverage of a terrain. Satellite images are increasingly used in ground water exploration because of their utility in identifying and outlining various ground features that may serve as direct or indirect indicators of the presence of ground water (Dept. of space, 1988, Ravindran and Jayaram, 1997). With the available spaceborne multi-spectral data, the geological, geomorphological and hydro-geomorphological maps on 1:250,000 scale have been generated at operational level (Reddy, 1987; Bhattacharya and Reddy, 1991). Analysis of remotely sensed data for drainage, geological, geomorphological and lineament characteristics of terrain in an integrated way facilitates effective evaluation of ground water potential zones. Similar attempts have been made in the generation of different thematic maps for the delineation of ground water potential zones in different part of the country (Chatterji *et al.*, 1978; Seelan Santhosh Kumar and Thiruvengadachari, 1980; Behera, 1989; Obi Reddy *et al.*, 1994; Krishna Murthy and Srinivas, 1995; Rao *et al.*, 1996; and Reddy *et al.*, 1996). Analysis of remotely sensed data along with Survey of India topographical and collateral information with necessary ground checks help in generating the base line information for ground water targeting. In the present study the Gaimukh wathershed of Bhandara district has been selected for qualitative evaluation of ground water potential zones using remotely sensed data.

Study Area

The study area is bounded by North latitudes 21° 16′ and 21°29′ and East longitudes 79°30′ and 79° 42′ and is located in south-western part of Bhandra district, Maharashtra with total area is around 320 Km^2. Climate of the study area is sub-humid sub-tropical with well defined summer (March-May), rainy season (June-October) and mild winter (November-February). The mean annual temperature is 25.5°C with a mean maximum of 42.5°C and a mean minimum of 12.5°C. The mean annual precipitation of the study area is 1120mm of which nearly 85 per cent is received during south-west monsoon period (June-October).

The study area is part of Sur river basin of Maharashtra having conspicuous physiographic variations comprising high hills, isolated hillocks, undulating plains and alluvial tract. Nearly 10 per cent of the area is covered by hills characterised by highly rugged and undulating topography. The hills comprise of, formations of Sausar Group and Tirodi Gneiss with an elevation ranging from 300 to 400 metres above mean sea level (msl). The undulating terrain bordering the hilly tract comprises of pediment zone with an elevation ranging from 250 to 300 metres above msl. Flat alluvial terrain formed by deposition of recent sediments occupy the flood plains of the Gaimukh river. The lower alluvial tract is located within an elevation ranging from 200 to 250 metres above msl. Drainage pattern is mostly dendritic and fracture/joint controlled. Sub-parallel drainage pattern is also developed at some places (Fig.1).

Materials and Methods

Geocoded IRS-IC LISS-III standard False Colour Composite (FCC) of 3rd March 1997 (Path 100, Row 57) generated from bands 4,3,2 on 1:50,000 Scale has been used in the present study. Survey of India (SOI) topographical map on 1:50,000 scale (No. 55 O/11) has been used for the generation of base and drainage maps of the study area.

The methodology includes generation of thematic maps showing drainage pattern, geomorphology (landforms), geology (rock types), lineaments and hydro-geomorphology of the study area through visual interpretation of

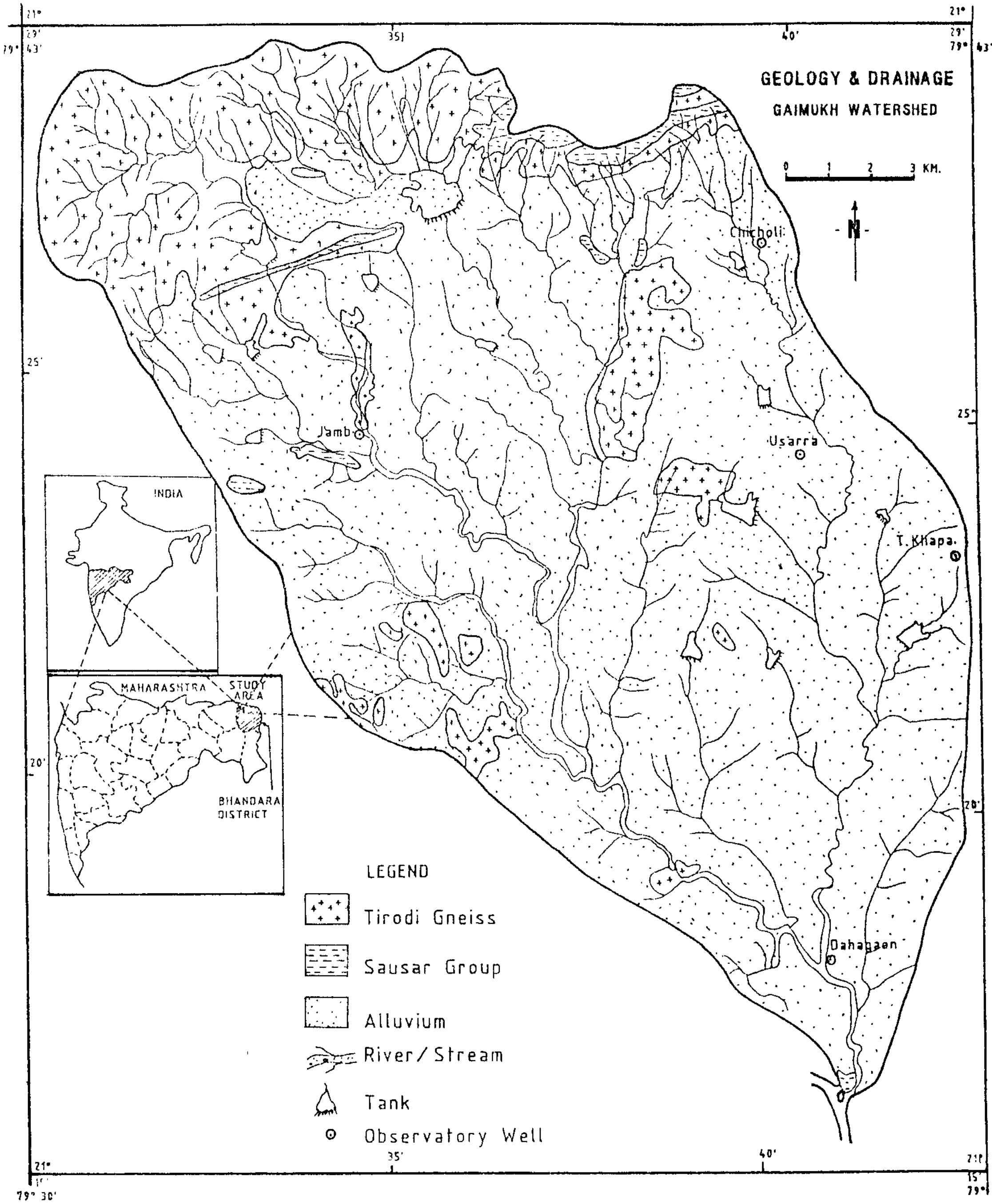
GEOLOGY & DRAINAGE
GAIMUKH WATERSHED
0 1 2 3 KM.
N
Chicholi
Jamb
Usarra
T. Khapa.
Dahagaen
INDIA
MAHARASHTRA
STUDY AREA
BHANDARA DISTRICT
LEGEND
Tirodi Gneiss
Sausar Group
Alluvium
River / Stream
Tank
Observatory Well

Fig. 1

IRS-IC LISS-III FCC data. The identification and delineation of various units on the thematic maps was based on the variation in tone, texture, shape, drainage pattern, colour, differential erosional characteristics. The Geological map of the study area has been generated through the interpretation of the satellite data keeping in view the geological map prepared by Geological Survey of India (GSI, 1978). Based on the concentration and length of the lineaments the lineament density map has been generated. The grids having major lineaments has been assigned one additional value to give more emphasis for the major lineaments. By integrating the drainage, geology, geomorphology and lineament density information, the composite hydro-geomorphological map has been generated and of ground water potential zones in the study area delineated. The available data from five observatory wells in the study area has been collected (CGWB, 1998) to workout the ground water level dynamics in pre-monsoon (March, April, May and June), monsoon (July, August, September and October) and post-monsoon (November, December, January and February) periods for the ten years (1988-98). The delineated ground water potential zones have been counter checked with average ground water level, variation or fluctuation in ground water level and yield data of five observatory wells in the area. The selected ground checks were carried out for the validation of the results.

Results & Discussions

Geology

Geologically the study area has been divided into three distinct classes i.e., formations of Tirodi Gneiss, Sausar Group and Alluvium (GSI, 1978, Fig. 1). The prominent rock types that occur in the study area belong to highly metamorphosed Tirodi Gneiss and Sausar Group of middle Proterozoic Archean age (Krishnan, 1982). The igneous rocks occur as intrusives within the metamorphic rocks. Lithologically the formations of Tirodi gneiss are predominantly argillaceous and arenaceous. These formations associated with kyanite and sillimanite bearing rocks consisting of chlorite-muscovite schistose and quartz-biotite granite are found mainly in the north-western part and isolated places in the rest of the watershed. The formations of Sausar Group include rocks like cale-granulite, magniferrous schist and manganese ores. The metamorphic rocks, belonging to the formations of Sausor Group are associated with ortho geniss of granulitic and granodioritic composition. Mica-schists, gneiss and quartzites are very prominent in these formations in north-eastern part of the study area. Quaternery alluvium deposits consist of loose, unindurated sequence of interlayered clay/silt and sand beds with occasional kankar layers admixed with cobbels and pebbles of granitic gneisses. Older alluvium is noticed in weathered pediplains and along the river/stream courses. The rocks have general strike along SW and NW – SE direction and having moderate to steep dips in the western direction.

Geomorphology

The relief, slope, depth of weathering, type of weathered material, thickness of alluvium, nature of the deposited material and the overall assemblage of different landforms play in important role in defining the ground water regime, especially in the hard rocks and the unconsolidated sediments. The erosional and depositional landforms identified in the study area are structural hills, inselbergs, linear ridges, weathered pediments, weathered pediplains and valley fills.

The northern and north-western parts of the Gaimukh watershed are covered by structural hills with structural trend lines in E-W and NW-SE direction. These hills are characterized with complex folding and faulting, and are also criss-crossed by numerous joints/fractures. The linear ridges and inselbergs (isolated residual hillocks) are the remanants of weathering and denudational action. Shallow weathered

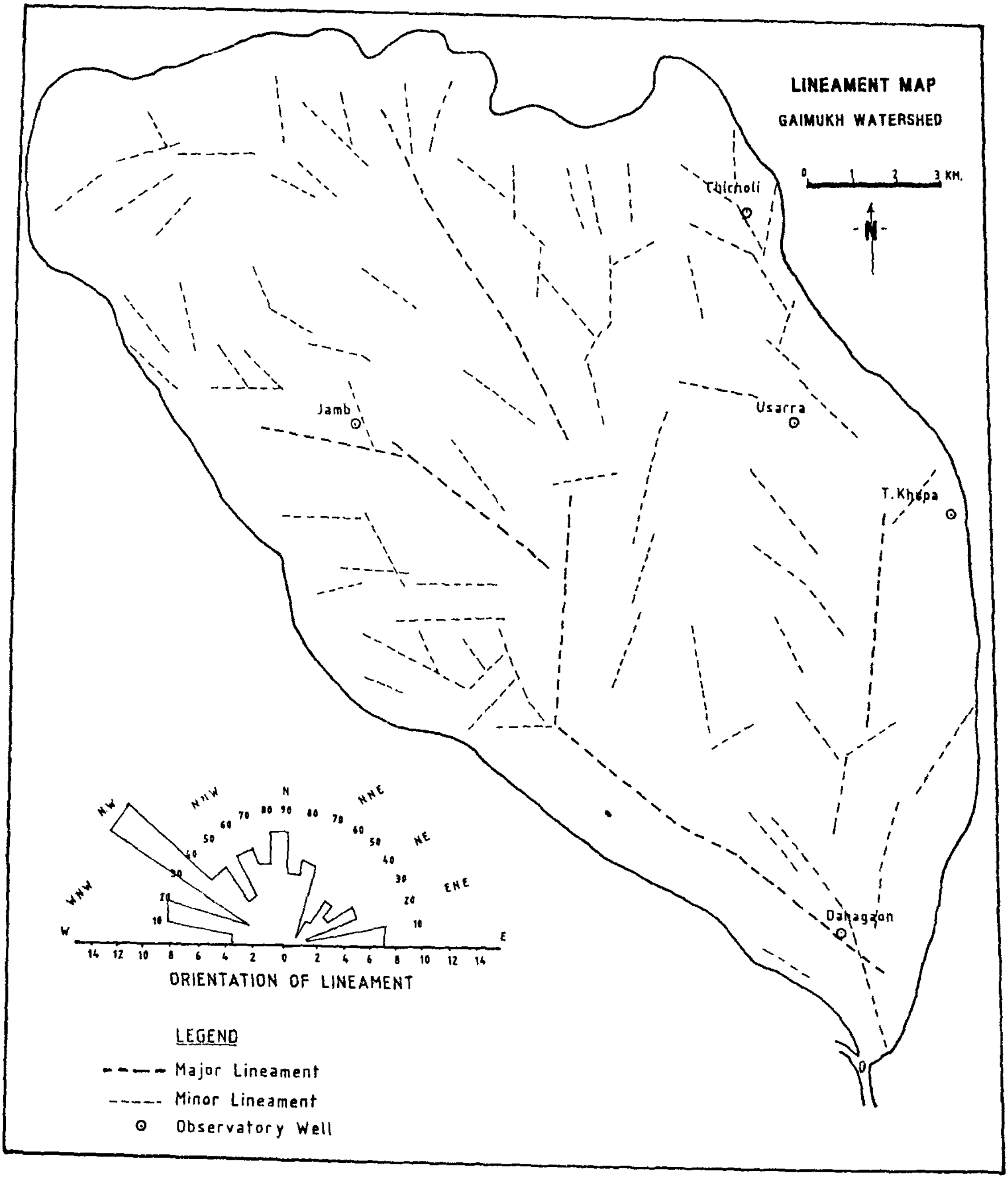
LINEAMENT MAP
GAIMUKH WATERSHED
0 1 2 3 KM.
N
Tulcholi
Jamb
Usarra
T. Khapa
Dahagaon
N
NNW
NNE
NW
NE
WNW
ENE
W
E
ORIENTATION OF LINEAMENT
LEGEND
Major Lineament
Minor Lineament
Observatory Well

Fig. 2

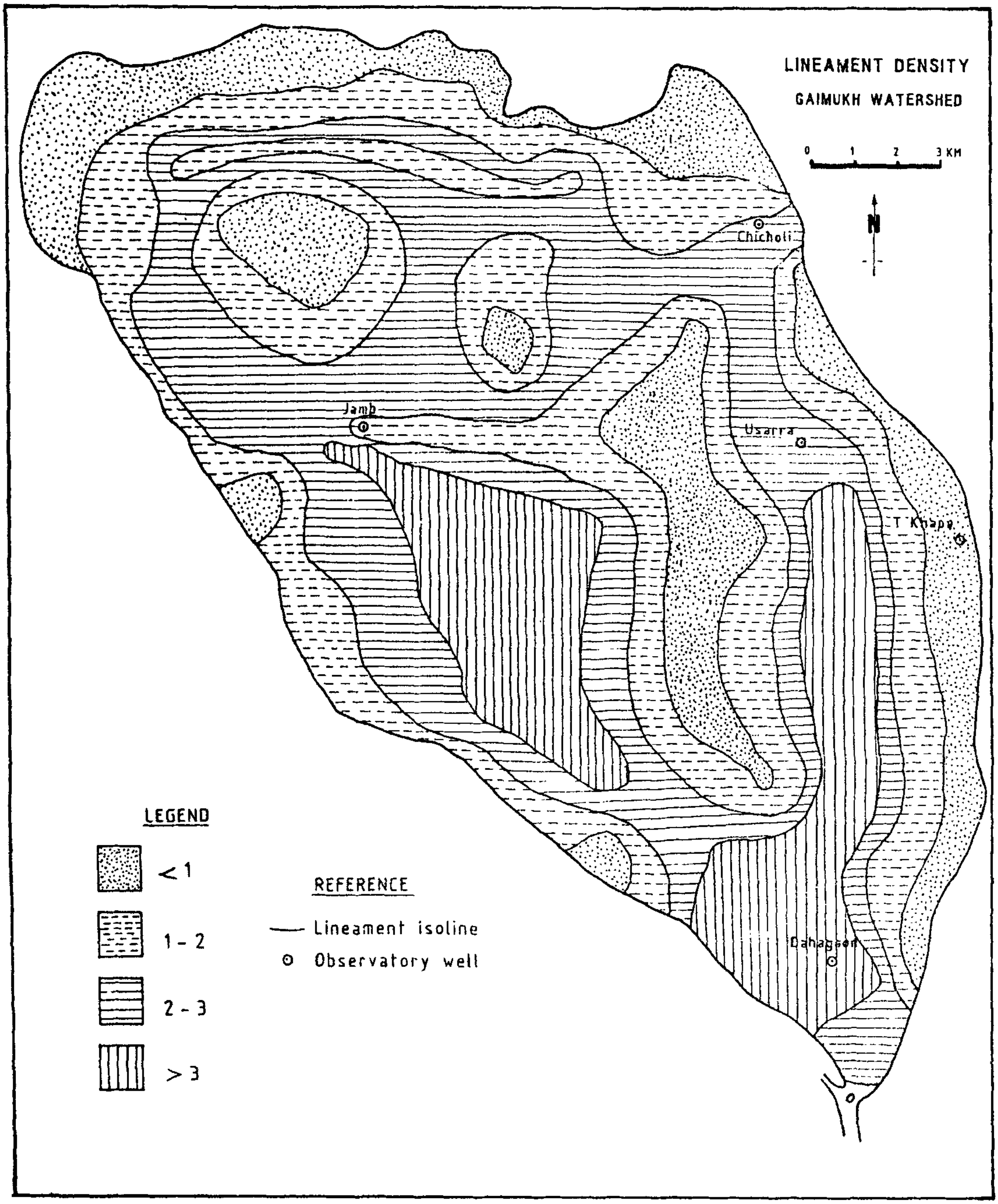
LINEAMENT DENSITY
GAIMUKH WATERSHED
0 1 2 3 KM
N
Chicholi
Jamb
Usarra
T Khapa
Dahagaon
LEGEND
< 1
1 - 2
2 - 3
> 3
REFERENCE
Lineament isoline
Observatory well

Fig. 3

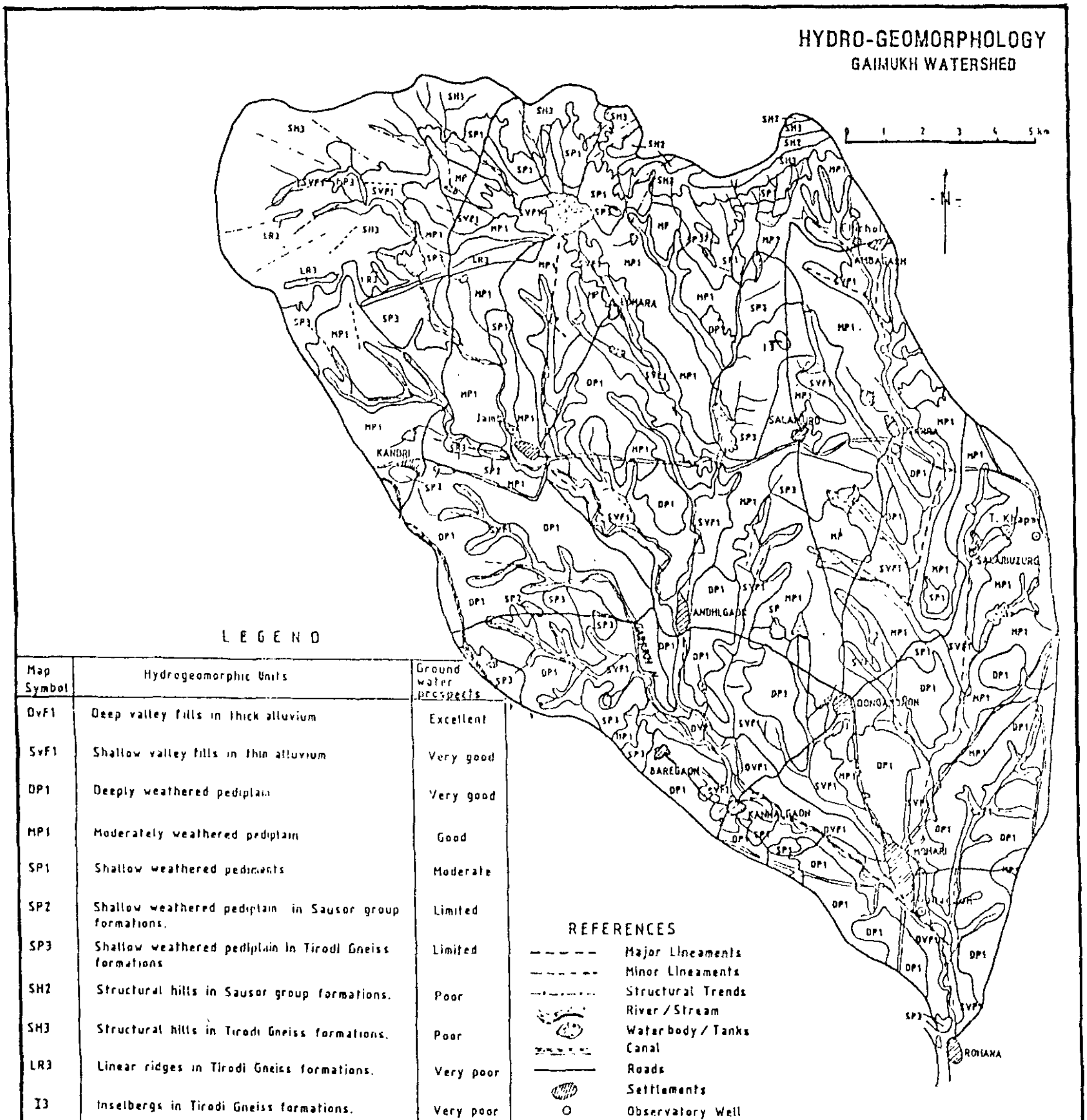
HYDRO-GEOMORPHOLOGY
GAIMUKH WATERSHED
LEGEND
Map Symbol
Hydrogeomorphic Units
Ground water prospects
DvF1
Deep valley fills in thick alluvium
Excellent
SvF1
Shallow valley fills in thin alluvium
Very good
DP1
Deeply weathered pediplain
Very good
MP1
Moderately weathered pediplain
Good
SP1
Shallow weathered pediments
Moderate
SP2
Shallow weathered pediplain in Sausar group formations.
Limited
SP3
Shallow weathered pediplain in Tirodi Gneiss formations
Limited
SH2
Structural hills in Sausar group formations.
Poor
SH3
Structural hills in Tirodi Gneiss formations.
Poor
LR3
Linear ridges in Tirodi Gneiss formations.
Very poor
I3
Inselbergs in Tirodi Gneiss formations.
Very poor
REFERENCES
Major Lineaments
Minor Lineaments
Structural Trends
River / Stream
Water body / Tanks
Canal
Roads
Settlements
Observatory Well
KANDRI
SALAKURD
ANDHLGAON
DONGARGAON
BAREGAON
KANHALGAON
ROHANA
T. KHapa
SALAIBUZURG
AMBAGADH

Fig. 4

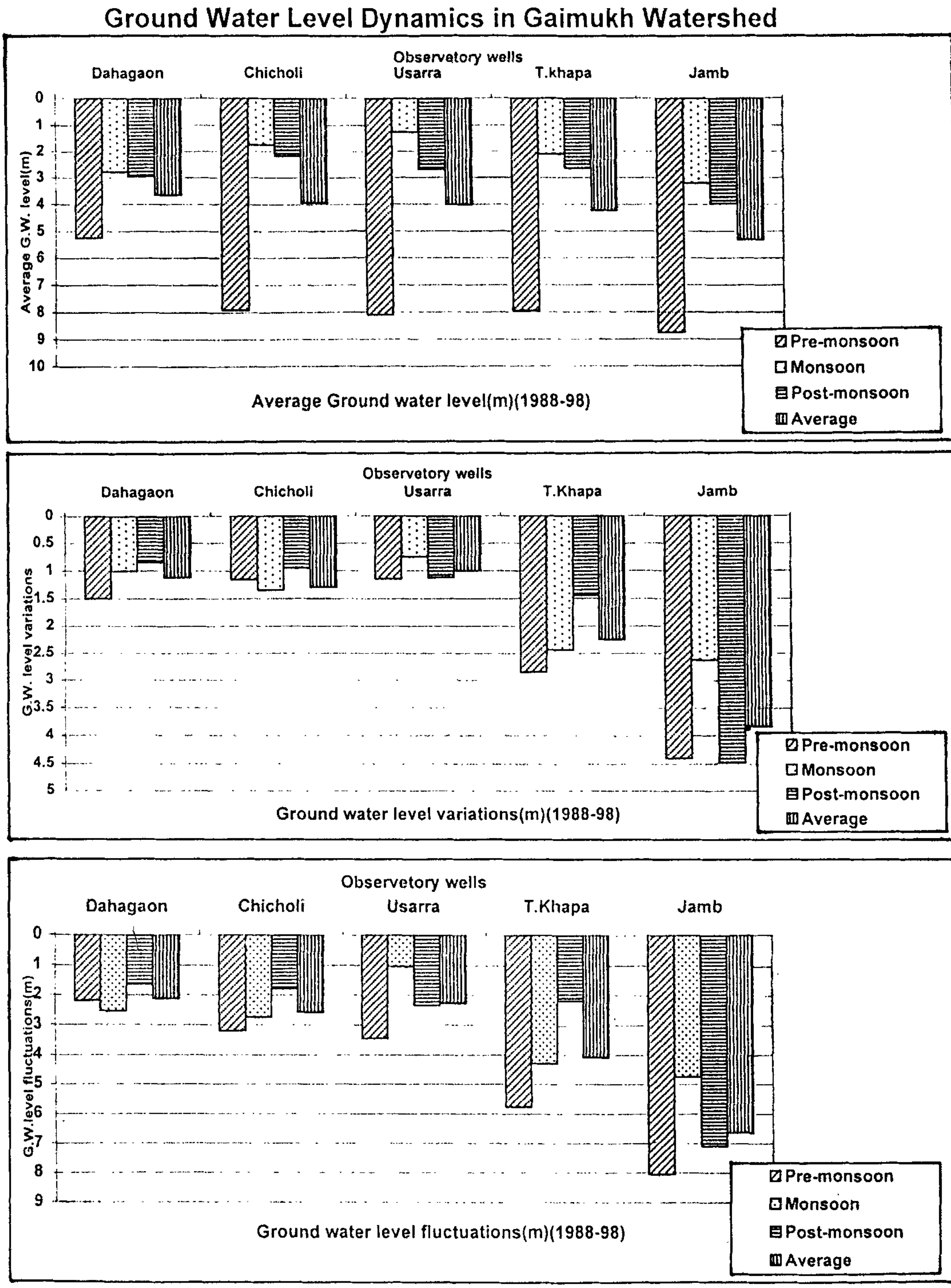
Ground Water Level Dynamics in Gaimukh Watershed
Observatory wells
Dahagaon
Chicholi
Usarra
T.khapa
Jamb
Average G.W. level(m)
0
1
2
3
4
5
6
7
8
9
10
Average Ground water level(m)(1988-98)
Pre-monsoon
Monsoon
Post-monsoon
Average
Observetory wells
Dahagaon
Chicholi
Usarra
T.Khapa
Jamb
G.W. level variations
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Ground water level variations(m)(1988-98)
Pre-monsoon
Monsoon
Post-monsoon
Average
Observetory wells
Dahagaon
Chicholi
Usarra
T.Khapa
Jamb
G.W.level fluctuations(m)
0
1
2
3
4
5
6
7
8
9
Ground water level fluctuations(m)(1988-98)
Pre-monsoon
Monsoon
Post-monsoon
Average

Fig. 5

pediments with thin alluvium was found on gently sloping plains along the foot hills of Tirodi Gneiss/Sausar Groups. Gently sloping rock cut surfaces formed due to erosion of the rock units existing in this area have been classified into three categories based on the thickness of weathered zone, i.e., shallow weathered pediplains (<5m), moderately weathered pediplains (5-20m) and deeply weathered pediplains (>20m). The shallow valley fills are formed due to fluvial deposition along the stream/river courses. This geomorphic unit consisted of gravel, sand and coarse fragments and is characterized with relatively thin unconsolidated material. The deep valley fills formed due to fluvial deposition consist of very thick alluvium and other unconsolidated material and occupy either side of the major streams in the study area.

Lineaments

In the hard rock areas, the movement and occurrence of ground water depends mainly on the secondary porosity and permeability resulting from folding, faulting, fracturing etc. The most obvious structural features that are important from the ground water point of view are the lineaments. They occur as linear alignments of structural, lithologic, topographic, vegetational, drainage anomalies etc., either as straight lines or as curvilinear features. The remote sensing data which offer synoptic view of large area, helps in understanding and mapping the lineaments both on regional and local scale. The lineament analysis of the area from remotely sensed data provides important information on subsurface fractures that may control the movement and storage of groundwater (Padeep Raj *et al.,* 1996).

In the study area, major lineaments are identified from the satellite data interpretation, which are surface manifestations of some structural features in the bed rock as fractures and joints, developed due to tectonic stress and strain. The major lineaments controlled the major river channels in the study area and generally trend in NW-SE, N-S, NE-SW directions (Fig.2). The minor lineaments identified in structural hills, pediments and valley fill zones in the study area are controlling the river channels and nalas. The minor lineaments in the Gaimukh watershed trend in NW-SE, N-S, NNW-SSE, NNE-SSW, E-W and NE-SW directions.

Lineament Density

The total length of lineaments in each grid covering one sqkm (2cm x 2cm) have been measured and plotted in the respective grid center (Haridas *et al.,* 1994). These values are joined by isolines to prepare a lineament density map (Fig.3) The high lineament density (more than 3 per sq. km) is noticed in the lower parts of the watershed along with major river courses associated with thick alluvium indicating high ground water potential. The medium lineament density ranging from 2 to 3 per sq. km. is found along the valley fills mainly in the central parts of the area indicating moderate to good ground water potential. The low lineament density ranging from 1 to 2 per sq. km. indicating limited to low ground water potential occupies mainly along the second order streams in the uplands. The very low lineament density of less than 1 per sq. km. is occupied in isolated places, extreme northern and western uplands of the study area associated with formations of Tirodi Gneiss/ Sausar Groups and thin alluvium having very poor ground water prospects.

Ground water potential zones

Ground water potential zones of the study area were demarcated after integrating the geological, geomorphological, lineament density and drainage information. Seven ground water potential zones viz., excellent, very good, good, moderate, poor and very poor were identified. (Table 1) (Fig.4). and discussed below.

Deep valley fills with thick alluviam (DVF1): Deep valley fills with thick alluvium

Table 1. Hydro-Geomorphological units Gaimukh Watershed

Map Symbole	*Geomorphic Unit*	*Lithology*	*Structure*	*Description*	*Ground water Prospects*
DVF1	Deep valley fills	Thick alluvium With gravel, sand, silt and clay	Criss-crossed by major fractures/lineaments	Very gently sloping hydro geomorphic unit formed by fluvial deposition of alluvium along the river courses	Excellent
SVF1	Shallow valley fills	Thin alluvium with gravels, sand, silt, clay etc.	The valleys are controlled by major and minor fractures/lineaments	Unconsolidated sediment/alluvium partially or fully deposited along the valleys of river channel	Very Good depending on the thickness of alluvium and weathered column of underlying formation
DP1	Deeply weathered pediplains	Tirodi Gneiss/Sausar Group formations overlain by thin alluvial cover	Major and minor fractures are present	Gently sloping plain with >20m thickness of weathered zone	Very Good
MP1	Moderately weathered pediplains	Tirodi Gneiss/ Sausar Group formations overlain by thin alluvial cover	Minor lineaments/fractures	Gently sloping plain with 5-20m thickness of weathered zone	Good
SP1	Shallow weathered pediments	Tirodi/Gneiss/ Sausar Group formations overlain by thin alluvial cover	-do-	Gently sloping plains at the foot hills zones having <5m weathered zone	Moderate, but good along the fractures/lineaments
SP2	Shallow weathered pediplains	Consist of Sausar Group formations	-do-	Gently sloping rock cut surface with <5m weathered zone	Limited, but moderate, along the fractures/lineaments
SP3	Shallow weathered pediplains	Tirodi Gneiss	-do-	Gently sloping rock cut erosional surface covered with thin veneer of soil and <5m of weathered zone	Limited, but moderate along the fractures/lineaments
SH3	Structural hills	Tirodi Gneiss formation	Associated with folding and criss-crossed by lineaments/fractures	Hills having high relief and steep slopes, with definite structural trends	Poor, but limited along the lineaments/ fractures on that tops
SH2	Structural hills	Sausar Group formations	-do-	-do-	Poor
LR3	Linear Ridges	Tirodi Gneiss and long narrow basic dykes intrusives into the basement	-do-	High relief, slope and very less areal extent; act as runoff zone and barrier for ground water movement	Very poor
13	Inselbergs	Tirodi Gneiss formations	-do-	Relict hills undergone process of denudation, acts as runoff zone	Very poor

are very gently sloping fluvial depositional plains built on either side of a main river course and underlined by unconsolidated thick alluvium consisting of sand, silt and clay with occasional kankar layers admixed with cobbles and pebbles. The unconsolidated thick alluvium expressing high recharging capacity and concentration of the major lineaments (NW-SE) criss-crossed by minor lineaments are caused for high groundwater prospects in this unit. This hydro-geomorphic unit was grouped under excellent ground water prospects zone. The Dahagaon observatory well located in this zone has high average ground water level from the surface (3.66 m), low variation (1.12m) and low fluctuation (2.13m) and high yield (>55,000 lph) (Table 2) (Fig. 5).

Shallow valley fills with thin alluvium (SVF1): This with thin alluvium consisting of gravels, sand silt and clay associated with unconsolidated Quaternary alluvium deposited by fluvial action along the valley floors of river channels. The drainage is mainly controlled by the major lineaments (NNW-SSE and NNE-SSW) with high lineament density. This unit is acting as a good recharging zone and it is marked under very good ground water potential zone. The Chicholi observatory well located in this zone shows high average groundwater level (3.94 m), low variation (1.30 m), low fluctuation (2.59 m), and high yield (45,000-50,000 lph).

Deeply weathered pediplains (DP1): This hydro-geomorphic unit is confined to deeply weathered pediplains (>20m) with unconsolidated moderately thick alluvium deposited over formations of Tirodi Gneiss/ Sausar Groups. This zone is associated with gentle slope and good major lineament/fractures density and it is delineated under very good water prospects zone. The Usarra observatory well is found in this zone and is having high ground water level (4.02m), low variation (1.01m), low fluctuation (2.08m) and high yield (40,000-45,000 lph).

Moderately weathered pediplains (MP1): This hydro-geomorphic unit has thin alluvium with thick weathered substrata (5-20m) of geological formations of Tirodi Geneiss and Sausar Groups. This zone is associated with moderated recharging capacity and cirss-crossed by minor lineaments with moderate density. This unit was grouped under good groundwater prospects zone. The Tamsar Khapa (T.Khapa) observatory well in this zone is indicating moderate ground water level (4.24m), low variation (2.25m) and low fluctuation (4.09m) and moderate yield (30,000-40,000 lph.)

Shallow weathered pediments (SP1): This unit in the geological formations of Tirodi Gneisses and Sausar Groups associated with sloping plains of the foothills with shallow weathered zone (<5m). Due to gentle slope, less infiltration capacity and less density of lineaments, this zone having moderate ground water prospects, but good yields are expected along the fractures/lineament zones. In this zone the Jamb observatory well showing low average ground water level (5.32m), high variation (3.83m) and high fluctuation (6.63m) and low yield (20,000-30,000 lph).

Shallow weathered pediplains (SP2 and SP3): The isolated shallow weathered pediplains (<5m) in the geological fromations of Tirodi Gneiss and the Sausar Groups. The gentle slope, thin soil cover and less density of lineaments are restricting the infiltration and resulting in more runoff. This unit is grouped under limited ground water prospects zone, but moderate yields can be expected along the fractures/lineament zones. The field observations indicate that the average ground water level in this zone is more than 6m.

Structural hills in Sausar Group and Tirodi Gneiss formations (SH2 and SH3): These units are associated with folding, steep slopes and it mainly acting as a runoff zone. Due to high steepness and very less density of lineaments and infiltration capacity these units are grouped under poor ground water prospects zone. This unit is mainly confined to northern part of the study area.

Table 2. Ground Water Level Dynamics in Gaimukh Watershed

Average Ground water level (m) 1988-98)					
Period/Station	Dahagaon	Chicholi	Usarra	T.khapa	Jamb
Pre-monsoon	5.25	7.9	8.1	7.95	8.75
Monsoon	2.79	1.75	1.27	2.11	3.22
Post-monsoon	2.95	2.18	2.7	2.65	3.98
Average	3.66	3.94	4.02	4.24	5.32
Average Ground water level Variations (m) (1988-98)					
Period/Station	Dahagaon	Chicholi	Usarra	T.Khapa	Jamb
Pre-monsoon	1.5	1.16	1.15	2.85	4.4
Monsoon	1.01	1.35	0.75	2.44	2.63
Post-monsoon	0.85	0.96	1.13	1.45	4.47
Average	1.12	1.3	1.01	2.25	3.83
Average Ground water level Fluactuations (m) (1988-98)					
Period/Station	Dahagaon	Chicholi	Usarra	T.Khapa	Jamb
Pre-monsoon	2.2	3.2	3.45	5.77	8.05
Monsoon	2.55	2.75	1.05	4.3	4.75
Post-monsoon	1.65	1.8	2.35	2.2	7.1
Average	2.13	2.59	2.28	4.09	6.63

Inselbergs and linear ridges in Sausar group and Tirodi gneiss (13 and LR3): These isolated units are associated with narrow basic dykes as intrusives into the basement and acting as barrier for ground water movement. This unit has very poor ground water potential.

Conclusions

The study has revealed the advantage of remotely sensed data in identifying favourable zones for ground water exploration in geologically and structurally complex terrain of

Gaimukh watershed. The analysis of the hydro-geomorphological characteristics of the study area indicate that deep valley fills with thick alluvium under excellent, shallow valley fills and deeply weathered pediplians with thin alluvium under very good and moderately weathered pediplains in formations of Tirodi Gneiss/Sausar Groups have good ground water potential. These units are highly favourable for ground water exploration and development. The shallow weathered pediments and pediplians have moderate and limited ground water potential respectively. The structural hills, linear ridges and Inselbergs in geological formations of Tirodi Gneiss/Sausar Groups due to high relief and slope, act as runoff zones and grouped under poor and very poor ground water prospect zones. However, medium prospects are expected along narrow intermontane valley fills which are controlled by lineaments and major fractures.

The surface water bodies, thickness of weathered zone and concentration of lineaments are directly influencing the pattern of ground water table particularly in the monsoon and post-monsoon periods. The lineaments are acting as a direct conductors in ground water movement, as a result the ground water level in the wells near the lineaments rise considerably during monsoon period. The good inter-relationship was found among the geological units, geomorphic units, lineament density, hydro-geomorphological units and ground water yields of the observatory wells in the study area.

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References

Behera SC (1989). Hydro-geomorphological studies in parts of Baitarni Basin. Keonjhar district, Orissa using remote sensing Techniques. A report on training project at IIRS Dehradun.

Bhattacharya A and Reddy PR (1991). Hydro-geomorphological mapping for ground water prospects in India using IRS imagery. How to meet the demand of drinking water. In Remote sensing in Asia and oceania-Environmental change and monitoring (ed. Shunji Murai). Asian Association of Remote Sensing Tokyo, Japan.

Central Ground Water Board (CGWB) (1999). Report on the hydrograph network stations in Bhandara district, Maharashtra, period (1978-98). (Nagpur: Central Ground Water Board)

Chattreji PC Surendra Singh and Qureshi LH (1978). Hydro-geomorphology of the central Luni basin, western Rajasthan, Indian Geoforum, 9:211-214.

Dept. of Space (1988). Preparation of hydro-geomorphological maps of India on 1:250,000 scale using satellite Imagery, project documen,t National Technology on Drinking water, Dept. of space 83p.

GSI (1978). Geological Quadrangle map of Topographical Sheet 550 (Nagpur): Madhya Pradesh-Maharashtra, Geological Survey of India, 1978.

Haridas VK, Chandra Sekaran VA, Kumaraswamy K, Rajendran S and Unni Krishnan K (1994). Geomorphological and lineament studies of Kanjamalai using IRS-IA data with special reference to ground water potentiality, Trans. Instt. Indian geographers, 16 (1):35-41.

Krishna Murthy J and Srinivas G (1995). Role of geological and geomorphological factors in ground water exploration-a study through remote sensing techniques, Int. J. Remote Sensing, 16, 2595-2618.

Krishnan MS (1982). Geology of India and Burma, Edison (IV):1-536.

Obi Reddy GP, Suresh Babu R and Sambasiva Rao M (1994). Hydro-geology and hydro-geomorphological conditions of Anantapur district, using Remote sensing data. Indian Geog. J., 69 (2): 128-135.

Pradeep Raj, Nand Lal L and Soni GK (1996). Nature of aquifer in parts of granitic terrain in Mahaboob nagar dist., A.P. Geol. Soc. India, 48(3):299-307.

Rao DP Bhattacharya A and Reddy PR (1996). Use of IRS.1C data for Geological and Geographical studies. Curr. Sci. Special Session:IRS-1C, 70 (7). 619-623.

Ravindran KV and Jeyaram A (1997). Ground water prospects of shahbad Tehsil, Baran district, Eastern Rajasthan and Remote Sensing Approach. J. Indian Soc. Remote Sensing, 25(4):239-246.

Reddy PR (1987). Geological and Geomorphological studies through remote sensing. In special volume of COSTED Remote Sensing Technology for Natural Resources.

Reddy PR, Vinod Kumar K and Seshadri K (1996). Use of IRS-1C data in ground water studies. Curr. Sci. Special Session:IRS-1C, 70 (7): 600-605.

Saraf A.K. and Choudhary PR (1998). Integrated remote sensing and GIS for ground water exploration and identification of artificial recharge sites, Int. J. Remote Sensing, 119(10):1825-1841.

Seelan Santhosh Kumar and Thiruvengadachari S (1980). An integrated regional approach for delineation of potential ground water zones using satellite data-an Indian case study. Abstracts of proc. 26th International Geological congress Paris, July 1980.