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## Application of Geoinformatics in Ground Water Augmentation of AAM Water Shed

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### Abstract

Groundwater is considered as the preferred source of water for meeting domestic, industrial and agricultural requirements, due to its longer residence time in the ground, low level of contamination, wide distribution, and availability within the reach of the end user. Even the existing wells are getting dried-up due to depletion of ground water table as the natural recharge is not sufficient. Groundwater recharge is a basic pre-requisite for efficient groundwater resource development and management, which is particularly vital for India with widely prevalent semi-arid and arid climate. In case the natural recharge is not sufficient, it has to be met through artificial recharge. To provide artificial recharge structures and to construct them, appropriate locations are selected. Scientifically, each hydro- geomorphic unit will be evaluated for its recharge potential and suitably a map showing such groundwater recharge potential zones for appropriate recharge would be prepared. Using remote sensing and geographic information system (GIS) a number of different thematic maps of the same area are prepared and overlaid them to form a new integrated layer. This study was aimed to identify the groundwater recharge potential zones, to be used for better and improved groundwater resources. The thematic layers considered in this study are geomorphology, soil, land use land cover, slope (%) which is prepared using satellite imagery and other conventional data. The thematic layers were first digitized from satellite imagery, supported by ancillary data such as toposheets and field investigation data, finally all thematic layers were digitized on Arc-GIS software to identify the groundwater recharge potential zones for the study area to generate a map and recharging methods were suggested.

### Keywords

*Ground Water, Recharge, Potential Zones, Satellite Imagery, Geomorphology*

### Introduction

Groundwater recharge refers to the entry of water from the unsaturated zone below the water table surface, together with the associated flow from the water table within the saturated zone. Groundwater recharge occurs when water flows past the groundwater level and infiltrates into the saturated zone. Field investigations help to explain the process of groundwater recharge and evaluate the spatial-temporal difference in the study area. However, these field investigations often focus on a single affecting factor or an indirect site-specific detail for groundwater recharge, reducing the reliability of the investigations. In recent times remote sensing and geographic information system technique is proved to be a cost effective and time saving tool to produce valuable data on geomorphology, geology, land use land cover, slope, lineament, lithology, etc., which also helps to decipher groundwater recharge potential zones. Many researchers such as Chaudhary et al. (1996), Rajat C. Mishra et al. (2010), and Jyoti Sarup et al. (2011) have used the approach of remote sensing and GIS for identification of groundwater potential zones and exploration of groundwater in locating the artificial recharge sites[5][8][10]. Akram Javed et al. (2009), Narendra et al. (2013) have used remote sensing and GIS techniques for delineation of groundwater potential zones[7][9]. Jothi prakash V. et al. (2003), Balachandar D. et al. (2010), Binay Kumar et al. (2011), Nepal C. Mondal et al. (2011) have used the remote sensing and GIS technique for generation of groundwater recharge zones map for the improvement and development of groundwater regions[1][2][11]. Subagunasekar M. et al. (2012) have applied GIS for assessment of the groundwater recharge potential zones. J. Brema et al. (2012) have used GIS for identification of sites suitable for artificial recharging and groundwater flow modelling[3][12]. Integrated approach of remote sensing and GIS can provide in decision making of mapping, planning of groundwater resources and management of groundwater resources for its efficient and cost effective use for a region or state.

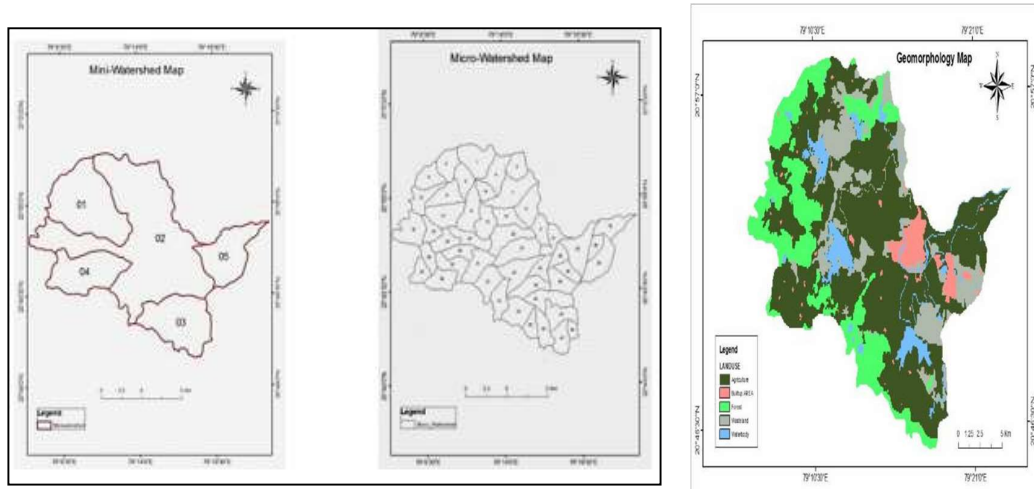
In this research, the study area of AAM watershed is divided into mini and micro sheds using GIS software. The ground water recharge and suitability of various artificial ground water recharge techniques were studied on basis of different geological parameters like geomorphology, land use land cover, slope and soil[4][6]. According to these geological parameters different zones of AAM watershed were divided and studied in detail. On the basis of these parameters correlation between the suitability of artificial recharge techniques and properties of different zones of AAM watershed was made by assigning specific method to different watersheds. Then the discharge of different watersheds was calculated. Actual discharge available for

artificial recharge was calculated using rational method after considering the losses.

### Study Area

The study area admeasuring 335.6sq.km is AAM River, which is a tributary of Wainganga catchment of Godavari basin which is located at Umrer tehsil in Nagpur district of Maharashtra. It extends with latitudes of 20° 54' 6.698" N to 21° 0' 0"N and longitudes of 79° 10' 20" E to 79° 39' 05" E, which lies in Survey of India toposheet bearing numbers 55P/1, 55P/5. This site was chosen because the depletion of water level depth and fall in long term trend of rainfall data. Hence the groundwater recharging methodology is suggested.

The study area is divided into three parts WGA-2A, WGA-3A and WGA-4A. 5 mini-watersheds and 48 micro-watersheds depending on the drainage characteristics with the slope, contour value and drainage flow. The mini, micro watershed and Geomorphological maps are shown in the Figure 1. The process of dividing was done with help of ARC-GIS software.



**Fig 1: Mini, Micro Watershed Maps and Geomorphological Map**

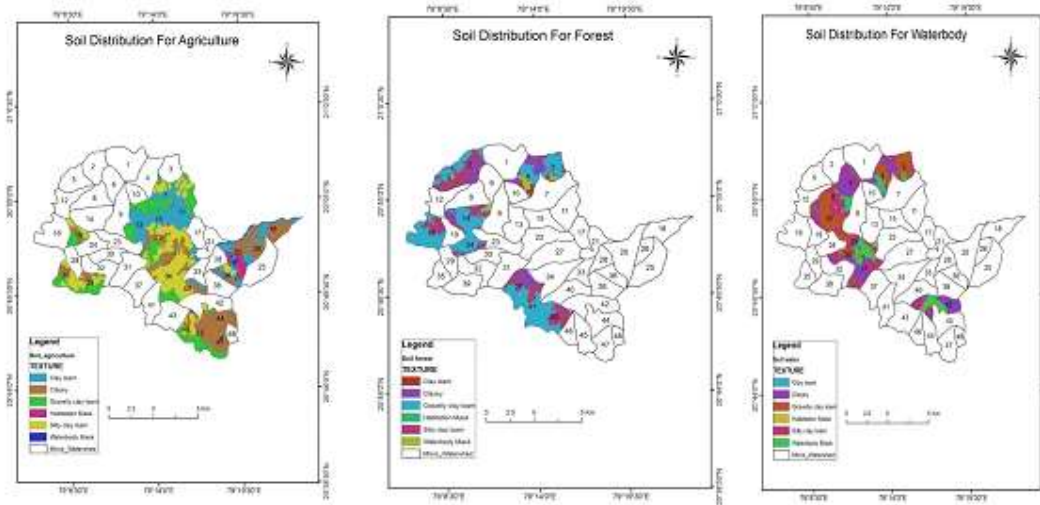
Using the land use land cover map of region the different zones like agriculture, forest, water body, wasteland, built up area were identified. This land use land cover map was superimposed with the micro-watershed map. Now the area under agriculture, forest and water body mask was considered for analysis. The watershed comprising of most of the area covered under above zones were selected and further studied for different geological parameters like soil, geomorphology and slope.

### Slope

The precipitous terrain causes rapid runoff and does not store water easily. Slope of any terrain is one of the factors allowing the infiltration of groundwater into subsurface or in other words groundwater recharge. In the gentle slope area, the surface runoff is slow allowing more time for rainwater to percolate, whereas, steep slope area facilitates high runoff allowing less residence time for rainwater to percolate and hence comparatively less infiltration. The slope map of the study area is derived from ASTER DEM 30 m and slope and area of the study area is given in Table 1. A sample Soil distribution of Agriculture, Forest and Water body mask obtained from ARC-GIS software is shown in Figure 2.

Sr. No.	Slope	Area Forest (Sq.Km)	Area Forest (%)	Area Water body (Sq.Km)	Area Water (%)	Area Agriculture (Sq.Km)	Area Agriculture (%)
1	0 - 3	21.69	28.67	25.42	38.51	47.67	34.60
2	3 - 5	21.49	28.41	18.08	27.40	41.57	30.17
3	5 - 8	20.41	26.98	15.18	23.00	33.58	24.37
4	8 - 14	10.46	13.82	6.54	9.91	13.16	9.55
5	14 - 34	1.60	2.12	0.78	1.19	1.81	1.32
<b>Total</b>		<b>75.15</b>		<b>66.06</b>		<b>138.08</b>	

**Table 1: Slope and Area of Different Zones**



**Fig 2: Soil Distribution of Agriculture, Forest and Water Body Mask Obtained From ARC-GIS Software**

### Methodology

#### Artificial Recharge Method for Different Micro-Watershed

After studying the suitability of ground water recharge method for various geomorphological parameters and then studying the various geomorphological parameters of different selected zones of AAM watershed we have suggested following recharge method for improving groundwater within the area

#### For Agricultural Zone

Following Table 2 shows best suitable recharge technique for agriculture zone in different micro-watersheds according to their different geomorphological properties discussed and studied above. In overall analysis in agriculture zone most suitable method is ditch and furrow. If existing wells are present over locations the combination of both methods can be used for better results.

Sr. No	Recharge Techniques	Watershed No.	Justification
1	Ditch and Furrow	46, 40, 39, 35, 27, 22, 19, 7	As these watersheds contains silty clayey and clayey loam soil and nearly levelled slope.
2	Recharge well	47,45,36,26,18,15,13,11,34,20	These watershed contains clayey soil and flat topography
3	Combination of both	All above watersheds	The excess of surface water from Ditch and Furrow is transferred to recharge the existing wells available within the zone

**Table 2: Suitable Techniques for Agricultural Zone**

#### For Forest Zone

Following Table 3 shows suitable recharge techniques for forest zone in different micro- watersheds in overall analysis percolation tank and recharge pits are most suitable methods that can be applied in forest zone.

Sr. No	Recharge Techniques	Watershed No.	Justification
1	Percolation tank	5,2,14,24	As the area is here nearly flat and soil is gravelly clay loam so the tanks can be constructed for storage and infiltration will be more
2	Ditch and furrow	3,4,16	This area has gentle sloping with silty clay loam soil which has lower infiltration rate so this method can be applied.
3	Recharge pits and shafts	37,41,43	Here presence of gravelly clay loam soil at shallower depth make this method most suitable

**Table 3: Suitable Techniques for Forest Zone**

### For Water Body Mask

Following Table 4 shows best suitable method for water body mask for different micro- watersheds. In overall analysis the most suitable method is Nalla bund due to presence of streams of order 1 to 4.

Sr. No	Recharge Techniques	Watershed No.	Justification
1	Nalla Bund	42, 30, 23, 14, 8	As the no of streams in the vicinity are large and we can use those streams for temporary storage by using Nalla Bund.
2	Recharge well	31, 6	As in this area recharge wells are present which can be used as recharging technique
3	Recharge pits and shafts	3, 4	This zones contains clayey soil and nearly leveled slope which is suitable for recharge pits and shafts.

**Table 4: Suitable Techniques for Water Body Mask**

### Result & Discussion

#### Estimation of Available Discharge for Recharge in Various Micro-zones

For different zones of agriculture, forest and water body of watershed the discharge was calculated in each micro-watershed using Rational Method. This method was originally developed for urban catchments. However, this method is fairly applicable to small agricultural watersheds. The Rational method is based on the assumption that constant intensity of rainfall is uniformly spread over an area. The maximum rate of outflow will occur when the rainfall duration is equal to the time of concentration. The relationship for peak runoff,  $Q_p$  is then expressed as  $Q_p = C.I.A/3.6$

Where,

$Q_p$  = peak runoff rate ( $m^3/s$ )

C = coefficient of runoff

I = mean intensity of precipitation (mm/h).

A = area of the drainage basin ( $km^2$ )

In this study “I”, i.e. intensity of rainfall was consider from monthly data of rainfall for Nagpur region. It is considered as 120 hours of rainfall with an average rainfall of 242.52 mm, and then the mean intensity is computed in mm/hr.

$$I = 242.52/120 = 2.02 \text{ mm/hr}$$

Sr.no	Months	Rainfall (mm)					Average Rainfall (mm)
		2011	2012	2013	2014	2015	
1	June	119.4	67.0	390.0	92.3	277.2	187.18
2	July	272.7	338.7	478.7	402.8	173.7	329.32
3	August	345.7	282.9	339.3	133.0	382.3	293.64
4	September	185.7	273.9	101.6	125.1	136.9	161.64
Yearly Average		153.37	240.6	327.4	188.3	242.52	Total Avg. - 242.52

**Table 5: Average Monthly Rainfall of Nagpur Region**

#### Typical Calculation of Discharge of a Watershed

A sample calculation of discharge is done using the data of Micro-water shed no. 1.

$$A = 8.64 \text{ Sq. Km}; \quad C = 0.4; \quad I = 2.02 \text{ mm/hr.}$$

The value of C is obtained from Table 6 depending on the type of vegetation cover, slope and type of soil.

$$\text{Discharge } Q = C.I.A/3.6 = 0.4 \times 2.02 \times 8.64/3.6 = 1.93 m^3/s$$

Type of Vegetation cover	Slope Range (%)	Runoff Coefficient (C)		
		Sandy Loam Soil	Loam / Loam Clay Soil	Stiff Clay Soil
Woodland and forests	0 - 5	0.1	0.3	0.4
	5 - 10	0.25	0.35	0.5
	10 - 30	0.3	0.5	0.6
Grassland	0 - 5	0.1	0.3	0.4
	5 - 10	0.16	0.36	0.55
	10 - 30	0.22	0.42	0.6
Agricultural land	0 - 5	0.3	0.5	0.6
	5 - 10	0.4	0.6	0.7
	10 - 30	0.52	0.72	0.82

**Table 6: Values of Runoff Coefficient Factor (C) for Different Soil Conditions in India**

The discharges of various zones i.e., Agriculture, Forest and Water body Mask are computed and shown in the Table 7, Table 8 and Table 9 respectively.

#### Discharge of Agriculture Zone

The discharge of different micro-watersheds of agriculture zone was computed and given in the Table 7. The total computed discharge of agriculture zone was 38.58 m<sup>3</sup>/s.

Sr. No.	Micro- watershed No.	Runoff coefficient (C)	Area (Sq. Km)	Discharge (m <sup>3</sup> /s)
1	11	0.4	8.65	1.94
2	13	0.4	7.21	1.618
3	15	0.5	5.83	1.635
4	18	0.55	7.03	2.169
5	19	0.5	4.26	1.195
6	20	0.55	11.59	3.251
7	22	0.5	9.85	2.763
8	26	0.55	3.46	1.067
9	27	0.5	11.09	3.11
10	34	0.5	10.4	2.917
11	35	0.4	4.46	1
12	36	0.5	4.01	1.125
13	39	0.5	7	1.963
14	40	0.5	6.91	1.938
15	44	0.6	7.36	2.477
16	45	0.5	6.01	1.686
17	46	0.5	3.78	1.06
18	47	0.6	6.1	2.05
19	7	0.5	12.92	3.625
<b>TOTAL</b>			<b>138.08</b>	<b>38.589</b>

**Table 7: Discharge in Agriculture Zone**

#### Discharge of Forest Zone

The discharge of different micro-watersheds of Forest zone was computed and given in the Table 8. The total computed discharge of Forest zone was 8.1776 m<sup>3</sup>/s.

Sr.no	Micro- watershed no.	Runoff coefficient (C)	Area (Sq.Km)	Discharge (m <sup>3</sup> /s)
1	2	0.3	7.05	1.186
2	3	0.1	5.91	0.3316
3	4	0.25	8.04	1.127
4	5	0.3	6.81	1.146
5	14	0.1	9.65	0.541
6	16	0.2	10.07	1.13
7	24	0.1	5.45	0.305
8	37	0.25	7.83	1.098
9	41	0.1	6.52	0.365
10	43	0.2	8.47	0.948
<b>TOTAL</b>			<b>75.15</b>	<b>8.1776</b>

**Table 8: Discharge in Forest Zone**

#### Discharge of Water Body Mask

The discharge of different micro-watersheds of Water body mask zone was computed and given in the Table 9. The total computed discharge of Water body mask zone was 11.3388 m<sup>3</sup>/s.

Sr.no	Micro- watershed no.	Runoff coefficient (C)	Area (Sq.Km)	Discharge (m <sup>3</sup> /s)
1	3	0.2	5.91	0.66
2	4	0.2	8.04	0.902
3	6	0.45	5.99	1.512
4	8	0.4	7.74	1.737
5	14	0.2	9.65	1.082
6	23	0.2	6.43	0.721
7	30	0.3	4.95	0.833
8	31	0.4	8.34	1.8718
9	42	0.4	9.02	2.02
<b>TOTAL</b>			<b>66.07</b>	<b>11.3388</b>

Table 9: Discharge in Water Body Mask

The total discharge available in Agriculture zone, Forest zone and Water body mask ( $38.589+8.1776+11.3388$ ) is  $58.10 \text{ m}^3/\text{s}$ . Therefore, the quantity of water through rainfall is  $58.1 \times 3600 \times 120 = 25099200 \text{ m}^3$ .

The following are the losses through which the actual quantity of water for augmentation is reduced. It is assumed that the evaporation loss is 10%, evapo-transpiration loss is 10%, infiltration loss is 10% and other losses are 10%. The total loss of discharge is  $(58.1 \times 40/100) = 23.24 \text{ m}^3/\text{s}$ . The quantity of water lost due to above losses is  $23.24 \times 3600 \times 120 = 10039680 \text{ m}^3$ .

Therefore, the available discharge for artificial recharge would be  $(58.1-23.24) = 34.86 \text{ m}^3/\text{s}$ . The quantity of water available for artificial recharge is  $(25099200 - 10039680) = 15059520 \text{ m}^3$ .

### Conclusions

- From the ARCGIS software the areas obtained under different zones, Agriculture zone, Forest zone and Water body mask zone are respectively  $138 \text{ km}^2$ ,  $75.15 \text{ km}^2$  and  $64.21 \text{ km}^2$ . Seventy percent area of Agriculture and Forest zones are covered by gravel, clayey, silty clay loam type of soil and thirty percent area is covered by clayey soil. Under Water body mask zone fifty percent area is covered by gravelly clay loam, twenty percent of silty clay loam soil and thirty percent is covered clayey soil.
- 70 to 80% under all the zones has gentle slope less than 5%. This is very favourable for ground water recharge.
- The total computed discharge in all the zones was  $58.1 \text{ m}^3/\text{s}$  out of which  $38.58 \text{ m}^3/\text{s}$  is from agricultural zone,  $8.17 \text{ m}^3/\text{s}$  from forest zone and  $11.38 \text{ m}^3/\text{s}$  from water body mask. The total losses in the discharge due to evaporation, evapotranspiration, infiltration and other losses is  $23.24 \text{ m}^3/\text{s}$ . The total quantity of water due to rainfall is  $25099200 \text{ m}^3$  and total quantity of water due to losses is  $10039680 \text{ m}^3$ .
- The available discharge for ground water recharge was found out to be  $34.8 \text{ m}^3/\text{s}$  and total quantity of water available for ground water recharge is  $15059520 \text{ m}^3$ .

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