MICRO-WATERSHED PRIORITIZATION USING MORPHOMETRIC ANALYSIS AND HYDROGEOMORPHOLOGY USING REMOTE SENSING AND GIS APPROACH – CASE STUDY OF SAMSHE HOLE WATERSHED, KARNATAKA, INDIA.

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Abstract

An attempt was taken to establish the relationship between morphometric variables and hydrologic parameters through watershed prioritization. Samshe hole watershed of Chikkamagalore district was selected as the study area. Overexploitation of Groundwater resource caused an extensive scarcity of water in this region. The major source of drinking water is from Groundwater resource. To control the overexploitation of Groundwater resource, it is necessary to practice an efficient management of watershed development. The research effectively focused on developing a methodology to analyze watershed condition using micro-watershed prioritization. Remote sensing and GIS tools were used in order to achieve the expected results. The secondary data, SoI toposheet was used to generate base map of the study area and used to extract drainage patterns and contour informations.Hydro-geomorphological map was created to analyze the influence of hydrological regime through morphometry. Selected Linear, Aerial and Relief parameters were calculated in this research. Thematic layer integration was applied to prepare prioritization map in GIS environment. Three categories of groundwater prospects were characterized such as poor, good and excellent micro-watersheds in this study area. The study emphasized the integrated applications of micro-watershed prioritization to effectively manage groundwater resources through action plans.

Keywords: *GIS, Micro watershed, Morphometric analysis, Geomorphology.*

Introduction

The rapid expansion of population in India leads to threat in water resource, both in terms of quality and quantity. Consequently, increasing usage of water for domestic, irrigation and industrial needs affected serous stress on groundwater resources. In addition, low intensity and erratic monsoons create further shortages of surface-water supply. As a result, the consequent sustainable approach to water resource for sustainable management is immediately required. The development of action plans towards acute stress on water resource is an important approach in developing countries. Over-exploitation of groundwater has led to the drying up of the aquifer zones in several parts of the country. Efficient management planning for watershed development is, therefore, essential to increase the recharge of the watershed. The siting of facilities to enhance the recharge is also of great importance in planning the development of watershed programs (Subba Rao 2008).

Study Area

The study area lies in a part of Western-Ghats, the hotspot zone for wildlife habitat and ecosystem. Samshe hole watershed is located on the western side of Mudigere, Chikkamagalore. The river originates at an altitude of 1860 amsl. The extent of watershed extends from 13^0 7’ N to 13^0 12’ N Latitudes and 75^0 15’ E to 75^0 20’ E Longitudes, covering an area of 52.7 km^2. The river extends upto a length of 17.11 km, which is composed of cobble-pebble-gravel at its upper reaches and coarse sand in middle and lower parts. The major soil type in the district comprises of red loamy & sandy soil. The location and extent of this study area is represented by Figure 2.1. The watershed was divided into three well-defined units such as hill ranges, midland and lowland through DEM and geomorphologic analysis.The altitude drops from 1900m to 780m within span of 12.49 km. The study area experiences a tropical climate marked by heavy rainfall. About 79 % of the annual rainfall is received during the monsoon months, from June to September.

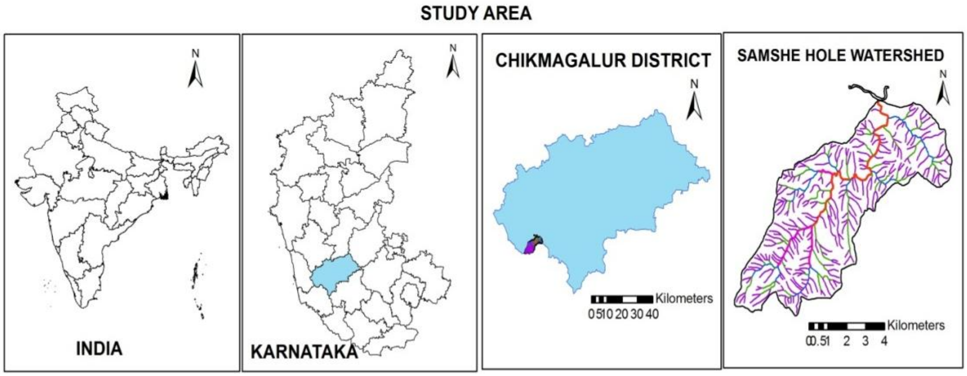

Figure 2.1: Samshe hole watershed map

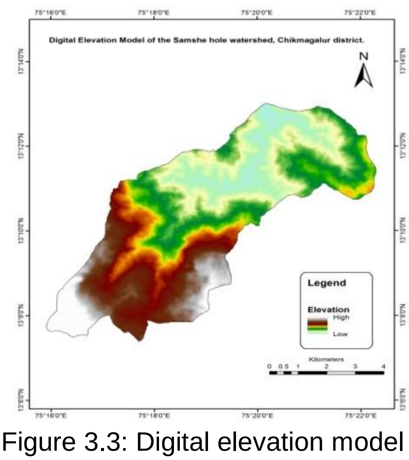

Figure 3.3: Digital elevation model

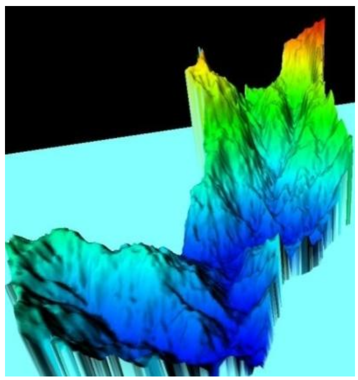

Figure 3.4: 3D surface map of the basins

Methodology

The Samshe hole watershed was delineated using Survey of India (SoI) Toposheet 48 O/8 with scale 1:50,000 and IRS–LISS III imagery of 2008. Geomorphology map of the watershed was carried by interpreting geology, DEM and slopeof the study area. The maps were prepared using collateral SoI and IRS-LISS IIIimagery in geographic information system (GIS) environment .

Interpreted geomorphic units were estimated at micro-watershed scales. Cartosat DEM was used for the analysis which was derived from Bhuvan portal (http://bhuvan.nrsc.gov.in). The DEM was used to derive slope map of the study area in ArcGIS 10.1.Results illustrated the maximum elevation of the watershed in 3D visualization above the MSL in Figure 3.3. The model indicates therelation between streams with rugged topography in steep gradient as shown in Figure 3.4.

Drainage and contour maps were extracted by feature digitization of SoI toposheet in AutoCAD map 2000. Eleven micro- watersheds were delineated based on the drainage characteristics and relief variability. Drainage networks were analyzed based on Horton principal (1945) and the stream order was carried using Strahler stream order method (Strahler 1964). Selected linear, areal and relief parameters of the micro-watersheds were calculated and micro-watershed -wise prioritization was carried out by assigning weightagesto individual geomorphic units and morphometric parameters.

Table 1: List of formulae used in morphometric analysis

Morphometric Parameters	Formulae	Reference
Linear parameters		
Stream order (u)	Hierarchical rank	Strahler (1964)
Stream length (L_u)	Length of the stream	Horton (1945)
Mean stream length (L_{sm})	$L_{sm}=L_u/N_u$	Strahler (1964)
Stream length ratio (R_L)	$R_L= L_u/L_{u-1}$	Horton (1945)
Bifurcation ratio (R_b)	$R_b= N_u/N_{u-1}$	Schumm (1956)
Mean bifurcation ratio (R_{bm})	R_{bm}= Average of bifurcation ratios of all orders	Strahler (1964)
Areal parameters		
Form factor (F_f)	$F_f= A/L^2$	Horton (1932, 1945)
Elongation ratio (R_e)	$R_e= 1.128\sqrt{A}/L$	Schumm (1956)
Circularity ratio (R_c)	$R_c = 4\pi A/P^2$	Miller (1953), Strahler (1964)
Shape factor (B_s)	$B_s = L^2/A$	Horton (1932)
Compactness co-efficient (C_c)	$C_c = 0.2821\ P/A^{0.5}$	Gravelius (1914)
Drainage density (D_d)	$D_d = Lu/A$	Horton (1932, 1945)
Stream frequency (F_s)	$F_s = \sum N_u/A$	Horton (1932, 1945)
Drainage texture (T)	$T = D_d \times Fs$	Horton (1945)
Constant of channel maintenance (C)	$C =1/D_d$	Schumm (1956)
Length of overland flow (L_o)	$L_o = 1/2D_d$	Horton (1945)

Results and Discussion

Morphometric and Geomorphology parameters were useful tools to analyze drainage networks.It provides relation with prevailing lithology, hydrological nature, drainage characteristics and exogenic/endogenic processes within the watershed. This watershed is represented by drainage pattern with majorly dendritic to micro-dendritic in nature. It is an illustrative representation of homogeneous lithological unit, gneisses.

Morphometric Analysis

The morphometric analysis is an effective and significant tool to prioritize micro-watersheds. Drainage patterns refer to spatial relations among streams, which are influenced in the geological settings such as, erosion by inequalities of slope, soils, rock resistance, structure and geologic history of the region. Linear, areal and relief parameters were derived to analyze groundwater prioritization units.

Linear parameters

Stream order

The streams of the Samshe hole watershed were ranked according to the Strahler's (1964) stream ordering system. Stream order (u) is a dimensionless number which can be used for geometry comparison of drainage networks on different linear scales. The total number of streams (Nu)is inversely proportional to the(u) stream order(Sreedevi et al. 2005). Number of total streams (Nu) was found to vary between 8 (MW-II) to 41 (MW-I) as shown in Figure 4.1 and Table 2. The lower Nu valuein micro-watershed indicated the maturity of topography, conversely higher values of Nu indicated the area prone to erosion.

Stream length (Lu)

Stream length (Lu) is a dimensional property used to understand the drainage network components which reflect the hydrological characteristics of the underlying rock strata over the areas of consecutive stream orders. The permeable rock formation is responsible for longer streams and conversely impermeable rocks develops smaller streams (Vijay Pakhmode et al. 2003). Results indicated the total stream length ($\sum L_u$) of minimum (2.92 km) in the MW-II and maximum (27.07 km) in the MW-I, with an average of 10.61 km as illustrated in Table 5.2. Further, it is described that, the L_u is maximum (average of 7.31 km) in case of first-order streams in all micro-watersheds.The $L_u$in each micro-watershed decreases consequently with an increase in stream order, indicating continuous variation in the relief over which the streams occurs. The average values of L_u computed for the first- and second-order streams were 0.51 (0.35–0.56) km and 0.86 (0.28–2.67) km, respectively, and that of third order streams were 1.32 (0.12–3.85) km as detailed in Table 3.The differences favour the distribution of number of streams and their lengths in different orders of streams.

Table 2: Linear morphometric parameters of the Samshe hole sub watershed

Sub-watershed/watershed	Length (L:km)	Number of streams (N_u) of Different Stream order(u)					$\sum N_u$	Bifurcation ration (R_b) N_u/N_{u+1}				Mean R_b
		1	2	3	4	5		1/2	2/3	3/4	4/5	
MW-I	5.11	33	7	1	-	-	41	4.71	7	-	-	5.85
MW-II	0.98	5	2	1	-	-	8	2.5	2	-	-	2.25
MW-III	2.89	15	4	1	-	-	20	3.75	4	-	-	3.87
MW-IV	2.41	8	3	1	-	-	12	2.66	3	-	-	2.83
MW-V	4.17	15	2	1	-	-	18	7.5	2	-	-	4.75
MW-VI	1.95	9	2	1	-	-	12	4.5	2	-	-	3.25
MW-VII	3.22	16	4	1	-	-	21	4	4	-	-	4
MW-VIII	1.94	6	2	1	-	-	9	3	2	-	-	2.5
MW-IX	2.71	21	3	1	-	-	25	3	3	-	-	3
MW-X	2.62	8	2	1	-	-	11	4	2	-	-	3
MW-XI	3.23	15	5	1	-	-	21	5	5	-	-	5
Average	5.11	13.72	3.27	1	-	-	18	4.05	3.27	-	-	3.66
Samshe Hole Basin	17.11	248	56	11	3	1	319	4.42	5.09	3.66	3	4.04

Stream length ratio (R_L)

Stream length ratio (R_L) is an analyzing factor to relate the discharge of surface flow with erosional stages of the watershed (Horton 1945). The R_L is defined as the ratio of the average length (L_u) of a stream of a given order (u) to the average length of a stream of the next lowest order (L_{u-1}), which tends to be constant throughout the successive orders of the watershed. Results indicatedan average R_L of the third order streams with high value of 2.9

(0.03–5.41) compared to the average R_L of the second-order streams within the watershed, i.e. 1.14 (0.46–4.71). The average R_L of all eleven micro-watershedsare found to vary from 0.06 to 3.07 as illustrated in Table 5.2. This indicated that, the rock formations in the area which are drained by the third-order streams were more permeable and the gradients are gentler than those formations drained by the lower order streams. It had been noticed that R_L between successive stream orders varied due to differences in slope and topographic conditions and has an important relationship with the surface flow discharge and erosional stage of the watershed (Sreedevi et al. 2005).

Table 3: Linear morphometric parameters of the Samshe hole sub watershed

Sub-basin/basin	Total stream length (Lu; km) of different orders (u)					$\sum L_u$	Average Lu (km) in different u (Lu/Nu)					Stream length ratio (R) (Lu/Lu–1))				Mean R_L
	1	2	3	4	5		1	2	3	4	5	2/1	3/2	4/3	5/4	
MW-I	18.73	4.49	3.85	-	-	27.07	0.56	2.67	3.85	-	-	4.71	1.43	-	-	3.07
MW-II	1.95	0.85	0.12	-	-	2.92	0.39	0.42	0.12	-	-	1.08	0.28	-	-	0.68
MW-III	8.15	2.40	1.65	-	-	12.21	0.54	0.60	1.65	-	-	1.10	2.75	-	-	1.93
MW-IV	4.94	0.86	1.01	-	-	6.82	0.61	0.28	1.01	-	-	0.46	3.51	-	-	0.06
MW-V	9.29	3.41	0.60	-	-	12.51	0.61	1.70	0.60	-	-	2.75	0.35	-	-	1.39
MW-VI	3.21	1.54	0.43	-	-	5.19	0.35	0.77	0.43	-	-	2.16	0.55	-	-	1.35
MW-VII	7.60	1.76	2.39	-	-	11.76	0.47	0.44	2.39	-	-	0.93	5.41	-	-	3.17
MW-VIII	2.92	1.86	0.50	-	-	5.29	0.48	0.93	0.50	-	-	1.91	0.53	-	-	1.22
MW-IX	11.16	1.15	1.96	-	-	14.27	0.53	0.38	1.96	-	-	0.72	5.10	-	-	2.91
MW-X	4.08	1.87	0.85	-	-	6.81	0.51	0.93	0.85	-	-	1.83	0.91	-	-	1.37
MW-XI	8.34	1.82	1.72	-	-	11.88	0.55	0.36	1.72	-	-	0.65	4.72	-	-	2.69
Average	7.31	2.006	1.32	-	-	10.61	0.51	0.86	1.32	-	-	1.66	2.29	-	-	1.809
Samshe hole	136.09	34.97	15.12	5.92	10.95	203.07	0.54	0.62	1.37	1.97	10.95	1.148	2.209	1.43	5.55	2.58

Bifurcation ratio (R_b)

Bifurcation ratio (R_b) is defined as the ratio of number of streams of any given order (u) to the number of streams (N_u) of the next higher order (Schumm 1956). Strahler (1964) revealed the $R_b$value ranged from 3 to 5 in a micro-watershed was not influenced by any geological structures. Lower value of R_b indicates,the watershed is underlined by uniform materials, and the streams are usually branched systematically (Vijay Pakhmode et al. 2003). Analyzed values of R_b of all eleven micro watersheds and total Samshe hole watershed are less than 5 (except the MW-I), which proved the control of drainage network from geomorphology. R_b of MW-I is greater than 5 and represents an indicative factor of structural control on the development of drainage network. Structural control had been validated from this earlier studies, that the middle portion of the main river channel (i.e. in MW-I).

Areal parameters

Form factor (F_f)

Form factor (F_f) is the ratio of the watershed area (A) to the squared value of the watershed length (L) (Horton 1945). The $F_f$ranges from 0 (in highly elongated shape) to 1 (in perfect circular shape). The Average Ff value of the Samshe hole micro watersheds is 0.34. In micro-watersheds, the Ff varies from 0.20 (MW-V) to 0.68 (MW-II), indicating that the micro watersheds in are elongated form as illustrated in Table 4.

Elongation ratio (R_e)

Elongation ratio (R_e) is the ratio between the diameter of a circle of the same arc as the watershed (A) and maximum watershed length (L). Higher value of R_e indicates active denudational processes with high infiltration capacity and low run-off in the watershed, whereas, lower R_e values indicate higher elevation of the watershed susceptible to high headward erosion along tectonic lineaments (Obi Reddy et al. 2004). The computed values of R_e for the micro watersheds vary from 0.51 (MW-V) to 0.93 (MW-II), and they are usually associated with high relief and steep ground slopes. The average value of Re of the whole Samshe hole watershed is 0.65, which revealed the fact that the watershed is in an elongated shape (Table 4). According to Schumm (1956), R_e values close to 1.0 are typical of regions of low relief, whereas those in the range of 0.6–0.9 are generally associated with high relief and steep ground slopes. Hence, the R_e values indicate that the Samshe hole watershed is associated with high relief and steep slopes.

Circularity ratio (R_c)

Circularity ratio (R_c) is the ratio of the area of the watershed (A) to the area of the circle having the same circumference as the perimeter (P) of the watershed (Miller 1953, Strahler 1964). The R_c is more influenced by stream length, stream frequency (F_s) and gradient of streams of various orders rather than the slope conditions and drainage pattern of a watershed (Strahler 1964). Low, medium and high values of R_c gave an indication of the young, mature and old stages of the tributaries in the watersheds, respectively. Thewatershed with R_c value of 1.0 is a representative of perfect circle in shape and the discharge quantity would be high (Miller 1953). The values of R_c ranges from 0.41 (MW-V) to 0.76 (MW-II) as shown in Table 5.This is an indicative of the watershed with not circular shape, and the quantity of discharge is comparatively less in micro-watersheds with lower R_c values. It may be attributed to differences in geomorphological features in the river watershed.

Shape factor (B_s)

Shape factor (B_s) provides a measurement of watershed shape irregularity. The watershed would be a perfect circle if the shape factor is equal to 1. The calculated value of Bs for the Samshe hole watershed is 3.14 as represented in Table 4.

Compactness coefficient (C_c)

Compactness coefficient (C_c) is the relationship of the shape of the drainage watershed to a circle. It is expressed as the ratio between the length of watershed boundary (the perimeter) and the perimeter of a circle with the same area. The watershed with Cc value equal to one is an indicative of perfect circular shape. The calculated value of C_c for Samshe hole watershed is 1.32 as detailed in Table 4.

Drainage density (D_d)

Drainage density (D_d) is the total length of streams of all orders divided by the area of drainage watershed (Horton 1932, 1945). It provides a numerical measurement of landscape dissection and run-off potential (Obi Reddy et al. 2004). According to Horton (1945), low D_d is an indication of the prevalence of highly resistant/permeable strata under dense vegetation and low relief, whereas, high D_d prevails in the weak/impermeable rocks under sparse vegetation and mountainous relief regions. In the Samshe hole watershed, D_d ranges from 3.42 (MW-I) to 8.27 (MW-VII) km/km2, with an average of 4.33 km/km2. Dd value greater than 5 suggests the permeable nature of the surface strata of the river watershed, which is a characteristic feature of a coarse-drainage density (Strahler 1957).

Stream frequency (F_s)

Stream frequency (F_s) is the ratio between the number of streams (N_u) of all orders within a watershed and the watershed area (A). The high value of F_s indicates greater surface run-off and a steep ground surface (Horton 1945). The computed F_s values of micro watersheds of Samshe hole watershed range from 5.02 (MW-V) to 12.04 (MW-II), with an average value of 7.23 per km^2 as shown in Table 4. It means, two streams are developed in an area of 7 km^2 in the watershed. High F_s values (> 8 km^2) of 12.04, 9.15 per km^2 are observed in the MW-II, MW-VI, respectively. The results indicated the micro-watersheds with steep slopes characterized by less permeable rocks, which facilitate greater runoff, less infiltration, sparse vegetation and high relief conditions. The low F_s values (< 7 km2) in the MW-I (5.18), MW-IV (6.52), MW-V (5.02), MW-VIII (6.32), MW-X (6.31) and MW-XI (6.78) reflect the gentle ground slopes and greater rock permeability in these micro-watersheds, where the run-off is low and the infiltration is high. Fs value with a range 8–7 per Sq.km was found in MW-III (7.39), MW-VII (7.20) and MW-IX (7.90) evidenced the occurrence of moderate ground slopes associated with moderately permeable rocks, which promote moderate run-off and infiltration.

Drainage texture (T)

Drainage texture (T) is the product of drainage density and stream frequency. It is a measure of closeness of the channel spacing, depending on climate, rainfall, vegetation, soil and rock type, infiltration rate, relief and the stage of development (Horton 1945). The drainage texture is highly influenced by the vegetation type and climate. The T is classified as coarse (< 31 per km), intermediate (31–40 per km), fine (40–45 per km) and ultra-fine (> 45 per km). The T values in the micro watersheds were found to vary between 17.56 (MW-I) and 59.58 (MW-VII), with an average value of 31.87. All the micro-watersheds with T values ranges between 17.56 and 26.09 and the Samshe hole watershed lies under the coarse drainage texture as discussed in Table 4. T values ranges between 33.38 and 36.28 and the watershed falls under intermediate drainage texture. This indicated the micro-watersheds comprised of formations with higher permeability and infiltration capacity except MW-II (53.13) and MW-VII (59.58), which have an ultra-fine drainage texture.

Constant of channel maintenance (C)

Constant of channel maintenance (C) is the inverse of drainage density (D_d) (Schumm 1956), which depends on the rock type, permeability, climatic regime, vegetation cover and relief as well as the duration of erosion. The higher the C values of a watershed, the higher the permeability of the rocks of that watershed and vice-versa (Vijay Pakhmode et al. 2003, subba Rao 2009). The C value of the third order Samshe hole watershed is 0.24 as described in Table 4, which indicated that, on an average, 0.24 km^2 of surface area is required to maintain 1 km length of stream channel. The MW-VII have low 'C' value (<0.2), indicated the influence of less structural disturbance, low permeability, steep to very steep slopes and high surface run-off, while a high value indicates structural disturbances and less run-off conditions.

Length of overland flow (L_o)

Length of overland flow (L_o) is used to describe the length of flow of water over the ground before it becomes concentrated in definite stream channels. It is one of the most important independent variables, affecting both the hydrological and physiographical developments of the drainage watersheds (Horton 1945). During the evolution of the drainage system, L_o is adjusted to a magnitude appropriate to the scale of the first-order drainage watersheds. Horton (1945) defined Lo as the length of flow path, projected to the horizontal of non-channel flow from a point on drainage divide (watershed boundary). The average L_o is approximately equal to half the reciprocal of the average D_d. The computed values of L_o of the Samshe hole watershed ranged between 1.71 (MW-I) and 4.13 (MW-VII) km2/km, with an average value of 2.16 km2/ km as represented in Table 4. For a comparison of the micro- watersheds in respect of the nature of flow path, the L_o is classified as: (1) low (< 1.8 km2/km), (2) medium (1.8–2.0 km2/ km) and (3) high (> 2 km2/km) in the study area. The high L_o values in the MW-II, MW-III, MW-VII, and MW-IX indicated the occurrence of long flow-paths, and thus, gentle ground slopes, which reflect areas of fewer run-offs and more infiltration. The low L_o values in the MW-I and MW-V reveal short flow paths, with steep ground slopes, reflecting the areas as associated with more run off and less infiltration. The MW-IV, MW-VI, MW-VIII, MW-X and MW-XI show medium L_o values, indicating ground slopes, flow-paths, run-off and infiltration being moderate.

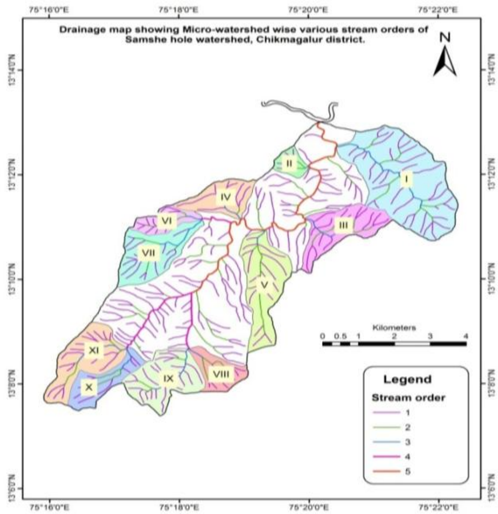

Figure 4.1: Drainage Map

Table 4: Micro-watershed-wise areal morphometric parameters of the Samshe hole watershed

Parameters	MW-I	MW-II	MW-III	MW-IV	MW-V	MW-VI	MW-VII	MW-VIII	MW-IX	MW-X	MW-XI	Average
Area(A: km^2)	7.90	0.66	2.70	1.83	3.58	1.31	2.91	1.42	3.16	1.79	3.09	2.76
Perimeter (P: km)	12.11	3.03	8.50	6.26	10.37	5.11	8.25	5.66	7.87	7.16	8.64	7.54
Form factor *(Ff)*	0.30	0.68	0.32	0.31	0.20	0.34	0.28	0.37	0.43	0.25	0.29	0.34
Elongation ratio (R_e)	0.61	0.93	0.64	0.63	0.51	0.66	0.59	0.69	0.73	0.57	0.61	0.65
Circularity ratio (R_c)	0.67	0.76	0.46	0.58	0.41	0.54	0.53	0.55	0.64	0.43	0.51	0.55
Shape factor (B_s)	3.31	1.46	3.10	3.18	4.86	2.91	3.56	2.66	2.34	3.84	3.37	3.14
Compactness co-efficient (C_c)	1.21	1.04	1.45	1.30	1.54	1.26	1.36	1.34	1.24	1.50	1.38	1.32
Drainage density (km/km^2) (D_d)	3.42	4.40	4.51	3.71	3.49	3.96	8.27	3.72	4.51	3.80	3.84	4.33
Stream frequency (km^{-2}) (F_s)	5.18	12.04	7.39	6.52	5.02	9.15	7.20	6.32	7.90	6.13	6.78	7.23
Drainage texture (km^{-1}) (T)	17.76	53.13	33.38	24.24	17.56	36.28	59.58	23.56	35.71	23.30	26.09	31.87
Constant of channel maintenance (km) (C)	0.29	0.22	0.22	0.26	0.28	0.25	0.12	0.26	0.22	0.26	0.26	0.24
Length of overland flow	1.71	2.20	2.25	1.85	1.74	1.98	4.13	1.86	2.25	1.90	1.92	2.16

Geomorphic characteristics

The earth's surface forms are primarily due to hypogene or endogenous processes. Geomorphology of the watershed has been interpreted based, geology, DEM, slope and SOI topographic maps as well as the satellite images in geographic information system (GIS) environment as shown in Figure 4.2.

Structural hills (SHs)

SHs are found in the western most part of the watershed mainly in MW-V, MW-VI, MW-VII, MW-VIII, MW-IX, MW-X and MW-XI. These consists complex folding, faulting and criss-crossed by numerous joints/fractures. These structural features facilitate infiltration of water and contain springs/seepages at lower part, although these regions are normally having poor source of groundwater. The total area covers 50.15%.

Denudational Hills (DHs)

Denudational hills are the massive hills with resistant rock bodies that are formed due to differential erosional and weathering processes. These which are fractured, jointed having no soil cover moderate to steep slope. On satellite imagery visualization, these landforms were identified by light or dark brownish with mix green color due to thick forest cover. Denudational hills occupying eastern and western portions of the Samshe hole watershed, this geomorphic unit (DH) is found in MW-I, MW-II, MW-III, covering an area of 6.37 km2, of which 66.4% is estimated to be distributed in MW-I as illustrated in Table 5.

Pediment (PD)

PD is an erosional geomorphic feature developed by the process of weathering. In this unit, groundwater prospects are normally poor due to massive rocky surface, whereas metabasalt terrains with numerous fractures or joints permit infiltration and storage of groundwater. Hence, depending on the thickness of weathered material and the presence or absence of secondary structures, groundwater potential is moderate to poor. In the Samshe hole watershed, this geomorphic unit (PD) is found in MW-IV, MW-V, MW-VI to MW-VII, covering an area of 1.47 km2, of which 29.2% is estimated to be distributed in MW-VI as defined in Table 5.

Pediplain

Pediplain is a result of weathering under arid and semi-arid conditions, representing the end stage of cyclic erosion. PDs with more or less over burden of accumulated materials on the shallow to moderately weathered rocks. Based on the visual observations, pediplains have been classified into two classes. Shallow weathered pediplain (PPS) is developed by continuous process of pedimentation at low gradient and covered with shallow weathered material and sparse vegetation, this geomorphic unit (PPS) is found in MW-I, MW-II, MW-III, MW-IV, MW-V, MW-VI and MW-VII covering an area of 5.77 km^2, of which 89% is estimated to be distributed in MW-IV as detailed in Table 6. Groundwater prospect is found to be poor (virtually dry environment) to moderate (gentle slopes adjacent to the stream courses/tanks) in this type of pediplain. Secondly, Moderately weathered pediplain (PPM) is found as nearly flat terrain gentle slope and occurs normally along all the major drainage courses/broken streams, which control the valley course. The PPM consists of relatively thick weathered material covered with soil and fairly thick vegetation, formed in low-laying areas and generally associated with lineaments. This geomorphic unit (PPM) is found micro watersheds in MW-I, MW-II, MW-III, MW-IV and MW-V covering an area of 0.74 km2, of which 8.9% is estimated to be distributed in MW-III as expressed in Table 6. Hence,

Geomorphic units	Water prospect	MW - I%	MW - II%	MW-III%	MW - IV%	MW - V%	MW - VI%	MW - VII%	MW - VIII%	MW - IX%	MW - X%	MW - XI%
Structural Hills	Poor	0	0	7.4	0	74.2	53	88.6	100	100	100	100
Denudational Hills	Poor	66.4	36.4	32.9	0	0	0	0	0	0	0	0
Pediment	Good	0	0	10	7.6	12.8	29.2	9.2	0	0	0	0
PPS	Good	28.9	59	41.1	89	13.6	16.8	2.4	0	0	0	0
PPM	Excellent	4.8	4.8	8.9	2.7	0.8	0	0	0	0	0	0

groundwater prospects in this unit are considered as good to excellent, depending upon the thickness of weathered zone.

Table 5: Quantification of micro-watershed-wise areal coverage of various geomorphic units and their prospects for groundwater.

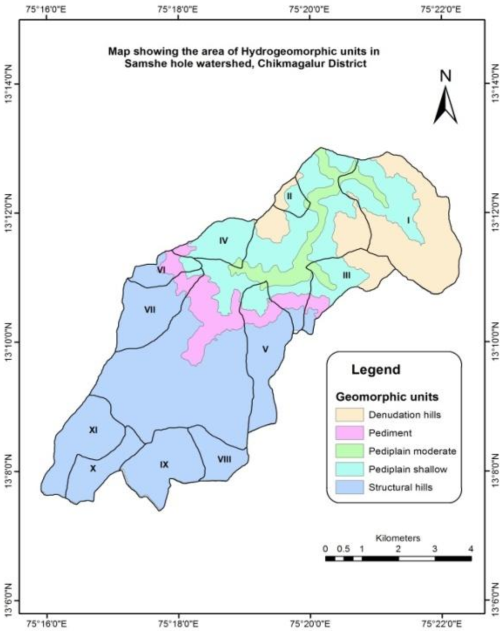

Figure 4.2: Hydrogeomorphic map

Conclusion

Watershed prioritization is an important aspect in planning and development for water conservation measures. This present study reveals that, the geomorphology and morphometric parameters were good proxies to evaluate the deficit and surplus zones of groundwater in micro-watershedscales. Quantification of geomorphic units showed that poor groundwater prospects in the micro-watersheds like MW-VII, MW-XI, MW-VI, MW-IX and MW-X, whereas in micro-watersheds MW-V, MW-III, and MW-VIII have good groundwater prospects. Groundwater potential is excellent in MW-II, MW-I and MW-IV micro-watersheds. The observed mean R_b value of 3.07 in MW-I indicates that the drainages are structurally controlled. Wherever the R_b are in the range of 0.06-1.22 in MW-II, MW-IV and MW-VIII indicates that geological structures failedto exercise a dominant control over the drainage pattern of the basin. Analysis of areal parameters such as F_f, R_e, R_c and B_s suggest that, the Samshe hole watershed is in an elongated form associated with high relief, steep ground slopes and variations in the geomorphological features. The D_d value suggested the nature of the surface strata with permeable formations, which is a characteristic feature of coarse-drainage density. The high relief ratio (R_r) and gradient ratio values indicate hilly regions from which the run-off volume could be evaluated. This study contribute ground water prospect map using morphometric and hydromorphic analysis.

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