Identification of Groundwater Recharge and Discharge Zone in Four Watersheds of Rampurhat Subdivision, Birbhum District, West Bengal

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Abstract

Groundwater levels are controlled by the balance among recharge to, storage in, and discharge from an aquifer. So identification of natural groundwater recharge and discharge zone within any administrative unit or watershed boundary is a pre-requisite for efficient groundwater resource management especially in regions with large demands for groundwater use, where such resources are the key to economic development. In this paper attempts have been made to demarcate recharge and discharge zone within four major river basins of Rampurhat subdivision of Birbhum district by applying a simple hydrogeological exercise, known as Grid Deviation method. Likewise previous literature in this study too, recharge zone is identified in up stream areas and discharge zone is demarcated in down stream areas of river basins of this subdivision. Groundwater potentiality is considered to be higher in the recharge zone and lower in the discharge zone which is examined with borehole yield data collected from field. So this method also makes clear indication to assess groundwater potentiality of any area.

KEYWORDS: Groundwater Recharge and Discharge, Grid Deviation Method, Groundwater Potentiality, Groundwater Yield

Introduction:

Groundwater recharge is considered as the hydraulic process of downward water movement from surface water to groundwater (Crosbie et al., 2010; O'Grady et al., 2010). Groundwater discharge is the loss of water from an aquifer. It can occur by leakage to the ocean, rivers or another aquifer (Cook et al. 2003). The locations and extent of recharge and discharge areas are thought to be very important in exploring hydrogeological relationships that define groundwater systems (Toth, 1963). Toth demonstrated that groundwater flow systems may occur on three characteristic scales: local, intermediate, and regional systems.

According to Toth's definitions, a local groundwater flow system has its recharge area at a topographic high and its discharge area at an adjacent topographic low. For intermediate systems, one or more topographic highs and lows may be located between the recharge and discharge areas, although these areas are not associated to the highest and lowest locations within the groundwater basin. Finally, the recharge area of a regional system occupies the upstream water divide of the basin, and its discharge area is located at the main (regional) valley bottom, i.e. at the lowest location of the basin.

Toth (1966) attempted to map recharge and discharge areas on the basis of field observations. There are five basic types of indicators as: 1.Topography, 2.Piezometric patterns 3.Hydrochemical trends, 4.Environmental isotopes and 5.Soil and land surface features. Among these most direct indicators are topography and piezometric patterns and also simplest to calculate by using field data (Toth, 1963). Other indicators are indirect and needs complex calculation steps. Simply discharge areas are topographically low and recharge areas are high. So, static ground water level and altitude data of open wells can be used to delineate these zones.

Grid deviation method has been used for representing the hydrogeological data to delineate groundwater recharge and discharge zones within basin boundaries (Saha and Chakravarthy, 1963). It is convenient, more informative and brings out more sharply the regional trend by eliminating the local interference (Biswas and Chaterjee, 1967). To evaluate the recharge-discharge zones this method has been used (Narasimha Prasad, 1984; Subramanian, 1985; Balasubramanian, 1986; Harinarayanan, et el., 2000 and Arshad, 2009.). In the present study attempts have been made to delineate recharge and discharge zone of groundwater within four watersheds of the study area.

Objectives:

- To delineate groundwater recharge and discharge zone within four watersheds of the study area
- To establish relationship between topographic character and groundwater recharge and discharge zone in the study area
- To make simplified assessment regarding groundwater potentiality of these two identified zones
- To judge validity of this method in determining groundwater potentiality by comparing with well yield field data

About The Study Area:

Rampurhat, the most populous subdivision (Census, 2001) of the Birbhum district is situated in the northern part of Birbhum district and extended between 23^{o}52’34”N-24^{o}33’16”N latitude and 87^{o}34’25”E-88^{o}00’53”E longitude covering an area of 1513.23 km^2 (Fig.-1). It is constituted with eight Community Development Blocks namely Murarai-I, Murarai-II, Nalhati-I, Nalhati-II, Rampurhat-I, Rampurhat-II, Mayureswar-I and Mayureswar-II with sixty two Gram Panchayats and two Municipalities (Fig-1).

Geologically, this area is comprised by four lithological formations i.e. alternative layers of sand, silt and clay (soft sediments) in the south eastern part, hard clays impregnated with caliche nodules (soft rock) in the eastern part, laterite and lateritic soil (soft and medium hard rock) in the western part and basaltic Rajmahal trap (hard massive rock) in the northern part (Krishnanunni. K., 2001).

Geomorphologically, this area can be subdivided into four major subdivisions i.e. flood plain in the south eastern part, upper mature deltaic plain and paradeltaic fan surface in the northern and eastern part, pedeplain or peneplain in the western and southern part and hills and valleys in the minor areas of south western part (Krishnanunni. K., 2001). The western part of the subdivision is plateau fringe area, characterised by 50m-100m altitude and >4 degree slope. In eastern part altitude varies between 20m-50m <2 degree slope

(Fig-3 & 4). The thickness of aquifer is lesser in the hard rock areas of the western part which increases towards eastern soft rock areas resulting the eastern part as highly potential for groundwater resources and western part as poorly potential (Govt. of India, 2007). Entire study area is part of Ganga River System in which four sub basin systems are clearly detectable (Fig.-1). From southern part to northern part, these are Mayurakshi basin, Dwarka Basin, Brambhani basin and Pagla-Bansloi basin.

Owing to the geographical location and physical characteristics, the climate of this subdivision can be classified as tropical monsoon climate where the summer temperature shoots above 40^{O}c and winter temperature drop around 10 ^{O}c. The annual average rainfall is about 1430.5 mm.

CGWB have identified three aquifer systems in this study area i.e. Basalt Aquifer in some minor pockets of western and northern part, Laterite Aquifer in the western part and Alluvial Aquifer in the eastern part of this subdivision (Fig.-4).

Materials and Methodology:

Groundwater level data of 35 selected wells, located in different parts of the study area for time period of 20 years (1996-2015), have been collected from the office of Central Groundwater Board Eastern Region, Kolkata. Block wise depth of groundwater level data for time period of 10 years (2001-2011) have been collected from the office of State Water Investigation Directorate. Groundwater level maps of four seasons namely pre monsoon, monsoon, post monsoon kharif and post monsoon rabi have been prepared separately. On the basis of which 50 sample site have been selected.
Elevation data of the well have been collected from digital elevation model map and verified in the field using GPS. Boreholes yield data have been collected directly from 15 drilled boreholes of the field. Borehole locations and actual yield data have been shown in Fig.-1 and Table-3.
Grid deviation of water tables for the study area has been prepared by using the following methodology (Table-1).

1. Water levels, measured below ground level have been recalculated to water level altitude Above Mean Sea Level (AMSL).
2. Annual average water level of each well has been computed, which is termed as Well average.
3. Using this of each wells, a zonal average has been computed for watershed and it is called the Grid average.
4. The deviation of values between well averages and the grid average for all wells have been computed.
5. The deviation values of each well have been used to prepare a thematic contour map called grid deviation groundwater table map. GIS software is used to prepare grid deviation groundwater level map.

Boreholes yield data have been used in order to validate the assumptions that discharge zone has high groundwater potentiality and recharge zone has poor groundwater potentiality. On the basis of field observation, the yield ranges of the study area have been grouped into 2 categories viz. <4.0 lps as low yield and >4.0 lps as high yield. Table-3 reveals the accordance between actual yield pattern, measured from field and predicted expected yield, obtained from the aforesaid assumptions. To assess the accuracy of the prepared potential map following formula are used

$$\text{Accuracy prediction} = \frac{\text{No.of boreholes under agreement of coherence}}{\text{Total number of borhole surveryed}} \text{ X100}$$

Results and Discussion:

The grid deviation map shows negativeve zones in the eastern part and positive zones in the western part of the subdivision which are as separated by a zero line located in middle of the study area, representing the grid average (Fig. - 5). The positive zones are recharge zones and negative zones are discharge zones. Recharge zone is located in the upstream areas characterized by relatively high altitude and greater slope whereas discharge zone is located in the downstream area characterized by low altitude and gentle slope (Fig.-2 &3). The normal groundwater potentiality is expected to be higher in the discharge zone than the recharge zone (Balasubramanian, 1986).

Watershed wise analysis of recharge and discharge zone is showing higher proportion of recharge area in the southern basins of the study area namely Mayurakhshi and Dwarka. Whereas higher proportion of discharge area is observed in the northern basins of the study area namely Brahmani and Pagla-Bansloi (Table-2).

Among 15 analyzed boreholes, 13 boreholes shows accordance with the assumed fact discharge zone has high groundwater potentiality. In Mayurakshi and Brambhani basins, 02 boreholes indicate discordance with the assumed fact. But the overall accuracy prediction value (86.66%) of the subdivision reflects that Grid deviation method, applied in the present study, generates significantly reliable and precise result.

Conclusion:

This simple hydro geological exercise makes clear indication regarding groundwater potentiality of the study area. Highly potential areas are feasible for construction of any kind of groundwater extraction structure following the temporal trend of water level and maintaining balance between per year availability of groundwater and its withdrawal for different purposes. In low potential areas, construction of all kind of groundwater extraction structure is not feasible and economically profitable. So from environmental and economical point of view construction of artificial recharge sites and execution of rainwater harvesting schemes will be more effective in this zone. Moreover the field verification has also proved that application of this grid deviation method is helpful for determining the potential zones before implementing any effective groundwater management strategy.

References:

Arshad, N. (2009). Environmental Management of Water Resources for Sustainable Development in Western Part of Hunsur, Karnataka, India Using Remote Sensing and GIS. Unpublished Ph.D Thesis, University of Mysore.

Balasubramanian, A. (1986). Hydrogeological Investigation of Tambraparani River Basin Tamil Nadu, Published Ph.D. Thesis, University of Mysore.

Biswas, A. B. & Chatterjee, P.K., (1967). On representation of water table by grid deviation method, *Bull. Geol. Soci. India.* Vol. 4, pp 12-14.

Census of India (2001). District Census Handbook, 2001, Birbhum District. Directorate of Census Operation, West Bengal.

Cook, P. G. (2003). A guide to regional groundwater flow in fractured rock aquifers. Adelaide: CSIRO Land and Water.

Crosbie, R. S., Jolly, I. D., Leaney, F., Petheram, C. & Wohling, D. (2010). Review of Australian groundwater recharge studies. *Adelaide: CSIRO Water for a HealthyCountry National Research Flagship.*

Government of India (2007). Ground Water Management and Ownership. Report of the Expert Group, Planning Commission.

Government of India (2007). Groundwater Information Booklet, Birbhum District, West Bengal. Central Ground Water Board, Ministry of Water Resources.

Harinarayana, P., Gopalakrishna, G.S. & Balasubramanaian, A. (2000). Remote sensing data for groundwater development and management in Keralapura watersheds of Cauvery basin, Karnat aka, India. *Indian Mineral.* vol. 34(2), pp. 11–17.

Krishnanunni, K. (2001). District Resource Map, Geological Survey of India.

Narasimha Prasad, N.B., (1948). Hydrogeological Studies in Bhadra River Basin, Karnataka. Unpublished Ph.D Thesis, University of Mysore.

O'Grady, A., Carter, J. & Holland, K. (2010). Review of Australian groundwater discharge studies in terrestrial systems. Hobart: CSIRO.

Pain, C., Gow, L., Wilford, J. & Kilgour, P. (2011). Mapping Approaches to Recharge and Discharge Estimation and associated input datasets. Geoscience Australia Professional Opinion No. 2011/01 Consultancy report prepared for Water for a Healthy Country Flagship

Saha, A.K. and Chakrovorthy, S.K., (1963). A quantitative petrological study of Bahalda Granodiorite, Mayurbhuni. *Journal of Deccan geological. Society*. Vol. 3, pp.50-59.

Subramanian, A. (1985). Surface and groundwater resources in the Northern part of Goa district, Union Territory of Goa, Daman and Diu, Proc Seminar: *Earth Resources for Goa's Development*, Panaji, Goa, pp. 475-483.

Toth, J. (1963). A theoretical analysis of groundwater flow in small drainage basins. *In: Proceedings of Hydrology Symposium No. 3*, pp. 75-106. Ottawa: GroundwaterNational Research Council of Canada.

Table-1: Grid Deviation Calculation Sheet

Sl. No.	Well Location	Lat.	Long.	Basin Name	Altitude	Hydraulic Head (m)				Well Annual Average (m)	Basin Average (m)	Grid Deviation (m)
						Pre Monsoon	Monsoon	Post Monsoon (Kharif)	Post Monsoon (Rabi)			
1	MURARAI	24.443	87.849	**Pagla-Bansloi**	32	11.58	13.25	12.77	12.23	12.46	**19.10**	-6.65
2	RATANPUR	24.482	87.861		34	13.83	16.48	17.01	15.12	15.61		-3.49
3	PALSA	24.485	87.862		33	25.32	32.27	31.27	30.72	29.90		10.79
4	MITRAPUR	24.417	87.852		31	17.95	17.99	15.15	18.55	17.41		-1.69
5	CHATRA	24.375	87.851		40	20.02	20.82	20.16	20.49	20.37		1.27
6	ABDULLAPUR	24.498	87.863		30.2	26.54	29.72	28.27	27.57	28.03		8.92
7	PANCHAHAR	24.470	24.470		26.5	6.90	8.04	7.53	7.34	7.45		-11.65
37	JOYPUR	24.506	87.809		40.6	23.00	25.00	24.00	23.00	23.75		4.65
38	BANKURA	24.412	87.806		34.23	21.00	22.00	20.20	21.75	21.24		2.13
39	MITRAPUR	24.429	87.956		34.26	7.75	9.00	8.00	8.50	8.31		-10.79
49	BORIA	24.544	87.782		47	24.00	27.00	24.50	27.00	25.63		6.52
8	NALHATI	24.298	87.830	**Brambhani**	50.8	45.72	49.15	47.95	47.50	47.58	**28.70**	18.88
9	AMLAI	24.302	87.803		48	37.54	38.67	39.23	38.06	38.38		9.67
10	KURUMGRAM	24.248	87.868		35	16.91	17.25	17.44	17.00	17.15		-11.55
11	SHRADHA	24.242	87.902		33.9	15.70	17.70	17.17	16.90	16.87		-11.83
12	HASTIKANDA	24.310	87.800		44.3	41.65	42.55	41.35	41.10	41.66		12.96
13	NASIPUR	24.294	87.761		51	47.47	49.11	48.54	48.00	48.28		19.58
14	NIDHIA	24.248	88.011		27.5	11.71	12.96	12.41	11.98	12.27		-16.44
24	KASTAGARA	24.243	87.728		51.5	50.09	50.59	49.78	48.15	49.65		20.95
31	TARAPUR PZ	24.309	87.907		36	17.36	17.45	17.08	20.30	18.05		-10.65
33	BIRASRIMUL	24.210	87.964		25.1	14.00	16.00	16.00	16.00	15.50		-13.20
35	RANGAIPUR	24.244	87.802		40	40.00	43.00	43.00	41.70	41.93		13.22
36	KENDITHA	24.377	87.944		35	11.75	12.00	12.40	12.00	12.04		-16.66
40	GOPALPUR	24.267	87.953		34.3	13.25	13.56	14.25	14.00	13.77		-14.94

15	GANPUR	24.078	87.708		51	43.16	46.32	45.18	43.32	44.50		4.42
16	MOLLARPUR	24.083	87.692		42.5	37.62	40.90	40.50	35.60	38.78		1.29
21	NARAYANGHATI	24.199	87.798		47.6	39.32	42.74	42.83	41.10	41.50		1.42
22	RAMPURHAT	24.120	87.703		42	38.80	39.13	38.54	38.60	38.60		1.47
23	NARAYANPUR	24.199	87.694		56.7	38.94	45.47	41.68	40.14	41.56		1.48
25	TUMBONI	24.190	87.734		71.3	61.69	66.91	63.91	62.65	63.79		23.72
26	KURUKDIGHI	24.199	87.724		47	42.23	44.48	43.30	41.10	42.78		2.70
27	DHANMARA	24.180	87.768		54.8	53.05	54.02	53.27	51.13	52.87		12.79
28	CHAKMANDALA	24.152	87.835	**Dwarka**	59.9	50.14	53.55	51.87	50.85	51.60	**40.07**	11.53
29	NISCHINTAPUR	24.103	87.810		45	35.55	38.51	37.97	35.11	36.79		-3.29
30	MARGRAM	24.188	87.912		37.5	22.06	21.41	22.21	22.10	21.95		-18.13
34	KAPDAS TOLA	24.128	87.621		61	37.00	40.50	38.75	35.60	37.95		2.13
41	RANGTARA	24.047	87.863		34,2	24.00	26.00	26.20	24.50	25.18		-14.90
42	SIHULIA	24.021	87.691		45.1	40.50	38.76	38.50	38.00	38.98		1.10
43	BASWA	24.135	87.881		28.7	34.00	35.00	35.00	34.00	34.50		-5.57
44	SAKIRPUR	24.139	87.777		39.9	47.75	50.00	48.50	47.50	48.44		8.36
50	DARURI	24.037	87.780		40.1	19.00	23.50	23.00	23.00	22.13		-17.95
17	DHARANINAGAR	23.958	87.745		54.7	52.36	52.74	51.91	49.20	51.55		18.72
18	KOTASUR	23.981	87.762		47.8	35.37	39.92	39.82	38.42	38.38		5.55
19	MAYURESWAR	23.888	87.823		47.75	35.50	36.98	37.72	35.65	36.46		3.63
20	NOAPARA	23.953	87.728		47.8	30.60	34.46	31.26	31.28	31.90		0.93
32	CHANDPARA	23.929	87.832	**Mayurakshi**	30.5	14.88	15.19	14.92	14.74	14.93	**32.84**	-17.90
45	DIARA	23.985	87.704		44	39.80	41.50	32.00	30.00	35.83		2.99
46	DADPUR	23.920	87.791		43.5	35.50	40.00	40.00	38.00	38.38		5.54
47	DASHPALSA	23.963	87.804		38	28.00	35.00	36.00	42.00	35.25		2.41
48	JOGAI	24.343	87.881		37	19.00	24.00	25.00	25.00	23.25		-9.59

Source: Calculated based on CGWB data

Table-2: Basin wise analysis of Recharge and Discharge Area in the Study Area

Name of the Watersheds	Recharge Area (Km2)	Discharge Area (Km2)	Total Area (Km2)	% of Recharge Area (Km2)	% of Discharge Area (Km2)
Mayurakshi	108.02	45.01	153.03	70.59	29.41
Dwarka	352.82	296.39	649.21	54.35	45.65
Brahmani	146.11	299.54	445.65	32.79	67.21
Pagla-Bansloi	115.71	154.98	270.69	42.75	57.25

Source: Calculated based on CGWB data

Table-3: Accuracy assessment regarding assumed groundwater potentiality

Sl. No.	Well Location	Latitude	Longitude	Actual Yield from drilled borehole in post monsoon kharif season (lps.).)	Actual yield remark	Expected yield predicted from the map	Agreement between actual and expected
1	ABDULLAPUR	24.498	87.863	3.8	Low	Low	Accordance
2	PANCHAHAR	24.470	24.470	6.45	High	High	Accordance
3	MURARAI	24.443	87.849	5.93	High	High	Accordance
4	NIDHIA	24.248	88.011	7.1	High	High	Accordance
5	GOPALPUR	24.267	87.953	5.61	High	High	Accordance
6	SHRADHA	24.242	87.902	5.4	High	High	Accordance
7	MARGRAM	24.188	87.912	6.12	High	High	Accordance
8	NALHATI	24.298	87.830	5.26	High	Low	Discordance
9	NARAYANPUR	24.199	87.694	3.52	Low	Low	Accordance
10	KAPDAS TOLA	24.128	87.621	3.24	Low	Low	Accordance
11	MOLLARPUR	24.083	87.692	3.9	Low	Low	Accordance
12	DARURI	24.037	87.780	5.23	High	High	Accordance
13	NOAPARA	23.953	87.728	6.8	High	High	Accordance
14	KOTASUR	23.981	87.762	4.95	High	Low	Discordance
15	BANKURA	24.412	87.806	2.82	Low	Low	Accordance

Source: Collected from the Field

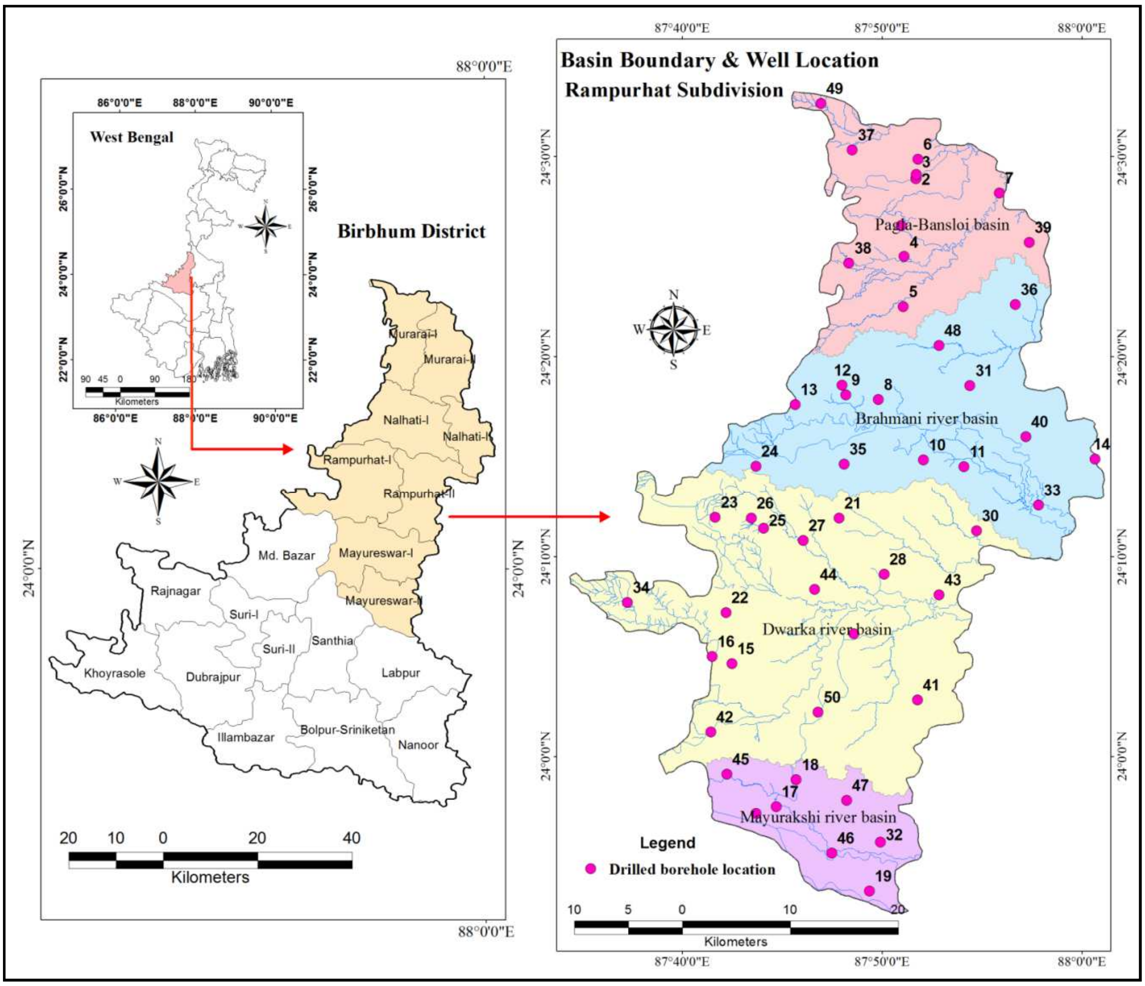

Fig.-1: Location Map of the Study Area

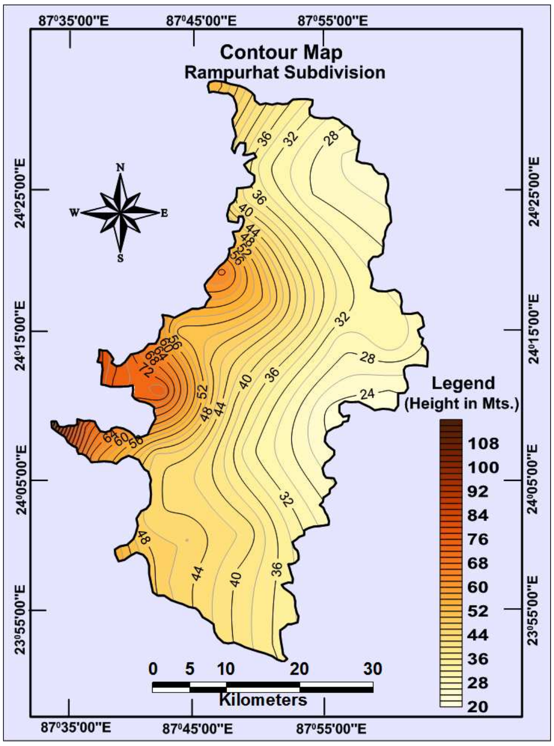

Fig.-2: Contour Map of the Study Area

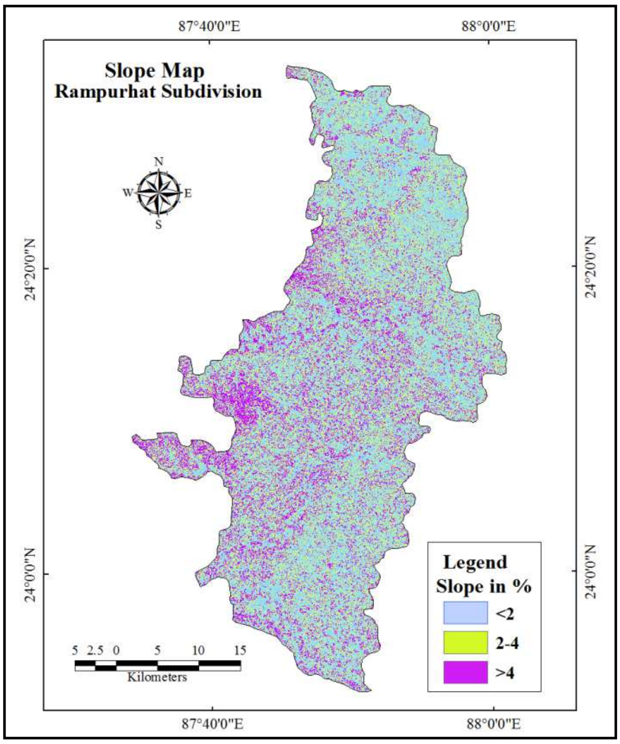

Fig.-3: Slope Map of the Study Area

Source: Toposheet and Satellite Imagery

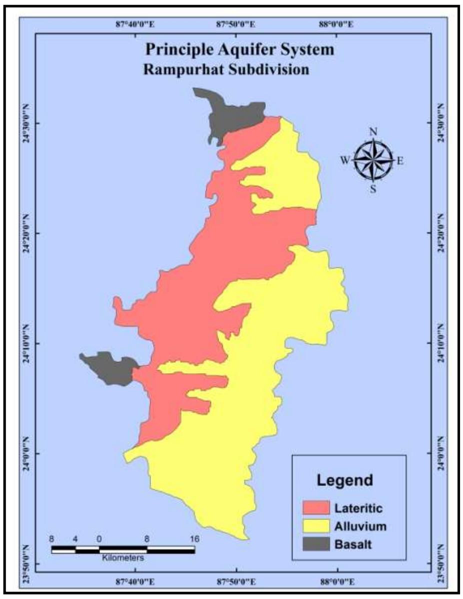

Fig.-4: Aquifer System Map of the Study Area

Source: National Remote Sensing Centre's Water Resource Information System webpage

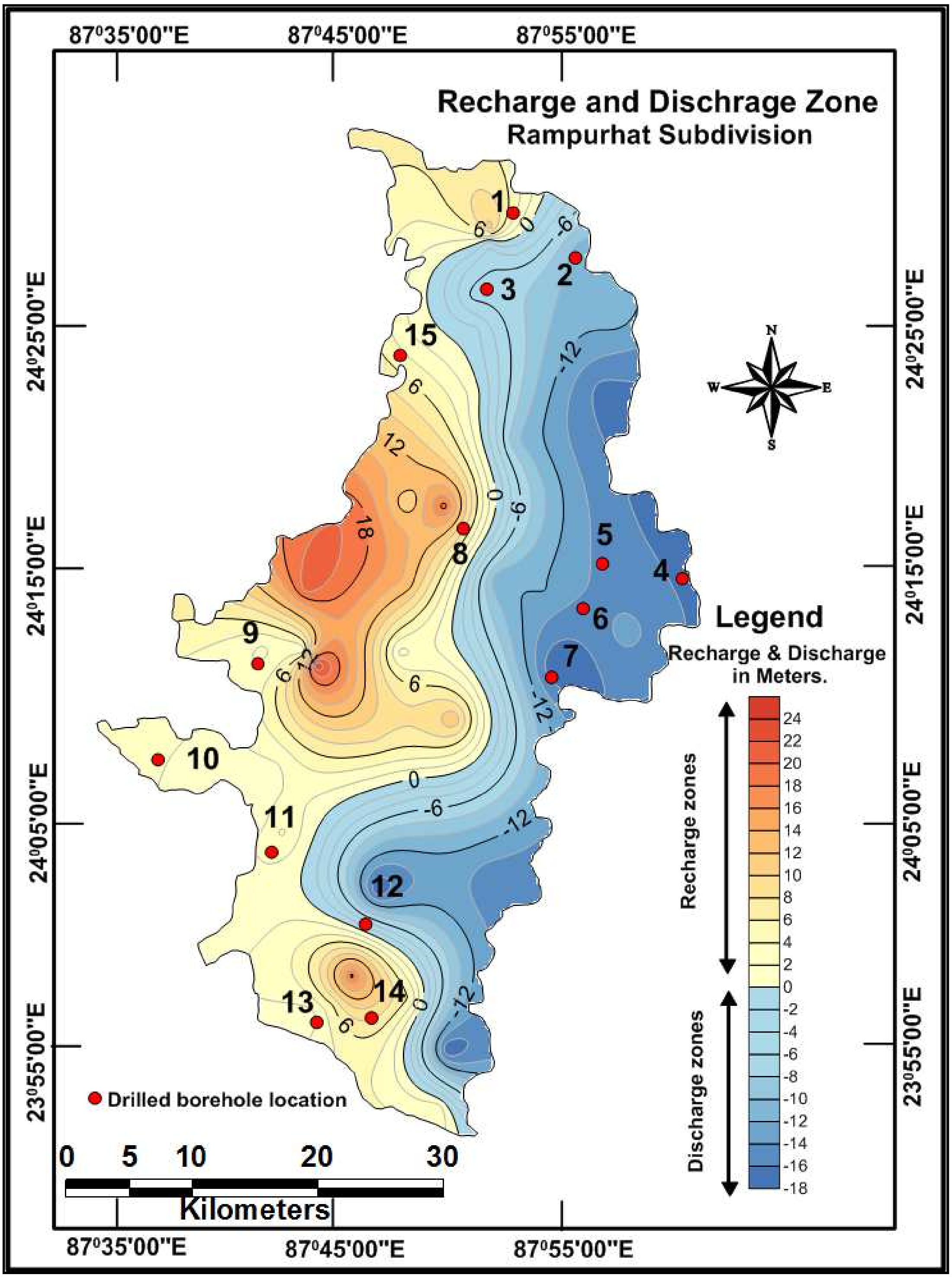

Fig.-5: Recharge and Discharge Zone of the Study Area