Groundwater resource management of the Morna River basin, Akola District, Maharashtra, India

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Abstract: Water is the most important natural resource and is the key element of socio-economic development of the country. There is growing trend toward the increasing exploitation of groundwater to meet the needs of growing populations. Both in terms of water availability and the quality of groundwater depends upon physical environment, origin and movement of water. As the water moves through the hydro geological cycle, various chemical, physical and biological processes change its original quality through reactions with soil, rock and organics matter. Natural processes and human activities cause changes in groundwater quality directory or indirectly. Groundwater is degraded when its quality parameters are changed beyond their natural variations by the introduction or removal of certain substances. The degradation may impair the usefulness of water, but is not necessarily harmful to health. The scarcity of clean potable water has emerged in recent year as one of the critical problems facing India today, even while the coverage of the people, with access to supply in India has reached levels of over 80%. Declining quality and quantity of water supply in India can be described as crises, which needs immediate intervention. The geomorphologic studies indicates the presence of five distinct kinds of landforms viz. shallow dissected plateau , moderately dissected plateau, undulating plains and valley fills.

A detailed geomorphologic map of the area is prepared with the help of Arc-GIS through visual interpretation of satellite imagery to show different landforms present in the study area. The groundwater salinity in Purna basin is very crucial as it has attracted the attention of many researchers. In this study, an attempt has been made to understand the groundwater regime of Morna River basin which is a major tributary of Purna River lying in parts of Akola and Washim districts in Maharashtra, India by utilizing GIS and Remote Sensing techniques. This paper describes the design and implementation of a GIS-based system for groundwater regime and water resources management. Physiographically, the study area consists of minor depositional and majority of erosional landforms, the topography is characterized by the presence various landforms like mesa, butte, lava hills, lava flat, escarpments and lava plateaus. The area is dominated by monotonous flat top terraces, which are results of lateral erosion of lava flows. The study area is drained by Morna River flowing south to north with almost dendritic to sub-dendritic drainage pattern. The detailed morphometric analysis of the study area reveals the predominance of dendritic drainage pattern with presence of sixth order stream. At places, local radial pattern of drainage is also seen. Different landforms were identified in the watershed based on ASTER (DEM) data and GIS software. Geomorphological, soil texture and slope maps have been prepared from satellite data. All the thematic maps are integratedin GIS environment anclassified the area in four categories of groundwater prospects from poor to excellent groundwater potential zones. With the help of RSGIS techniques, an attempt has been made to understand the hydrogeological characteristics of the Morna River basin and 'potential groundwater contributing zones' were delineated.

Key Words:-Groundwater regime, landforms, Remote Sensing, GIS, Groundwater prospects

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I. INTRODUCTION

Groundwater is a dynamic and replenish-able natural resource. But, in hard rock terrain availability of groundwater is limited. In such terrains ground water is essentially confined to fractured and weathered zones. Therefore, exploration and exploitation of ground water resources require thorough understanding of geology, hydrogeology and geomorphology of the area. Integration of various data and thematic maps, such as terrain features derived from remote sensing images, hydro-geomorphical details, depth to groundwater table and geophysical resistivity sounding data help in generation of groundwater potential zone maps Water resource management is an apt consideration for development sustained in an area. In the context of computer-aided analysis for resource management remote sensing technique with GIS can be used. Remote Sensing and GIS analysis can show where water enters a system and how it leaves through evapotranspiration and runoff. Therefore, in view of the upcoming industrialization in the region there is need to exploit groundwater resource, which is limited and confined to fractured and weathered zones. Even though the region receives copious rain, the terrain and soil condition allows little storage of water. Hence, the region faces shortage of water in dry seasons. Therefore, it is necessary to explore and study the ground water resources effectively using suitable techniques.Using this information, planners can identify areas where there is potential for development of new water resources; where water can be reallocated from one use or one basin to another; and identify potential areas of water scarcity before water shortages occur.Watershed is defined as 'natural hydrologic entity that covers a specific area expanse of land surface from which the runoff (due to rainfall) flow to defined drain, channel, stream or river at any particular point'. Watershed modelling implies the proper use of all land, water and natural resource of watershed for optimum production with minimum hazard to natural resource, an integrated approach to watershed modelling is insisted for sustained development of water resource.The main objective of this research is to understand the groundwater regime of the Morna River basin by using RS and GIS in combination with hydraulic models. The results helped in devising guidelines, which in turn will help the policy makers to release the water supplies based on crop requirement only rather than supply based. Topographic is a basic need for any hydrologic analysis and modeling. Remote sensing can provide quantitative topography information of suitable spatial resolution to be extremely valuable for model inputs. The GIS can be used to combine spatial data forms such as topography, soils maps as hydrologic variables such as rainfall distributions or soil moisture.Where their Grouped Response Unit (GRU) included satellite based land use and lies within a computational element that may be either a sub basin or an area of uniform meteorological forcing.The morphometric analysis of Morna basin is based on the integrated use of remote sensing and GIS techniques. The drainage map of thebasin was delineated using Survey of India Toposheets as reference. Morphometry provides the basis of investigation of maps for a geomorphological survey Agarwal,(1992); The area, altitude, volume, slope, Profile and textures of landforms comprise principal parameters of investigation. Dury, (1952); applied various methods for landform analysis. A major emphasis on geomorphology over the past several decades has been on the developmentof quantitative physiographic methods to describe the evolution and behaviour surface drainage network. The present study area, which is a hard rock terrain, having undulating topography though get sufficient rainfall, suffers from water scarcity for domestic, agricultural, and industrial purposes due to limited nature of aquifers (inadequate weathered and fissured zones). Taking into consideration the above scenario an attempt has been made for mapping of ground water potential zones, by integrating various thematic maps, as generated from processed and enhanced remote sensing multi band data, digital elevation model (DEM) created from SRTM data along with other geo hydrological data in GIS environment.

II. METHDOLOGY

Morphometric can be defined as the measurement and mathematical analysis of the configuration of the Earth's surface and of the shape and dimensions of its landforms. The Morphometric analysis of the river basin area is very important factors for the purpose of the management and conservation of soil, water, natural resources and environmental protection. Remote sensing data and extensive ground truth data are combined with a hydrological network model in a geographical information system. Assessment of the drainage network of a basin using thequantitative morphometric analysis gives information about the hydrological background of the rock formation exposed within the drainage basin. Morphometric analysis of a basin provides an indication about permeability, storage capacity ofthe rocks and gives an indication of the yield of the basin. Analysis of drainage basins involves the evaluation of drainage parameters such as bifurcation ratio, length ratio, drainage density, drainage frequency, length of overland flow and stream frequency.In the linear aspects, the stream order, stream length, bifurcation ratio, mean lengths of streams, stream length ratio, and mean stream length ratio are analyzed (Table 1). In the basin geometry, the factors such as area of the basin, total stream length, stream length ratio and perimeter of the basin were computed using Arc GIS and remote sensing techniques. In this study of basin area the drainage densityis calculated as total channel length/ basin area. In order to calculate drainage density for a basin or sub-basin, one must first ensure that you have the lengths of all channels within its boundaries (rivers, streams, etc) as well as the area for the entire basin. It is very important to note that before any calculations are made, the data must be projected and units must be set. The Remote Sensing and GIS have been widely used for understanding the causes of study area. Utility of the Remote Sensing data has also been amply demonstrated through a number of studies. For physiography or landforms delineation, contours were transferred from Survey of India toposheets to image interpretation sheet and satellite data were interpreted for various landform units like plateau, undulating uplands, upper valley floor and middle valley floor.

III. STUDY AREA

The Morna River basin which is a tributary of Purna River lies towards the northern and southern part of Akola district, and parts of Washim district, forming near about 190 to 200 meters thick lava flows covering an area of 941.39 sq. km. and lies between 76^{o}45’38” to 77^{o} 5’ 26” E longitude and 20^{o} 25’ 7” to 20^{o} 29’ 34” N Latitude and Survey of India Toposheets No. 55H/1,H/2, H/15, D/3, and 55D/15(Fig 1).

IV. GEOMORPHOLOGICAL MAPPING

The study area consists of various erosional surfaces in step-like terraces. The horizontal dispositions of the lava flows with a fair degree of uniformity in lithology have considerably simplified the changes brought by the secondary processes like weathering and denudation. Differential weathering forces has resulted in wiping out of thick lava pile. The result of geomorphic analysis indicates the predominance of erosional landforms over the depositional landforms. The study area can be interpreted as a moderate morphogenetic region. The contour map of the area is prepared with the help of Arc-GIS to show the physiography of the region, contour lines are defined as the lines joining the points of equal elevations. The southern part of the basin such as Patkhed, Rajanda, Waghjali, Mahagaon, up to Rajur the terrain represents positive relief features. The contour spacing is close in the southern part of the basin but in the middle it is more (Fig.3). The Patkhed hills have moderate slope, Rajanda hills have steep slopes. The Rudrayani and Rajur hills are having moderate to gentle slope. The cuesta like feature is present in Pardi, Pangara area.

The study area is dominated by erosional land forms like lava plateau, lava plains, linear ridges, conical hills, mesa, butte and escarpments, and depositional landforms such as alluvial cones, alluvial fans, and Bajada deposits. The Morna River, which is one of the tributary of the Purna River, rises in the southern part of Paturtahsil and flows to the northern side for about 80 km length and merges into the Purna River near Andura Village of Akola district. The map showing drainage pattern in the study area was prepared after detailed ground check with GPS survey, the drainage map of the area is prepared with the help of Arc-GIS the map clearly shows high drainage density in the southern part of the basin i.e. in the Patur area and drainage pattern is dendritic to sub dendritic and at places shows radial pattern to the major river Purna (Fig. 2, 3, 4,5).

In the study area, the water table occurs under confined and unconfined conditions. The physico-chemical characteristics of groundwater in unconfined regime along with the mode of occurrence have been highlighted. The results of well inventory data analysis of wells for pre -monsoon and post-monsoon seasons demonstrate a consolidate range of fluctuations in the water level which can be divided into three groups such as low level fluctuation (1.5m bgl), moderate level fluctuations (1.5-3 m bgl) and high level fluctuations (>3 m bgl). The probable reasons for the water level fluctuations are the distinct valuation in the rainfall and also the indiscriminately pumping of the groundwater in the

ISSN: 2321-8169
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region. In addition, two years data of groundwater fluctuations collected from various observation wells was computed to understand the nature of groundwater regime. Detailed climatological and meteorological data of past 20 years was computed to understand water level fluctuations and favorable sites for groundwater development, which might be due to the nature of topography, frequency of rainfall and withdrawal of the water from the aquifers. This detailed study demonstrates various measures for improving the groundwater potential and water level fluctuations in the region with emphasis on environmental management.

It has been observed that the presence of poor water quality in the Northern saline tract of the alluvial zone which is not suitable for drinking and irrigation purposes. Whereas, the trap region shows fair to excellent quality for groundwater. In the study area the highly fractured, weathered and jointed horizons of Deccan trap have maximum yielded amount of water showing potential aquifers. The area of investigation is characterized by the presence of multiple aquifer system showing productive and unproductive zones due to the presence of alternating massive and vesicular units with lateral variation. The depth to water level studies indicates distinct zones and influence by irrigation methods showing recharge of groundwater table. The groundwater level fluctuation mainly depends on the difference in water levels of pre-monsoon and post-monsoon periods, which can be directly linked, to recharge and discharge of groundwater. In addition, SRTM map of the Morna river basin has been prepared using Arc GIS techniques to understand the hydrogeological regime of the river basin.

The study area interoperated as moderate morphogenetic region showing horizontal nature of the lava flows with a uniform rock types. This has considerably simplified the changes brought by weathering and denudation. The continuous action of degradation agencies with possible fluctuation in the intensity of the course might have resulted in the wiping out of at least 200 meters thick pile of lava flows.

Compactness and vesicularity are mainly responsible for the variation in the landscapes the linear ridges breaking the monotony of the plain represent the topographic forms developed by the intrusive phases of igneous activity which offers more resistance to the weathering agencies, and as a result stand as positive relief features. From the SRTM data 3D-Model of the basin is prepared and it is found that the southern side of basin shows elevated topography than northern side of basin.

Remote sensing and GIS approach has successfully used in the present investigation to obtain a detailed evaluation of groundwater conditions of the study area. The integrated maps were classified into four groundwater potential zones from excellent to poor.

Based on the geomorphological mapping, lineament density and resistivity data, the following broad conclusion can be drawn. The present study brings out the close relationship among the geomorphic, geologic, hydrogeological and geophysical parameters of groundwater. The ground water potential zones are also verifying with bore wells yield data of the study area. The comparison shows that the groundwater potential zones are in agreement with the bore wells yield data.

Figure 1. Location map of the study area

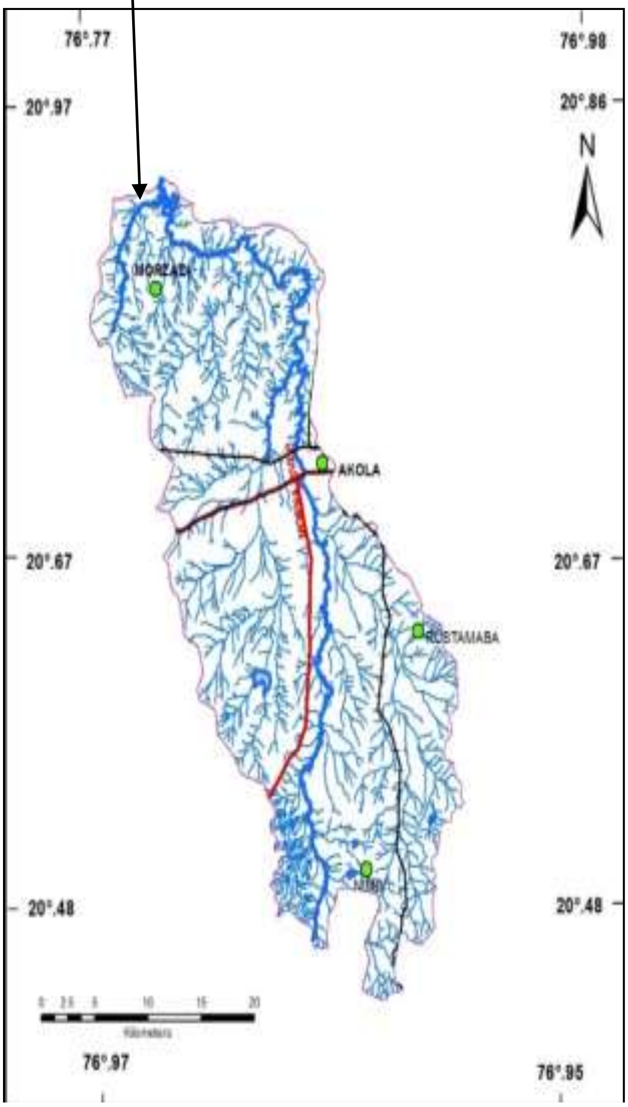

Figure 2. Physiographic contour map of the Morna River basin

 ISSN: 2321-8169
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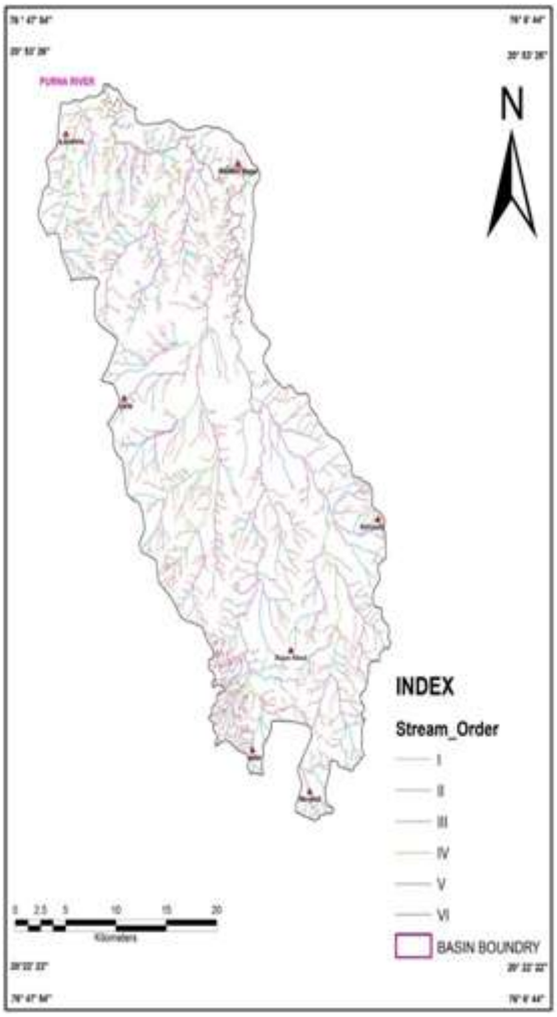

Figure 3. Drainage network of the Morna River basin

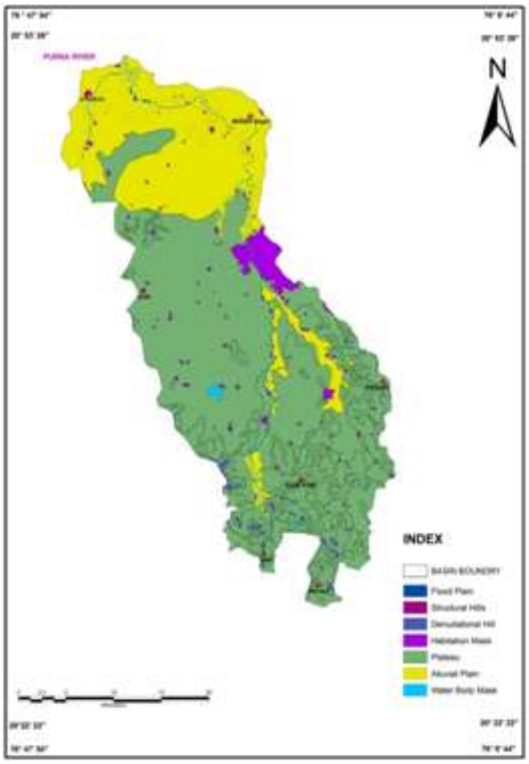

Figure 4. Geomorphological map of the Morna River basin.

Table I. Classification of landscape features in the study area.

Landscape Features	Morphological Description	Locality	Geomorphic processes operated	Soil cover	Degree of slope
Lava plain	Surface form with very little topographical inequalities	Sangvi, Mohadi, Agar, Sukali.	Physical weathering and erosion.	Thick. 6 to 30 cm	00 to 10
Undulating Plains	Undulating with intervening, low lying hillocks	Ural, Bhod, Morzadi, Morgaon.	Differential weathering and erosion	Fairly thick 30 cm to 1.5 m	10 to 50
Flat topped hills	Surface form with flat top and terraced appearance	Rudrayani, Chincholi, Nandkhed, Patkhed Mahagaon.i.e at Southern part.	Differential weathering and erosion	Moderately thick 30 cm to 90 cm.	Top is almost flat.

Figure 5. Flow intensity map of Morna River basin

V. WATERSHED DELINEATION OF DEMDATA

Base map of the study area was prepared using Survey of India (SOI) toposheets 55H/1, H/2, H/15, D/3, and 55D/15. The topographical information of the watershed in 1:50000 scale with contour interval 25m acquired from SOI toposheets were digitized using capability of Arc-info and Arc-GIS tools. Subsequently drainage network was also digitized. Then the watershed boundary and sub-watersheds boundary were delineated. The contours were generating the line feature class in Arc-GIS, and then it was polygonized to determine the area enclosed by each contour.

TableII. Morphometric Analysis of Morna River basin- Comparative characteristics by utilizing Remote sensing and GIS techniques

SN	Morphometric Parameter	Formula	Reference	Results
		A. Drainage Network		
1	Stream Order (S_u)	Hierarchical Rank	Strahler (1952)	1 to 6
2	1st Order Stream (S_{uf})	Suf = N1	Strahler (1952)	1133.00
3	Stream Number (N_u)	$Nu = N_1+N_2+ \ldots N_n$	Horton (1945)	1553.00
4	Stream Length (L_u) Kms	$Lu = L_1+L_2 \ldots L_n$	Strahler (1964)	1559
5	Stream Length	-	Strahler	1.46-12.84

 ISSN: 2321-8169
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	Ratio (L_{ur})		(1964)	
6	Mean Stream Length Ratio (L_{urm})	-	Horton (1945)	2.57
7	Weighted Mean Stream Length Ratio (L_{uwm})	-	Horton (1945)	1.90
8	Bifurcation Ratio (R_b)	-	Strahler (1964)	3.6-5.0
9	Mean Bifurcation Ratio (R_{bm})	-	Strahler (1964)	4.10
10	Weighted Mean Bifurcation Ratio (R_b)	-	Strahler (1953)	3.70
11	Main Channel Length(C_L) Km.	GIS Software Analysis	-	80
12	Valley Length (V_l) Kms	GIS Software Analysis	-	90
13	Minimum Aerial Distance (A_{dm}) Kms	GIS Software Analysis	-	82
14	Channel Index (C_i)	$C_i = C_l / A_{dm}$ (H & TS)	Miller (1968)	0.97
15	Valley Index (V_i)	$Vi = V_l / A_{dm}$ (T_S)	Miller (1968)	1.09
16	Rho Coefficient (ρ)	$\rho = L_{ur} / R_b$	Horton (1945)	0.63
	B Basin Geometry			
17	Length from W's Center to Mouth of W's (L_{cm})Kms	GIS Software Analysis	Black (1972)	39.7
18	Width of W's at the Center of Mass(W_{cm}) Kms	GIS Software Analysis	Black (1972)	18.56
19	Basin Length (L_b) Kms	GIS Software Analysis	Schumm(1956)	80
20	Mean Basin Width (W_b)	$W_b = A / L_b$	Horton (1932)	11.76
21	Basin Area (A) Sq Kms	GIS Software Analysis	Schumm(1956)	941
22	Mean Area Ratio (A_{rm})	-		0.39
23	Weighted Mean Ratio (A_{rwm})	-		1.09
24	Basin Perimeter (P)Kms	GIS Software Analysis	Schumm(1956)	175
25	Relative Perimeter (P_r)	$P_r = A / P$	Schumm(1956)	5.78
26	Length Area Relation (L_{ar})	$L_{ar} = 1.4 * A^{.6}$	Hack (1957)	85.162
27	Lemniscate's (k)	$k = L_b^2 / A$	Chorley (1957)	6.80
28	Form Factor Ratio (F_f)	$F_f = A / L_b^2$	Horton (1932)	0.147
29	Shape Factor Ratio (R_s)	$S_f = L_b^2 / A$	Horton (1956)	6.80
30	Elongation Ratio (R_e)	$R_e = 2 / L_b * (A / \pi)^{0.5}$	Schumm(1956)	0.43
31	Elipticity Index (I_e)	$I_e = \pi * Vl^2 / 4 A$		6.75
32	Texture Ratio (R_t)	$R_t = N_1 / P$	Schumm(1965)	6.48
33	Circularity Ratio (R_c)	$R_c = 12.57 * (A / P^2)$	Miller (1953)	0.40
34	Circularity Ration (R_{cn})	$R_{cn} = A / P$	Strahler (1964)	5.37
35	Drainage Texture (D_t)	$D_t = N_u / P$	Horton (1945)	8.87
36	Compactness Coefficient (C_c)	$C_c = 0.2841 * P / A^{0.5}$	Gravelius (1914)	1.62
37	Fitness Ratio (R_f)	$R_f = C_l / P$	Melton (1957)	0.45
38	Wandering Ratio (R_w)	$R_w = C_l / L_b$	Smart & Surkan (1967)	1
39	Watershed	$\tau = [(\lvert L_{cm}^2 -$	Black	1.90
	Eccentricity (τ)	$W_{cm}^2\rvert)]^{0.5} / W_{cm}$	(1972)	
40	Centre of Gravity of the Watershed (G_c)	GIS Software Analysis	Rao (1998)	76.92E & 20.66N
41	Hydraulic Sinuosity Index (H_{si}) %	$H_{si} = ((C_i - V_i)/(C_i - 1))*100$	Mueller (1968)	36.33
42	Topographic Sinuosity Index (T_{si})	$T_{si} = ((V_i - 1)/(C_i \% - 1))*100$	Mueller (1968)	11.41
43	Standard Sinuosity Index (S_{si})	$S_{si} = C_i / V_i$	Mueller (1968)	0.97
44	Longest Dimension Parallel to the Principal Drainage Line (Clp) Kms	GIS Software Analysis	-	51.1
	C. Drainage Texture Analysis			
45	Stream Frequency (F_s)	$F_s = N_u / A$	Horton (1932)	1.65
46	Drainage Density (D_d) Km/Km^2	$D_d = L_u / A$	Horton (1932)	1.66
47	Constant of Channel Maintenance (Km^2 / Km)	$C = 1 / D_d$	Schumm(1956)	0.60
48	Drainage Intensity (Di)	$D_i = F_s / D_d$	Faniran (1968)	0.99
49	Infiltration Number (If)	$I_f = F_s * D_d$	Faniran (1968)	2.74
50	Drainage Pattern (Dp)		Horton (1932)	Den. & SubDen
51	Length of Overland Flow (Lg) Kms	$L_g = A / 2 * L_u$	Horton (1945)	0.31
	D. Relief Characters.			
52	Height of Basin Mouth (z) m	GIS Analysis / DEM	-	236.00
53	Maximum Height of the Basin (Z) m	GIS Analysis / DEM	-	440.00
54	Total Basin Relief (H) m	$H = Z – z$	Strahler (1952)	204.00
55	Relief Ratio (Rhl)	$Rhl = H / Lb$	Schumm(1956)	2.55
56	Absolute Relief (Ra) m	GIS Software Analysis		440.00
57	Relative Relief Ratio (Rhp)	$Rhp = H * 100 / P$	Melton (1957)	116.57
58	Dissection Index (Dis)	$Dis = H / Ra$	Singh & Dubey (1994)	0.46 `
59	Channel Gradient (Cg) m / Kms	$Cg = H / \{(\pi/2) * Clp\}$	Broscoe (1959)	2.54
60	Gradient Ratio (Rg)	$Rg = (Z - z) / Lb$	Sreedevi(2004)	2.55
61	Watershed Slope (Sw)	$Sw = H / Lb$		2.55
62	Ruggedness Number (Rn)	$Rn = Dd * (H /1000)$	Patton & Baker (1976)	0.34
63	Melton Ruggedness Number (MRn)	MRn = H / A0.5	Melton (1965)	6.64
64	Total Contour Length (Ctl) Kms	GIS Software Analysis	-	2410.26
65	Contour Interval (Cin) m	GIS Software Analysis	-	10.00
66	Length of Two Successive Contours (L1+L2) Km	GIS Software Analysis	Strahler (1952)	318.27
67	Average Slope Width of Contour (Swc)	$Swc = A / \{(L1+L2) / 2\}$	Strahler (1952)	5.91
68	Slope Analysis (Sa)	GIS Analysis / DEM	Rich (1916)	00.0'-890.99'
69	Average Slope (S) %	$S = (Z * (Ctl/H)) / (10 * A)$	Wenthworth's (1930)	0.55

70	Mean Slope Ratio (Sm)		Wenthworth's (1930)	2.47
71	Weighted Mean Slope Ratio (Swm)		Wenthworth's (1930)	3.26
72	Mean Slope of Overall Basin (ϴs)	ϴs = (Ctl * Cin) /A	Chorley (1979)	0.26
73	Relative Height (h/H)	see Table 4 (h/H)	Strahler (1952)	100-0
74	Relative Area (a/A)	see Table 4 (a/A)	Strahler (1952)	0-100
75	Hypsometric Integrals (Hi) %	Hypsom Curve h/H & a/A	Strahler (1952)	39
76	Erosional Integrals (Ei) %	Hypsom Curve h/H & a/A	Strahler (1952)	------
77	Clinographic Analysis(Cga)	Tan Q = Cin /Awc	Strahler (1952)	8.33
78	Erosion Surface (Es) m	Superimposed Profiles	Miller (1953)	490-500
79	Surface Area of Relief (Rsa) SqKm	Composite Profile	Brown (1952)	941
80	Composite Profile Area (Acp) Sq Kms	Area between the Composite Curve and Horizontal line	Pareta (2004)	941
81	Minimum Elevated Profile Area as Projected Profile (App) Sq Kms	Area between the Mini. Elevated Profile as Projected Profile and Horizontal Line	Pareta (2004)	750
82	Erosion Affected Area (Aea) Sq Kms	Aea = Acp - App	Pareta (2004)	52.98
83	Longitudinal Profile Curve Area (A1) Sq Kms	Area between the Curve of the Profile and Horizontal line	Snow & Slingerland (1987)	285
84	Profile Triangular Area (A2) Sq Kms	Triangular area created by straight Line, the Horizontal Axis traversing head of profile	Snow & Slingerland (1987)	650
85	Concavity Index (Ca)	Ca = A1 / A2	Snow &Slingerland(1987)	0.54

VI. WATERSHED MANAGEMENT

The area under investigation is traversed by Morna river basin experiencing sub-tropical or tropical monsoon climate. The area is characterized by undulating relief with the presence of alluvial horizon towards the northern part and massive to highly altered basalt towards southern part of the basin. The area is characterized by the presence of heterogeneity within the rock formation which in turn affects groundwater recharge. On the basis of major geomorphic processes and agent involved in the study area. The landforms can be grouped in to structural, denudetional and fluvial origin. The occurrence of groundwater in lava flow is prominent in highly altered fractured, jointed horizon which serves as a potential flow zones for the accumulation of the groundwater. Where as in vesicular formations groundwater occurs in interconnected vesicles both under water table and confined conditions .The dug wells in a few trappean terrains located in favourable hydrogeological sites have yields of the order of 100-125 m^3/day However, in general the study area is characterized by lowest permeability range (6-8m/day).

A. *Forms of fluvial origin*

The landforms of fluvial of origin can be broadly divided into three types viz. Alluvial plain (AP), Older Alluvial plain (OAP) and Younger Alluvial plain (YAP).An alluvial plain is a relatively flat landform and created by the deposition of highlands eroded due to weathering and water flow in study area. The sediment from the hills is transported to the lower plain over a long period of time. It identified on the imageries dark reddish moderate to fine texture due to agriculture activities. Alluvial deposits of the area constitute gravel, sand, silt or clay sized unconsolidated material. It covers an area of 60% of the basin. The alluvial plain consists of gravel, sand, silt and clay, material of varying lithology, which is formed by earlier cycle of deposition of alluvium by major river system. This unit is characterize by nearly flat and undulating surface. The older alluvium plain consists of predominantly gravel, sand, silt and clay material of varying lithology which is formed by earlier cycle of deposition showing flat and gentle undulating surface whereas the younger alluvial plain is characterized by the presence of predominantly gravel, silt and clay matter formed by late cycle of deposition. The overall groundwater prospect in this landform is excellent (Fig.8; Table 3).

B. *Forms of denudetional origin*

Landforms of denudetional origin can be grouped into denudation hill (DH) and denudetional slope (DS). Denudetional hills are the massive hills with resistant rock bodies that are formed due to differential erosional and weathering processes, Yokoyama, 2002).

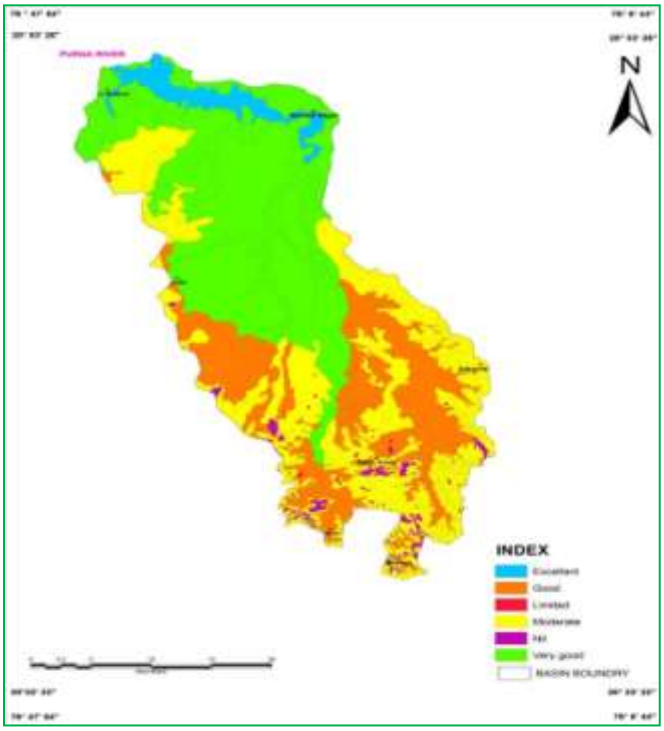

Figure8. Groundwater potential map of the Morna River basin.

These hills are composed of basaltic rock of Deccan Trap which having thin soil cover, moderate to steep slope.

On the satellite image, these landforms were identified by light or dark brownish with mix green color due to vegetative cover. Denudetional hills occupying southern portions of the study area. The groundwater prospect in this region is poor due to the presence of massive lava flows, whereas, the denudetional slope consists of moderately sloping region consisting of weathered and fractured lava flows showing moderate prospect of groundwater (Fig 10; Table 3).

C. *Forms of structural origin*

Structural hills are representing the geologic structures such as bedding, joint, lineaments etc. Mith, (2005). In the study area they are located in the southern parts of the basin having greenish and reddish tone with rough texture on the satellite image. The landforms of structural origin consist of moderately dissected plateau (MDP) which is characterized by basaltic plateau with moderate dissection forming moderately high hill upland and may be crisscrossed by fractures, joints and lineaments. This landform contains deep valley gullies with gentle sloping land developed due to river erosion on the plains. This landform can be further divided into three different zones viz. runoff zone (MDPA or A) recharge zone (MDPB or B) and storage zone (MDPC or C) the runoff zone is characterized by the presence of moderately dissected plateau consisting of very thin soil cover with altered and fractured rocks showing moderate groundwater resources. Whereas the storage zone is dominated by weathered and fractured area with thick soil cover showing good potential for groundwater resource development (Fig.10, Table III).

TableIII.Hydro geomorphological units of Morna River basin

S N.	**Geomorphic Unit**	**Lithology**	**Structure**	**Description**	**GroundWater prospectus**
1	Alluvial plain	Consist of gravel sand and clay of varying lithology	-----------	Form by excessive deposition of alluvium by major river system	Excellent
2	Older Upper Alluvial plain	Predominantly by gravel sand and clay of varying lithology	----------	Flat gently undulating surface form by river action. Older refers to earlier cycle of deposition	Excellent
3	Younger Lower Alluvial plain	Predominantly by gravel sand and clay of varying lithology	---------	Like older alluvial plain but younger refers to late cycle of deposition.	Excellent
4	Denudational hill	Small isolated Basaltic hillocks with steep slope.	--------	Erosion by differential weathering so that a more resistant formation stand as mountain/hill	Poor
5	Denudational Slope	Moderately sloping area of hill with weathered Basalt	---------	-------	Moderate to Poor
6	Moderately dissected plateau.	Basaltic plateau with moderate dissection forming moderately high upland.	Criss-crossed by fracture/joint lineament.	Deep valley/gullies with a gentle slopping land developed due to stream/river erosion on plane.	Moderate to Poor
7	Unit A	Area of rock exposed very thin soil.	Runoff Zone	---------	Poor
8	Unit B	Weathered rock with very thin soil.	Recharge Zone	---------	Moderate
9	Unit C	Weathered rock with moderately thick soil.	Storage Zone	-----------	Good

VII. CONCLUSIONS

Geomorphological units have been mapped using the IRS-1C, LISS III False Color Composite (FCC). The satellite images characteristics have been identified and assessed. The study area which belongs to Morna river basin, Akola District Maharashtra, India, exhibits diverse hydro geomorphological conditions where the ground water regime is controlled mainly by topography and geology. The main hydrogeomorphic units found in the area are alluvial plain, Pedi plain, pediment, valley fill, meander scar and water bodies. Groundwater in this hard rock terrain with remnants of palaeochannels is multivariate in nature because of its relation to topography, depth and extent of weathered material overlying bed rock and interconnection of joints and faults. The study reveals that remotely sensed data (ASTER-DEM) and GIS based approach in evaluation of drainage morphometric parameters and their influence on landforms, soils and eroded land characteristics at river basin level is more appropriate than the conventional methods. Quantitative description of drainage network, basin characteristics,and landform analysis has been carried out for the Morna River Basin. Various parameters like the numberand lengths of streams of different order, drainage area,basin perimeter and maximum basin lengths were calculatedafter cleaning and then topology building of thedrainage layer in GIS software, from these parametersvarious drainage characteristics are calculated such asbifurcation ratio (Rb), drainage density (Dd), stream frequency(Fs) circulatory ratio (Rc), elongation ratios (Re) forbasin evolution studies.The understanding of streams in a drainage systemconstitutes the drainage pattern, which in turn replicatesmainly structural/lithologic controls of the underlyingrocks. The study area possesses dendritic drainage patterns,despite stream lengths and other hydrological properties.They are generally characterized by a treelike branchingsystem, which indicates the homogenous and uniformity.The above study has demonstrated the capabilities of using remote sensing, geoelectrical data and GIS for demarcation of groundwater potential zones, especially in diverse geological setup. This gives more realistic groundwater potential map of an area which may be used for any groundwater development and management plan. Geologically, the study area comprises deep alluvium, which is of basaltic and volcanic origin. Water quality was monitored at various locations along the stretch of Morna River, upstream and downstream, the assessment was carried during pre-monsoon, monsoon and post-monsoon seasons. The analytical results indicate higher concentrations of certain ions during pre-monsoon and post-monsoon seasons may be attributed to seepage of ground water from aquifer to surface water body and lower concentrations during monsoon may be due to dilution effect with surface runoff.

The morphometric analysis carried out for the Morna RiverBasin confirms that the basin has low relief and elongated shape. Drainage network of the basin exhibits as mainly dendritic type, which indicates the homogeneity in texture and lack of structural control and to understand various terrain parameters such as nature of the bedrock, infiltration capacity, runoff, etc. Lower drainage density and stream frequency indicates high permeability rate of the subsurface formation. The observed drainage parameters reveal for recharge-related measures and areas where surface water augmentation measures can be undertaken for the water resource management. Observations derived from the morphometric analysis of Morna River Basin gives up-to-date information about various factors such as morphological characteristic of the basin and important hydrological parameters such as bifurcation ratio, elongation ratio, drainage density, relief ratio, and circulatory ratio which are responsible for the river basin evaluation, watershed prioritization for soil/ water conservation, natural resources management and groundwater potential targeting for efficient planning and management. This analysis can be used for site suitability analysis of soil and water conservation structures development and subsequently, these parameters were integrated with other thematic information viz., land use/cover, land forms, drainage, slope, and soil in the GIS domain to arrive a decision regarding a suitable site for having soil and water conservation structures (nala bund, check dam, and percolation tank, recharge shaft, etc.) in the area for groundwater resources development and management.

Thus, the studyshows that GIS techniques have efficient tools in delineation of the drainage pattern to understand terrain parameters such as the Ground water resources management, infiltration capacity, surface run off, etc., which helps in better understanding the status of land form and their processes, drainage management and evolution of groundwater potential for watershed planning and Ground Water Resources management. This will be useful for soil and water conservation and is a positive scientific contribution for the people of Morna River Basin area. This work will be useful for natural resources management at micro-level of any terrain for the sustainable development by planners and decisionmakers.

VIII ACKNOWLEDGMENT

The authors are thankful to the Hon'ble Vice-Chancellor, SGB Amravati University for providing the necessary research facilities

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