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Watershed Management through GIS & Remote Sensing: A case of Halali and Dudhi Mili-Watershed, Phanda Block, Bhopal District (M.P.), India

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Abstract
Phanda Block in Bhopal district has been identified as one of the problematic blocks under the critical category in terms of water crisis as per the report of State Groundwater Data Center, Bhopal (M.P.). The current study attempts to mitigate the problems occurring in Halali and Dudhi mili-watersheds covering major portion of Phanda block. The research employs an integrated approach through GIS and Remote Sensing since groundwater conditions of the area are controlled by many parameters i.e. drainage, geology, geomorphology, slope, lineaments, landuse and landcover. All the thematic maps were digitized through interpreting satellite imageries in conjunction with sufficient ground truth and used as an input variable in GIS. In addition, well data and water quality data were integrated with spatial data. The output map of Groundwater potential zones was prepared. Considering the present status and future water requirement of the area, a complete Water Resource Action plan was prepared demarcating the areas for soil conservation, areas for rainwater harvesting and artificial recharge structures and areas for appropriate exploitation in addition to suggested water quality improvement measures.

Keywords: watershed management, water resource action plan, groundwater potential zones, rainwater harvesting, artificial recharge structures, GIS, Remote Sensing

Introduction
Survival of human beings and their associates, always, depends on the most important natural resources i.e. water, air, soil, fauna and flora. Unplanned and mismanaged utilization of natural resources have already caused depletion of water resources particularly Groundwater, soil erosion and destroyed forests [10]. It has finally left degraded environment and caused ecological imbalance. Conservation of these resources is called for, sustainable development of water and soil.

In India about 60 to 70 percent population is in the rural areas. Most of the villages where the rural population inhabits are in the watershed areas. Watershed development plays a key role in the economic growth of this population. The goal of watershed management is to plan and work towards an environmentally, economically and healthy watershed that benefits all. More than 90 percent of rural and nearly 30 percent of urban population depends on Groundwater for meeting their drinking and domestic requirements. In addition, it accounts for nearly 60 percent of the irrigation potential created in the country. The distribution of Groundwater is not uniform in all regions. The spatio-temporal variations in rainfall and regional/local difference in geology and geomorphology have led to an uneven distribution (poor prospects) and indiscriminate tapping (over-exploitation) in certain zones are the main reasons leading to scarcity of water in many parts of the country [12]. In view of this, a large number of habitations in the country have remained as problem villages not having sustainable water sources.

In Madhya Pradesh 70 percent requirement of water in rural areas and about 30 percent in urban areas is fulfilled by groundwater resources. Increasing demand of drinking water, irrigation and industrial water is causing the exploitation of groundwater. Due to heavy drafting of groundwater, the water table is declining; as a result, it becomes very important either to minimize the overall exploitation or to maintain the equilibrium between the recharge and discharge [4, 5]. However, minimizing the groundwater exploitation is not an easy task, because of alarming rate of increasing population and increasing rate of irrigation for better food grain production. Therefore, it is immensely required to develop strategies for conservation and management of water resources.

Phanda Block in Bhopal district has been identified under critical category in the list of problematic blocks of Madhya Pradesh as per the report of State Groundwater Data Center, Bhopal (M.P.). The area is for most part of the year unsuitable for permanent agriculture and the improper land use practices. The area has chronic water scarcity. Together with poor soil, results in frequent crops failure or low crop yields. Sufficient fodder is also not available for the large cattle population. Extensive grazing has been detrimental for the growth of the vegetation. Due to heavy drafting of groundwater, the water table is declining, wells become dry during pre monsoon season, as a result, it becomes necessary to adopt suitable soil and water conservation measures. To fulfill these objectives and help in better management a ‘defined area’ is prerequisite for planning in a scientific manner. This defined area is termed as watershed [3, 4, and 5].

The study aims at conserving soil and water, as well as land development to increase the welfare of the people of watershed. The study evaluates groundwater prospective zones using Geographic Information System (GIS) and Remote Sensing and proposes a water resource action plan.

Data & Study Area

The study area (Figure 1) covers two mili-watersheds, comprising of Halali and Dudhi River. The study area spreads over 137.23 sq. Kms. covering major portion of Huzur tahsil, Phanda block located at southern part of the Bhopal district (M.P.). It refers to Survey of India Toposheet No. 55 E/7 and bounded by latitudes 23^0 15’ to 23^0 25’ N and longitudes 77^0 15’ to 77^0 22’ E. The entire area is approachable except during rainy season by National Highway-12 (Jabalpur-Jaipur) which is passing through the study area.

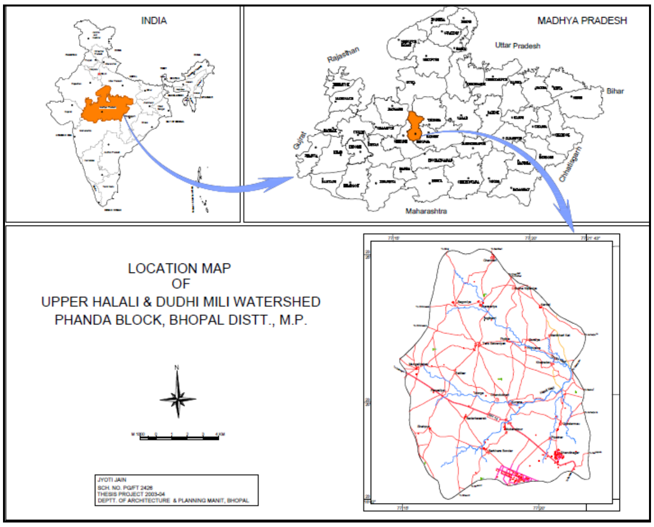


Figure 1: Study Area

The area is lying on the edge of Malwa plateau, maximum and minimum height of the region varies between 585 and 460 meters (MSL). The highest elevation of 585 m., a hillock of Vindhyan range is recorded near Bhopal Airport. The present topography is mainly the product of differential erosion of the rocks. The area experiences humid and tropical type of climate. The average annual rainfall is 1154 mm. About 92% of the total rainfall takes place only during the monsoon period. The maximum rainfall takes place during the month of July i.e. about 39% of the annual rainfall. The temperature starts rising from beginning of February reaching the maximum in the month of May. The normal daily mean monthly maximum temperature is 40.6^0 C and minimum is 25.3^0 C. The individual daily temperature in May goes up to 44^0 C. The normal maximum daily temperature in January is about 22.49^0 C and minimum about 9.7^0 C. The highest Humidity level is 88% in August and lowest is 17% in April. The wind velocity is highest in June around 19.6 Km/hr. and lowest is 6.8 Km/hr. in November.

The study area consists of 27 villages and the total population is 26150 (2001 Census). The male and female population is equal. The village boundaries were transferred from Majmooli map to SOI Toposheet in order to get better representation of socio-economic data. The data is collected with a prime objective of creating the image of villages in term of its people and the manpower. This is important because the recent concept of watershed development, deals not only with soil and water conservation, but also include peoples in broad sense, involving their motivation, employment generation and overall improvement in living standards. Around 30% of male population comes under working category, whereas less number in female workers. The main activities in the study area are agriculture, cultivation and forestry.

Groundwater Quality Data

The chemical analysis of the water samples was carried out in the chemical laboratory of Central Ground Water Board, Bhopal by using standard methods as given in APHA (1998). The statistical results of chemical analysis for chemical composition and trace elements study are given in Table 1.

Table 1: Groundwater Quality Data

S.no.	Ions	Range
1	PH	7.14-8.64
2	EC (uS/cm at 25^0 C	598-1240
3	Chloride (mg/I)	20.5-516
4	Sulphate (mg/I)	1.25-72.08
5	Nitrate (mg/I)	1.48-196
6	Total Hardness	144-588
7	Calcium (mg/I)	22.44-639.5
8	Magnesium (mg/I)	19.24-90.56
9	Sodium (mg/I)	2.5-81.7
10	Potassium (mg/I)	3.8-21.3

Source: State Water Data Center, Bhopal, M.P. & Central Ground Water Board, Bhopal, M.P.

The above Table reveals that ground water in habitation in the Guraiya village is polluted as Nitrate concentration is exceeding the mandatory limit of 100mg/l and 45 mg/I suggested by various agencies like BIS, WHO and USEPA for irrigation and drinking water respectively. Except nitrate, all the other constituents are within the acceptable limits of BIS (1991). The presence of nitrate in the ground water shows that process of ground water pollution has taken place and ground water at Guraiya village has become undesirable for drinking as well as irrigation purpose.

Water Table Fluctuation Data

Measurements of water levels (Table 2) are used in the analysis of ground water with respect to its occurrence, storage, movement, recharge and discharge.

Table 2: Water Table Fluctuation Data

Village Name	Latitude	Longitude	Diameter of well in (m)	Total Depth in (m)	Pre Monsoon WL. in (m)	Post Monsoon WL.in (m)	Water Table Fluctuation in (m)	Year
Ratibar	23 21' 0"	77 17' 0"	4.3	9.05	8.2	2.1	6.1	2002
Kurana	23 20' 0"	77 19' 0"	6.05	9.5	7.2	6.2	1	2002
Mungaliyahat	23 21' 0"	77 16' 0"	6.9	9.5	7.5	6	1.5	2002
Manikheri Kat	23 22' 15"	77 20' 30"	5.9	9.5	9.15	7.8	1.35	2002
Sukha Nipaniya	23 23' 30"	77 19' 30"	4	18	17.16	7.4	9.76	2002
Parwaliya	23 20' 15"	77 16' 45"	1.95	7.60	Dry	0.95	Nil	2002
Guraiya	23 22' 0"	77 19' 45"	2.9	12.5	Dry	4.4	Nil	2002
Pipaliya	23 22' 0"	77 19' 15"	6	8.1	Dry	4.86	Nil	2002
Chandpur	23 21' 0"	77 21' 30"	7	14.5	12.2	6	6.2	2002
Piplaner	23 18' 30"	77 20' 15"	7.8	7	Dry	4.75	Nil	2002
Mubarakpur	23 19' 0"	77 19' 0"	7.2	15.75	15.5	5.7	9.8	2002

Source: State Water Data Center, Bhopal, M.P. & Central Ground Water Board, Bhopal, M.P.

Methods

A basemap has been prepared on the basis of SOI toposheets on 1:50,000 scale. The information about important settlements, roads, and major streams are directly transferred from toposheet on basemap.

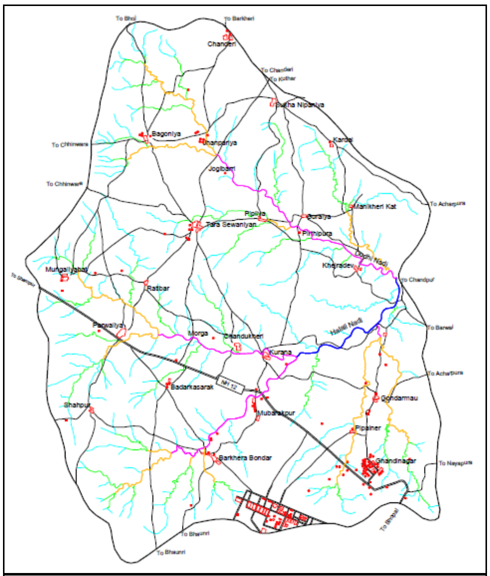
Data Input Layers

Thematic maps such as drainage (Figure 2), slope (Figure 3), landuse & landcover (Figure 4), geology (Figure 5), lineament (Figure 5), and geomorphology (Figure 6), were generated after visual interpretation. Further, a Hydro-geomorphology map (Figure 7) of the study area was generated through integration of geology, lineament and geomorphology maps. This map is further integrated with other thematic maps to prepare Ground water prospects map. The digitized maps were used as input variable for GIS analysis. These thematic maps have been prepared on 1: 50,000 scale.

Data Integration & Analysis

An integrated approach was adopted for groundwater prospect zoning since groundwater conditions of the area are controlled by many parameters like geology, geomorphology, slope, lineament, and landuse-land cover [11]. For this purpose following parameters have been taken into account which governs groundwater conditions:

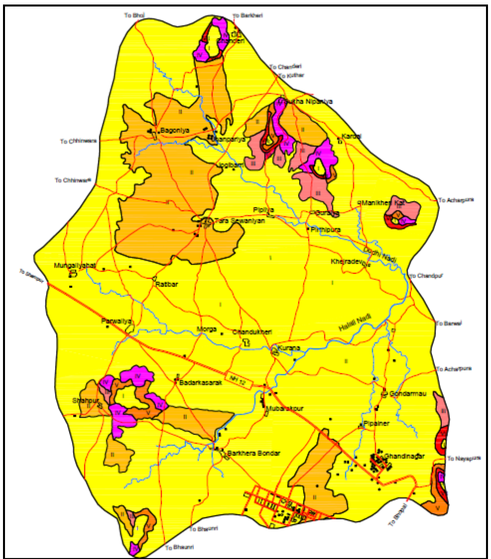
a. Geology
b. Geomorphology
c. Lineament
d. Hydro-geomorphology
e. Slope
f. Landuse-land cover
g. Pre monsoon water level
h. Post monsoon water level
i. Water level fluctuation
j. Water quality data



LEGEND

SYMBOL	STREAM ORDER	STREAM NOS.	LENGTH IN (KM.)	BIFURCATION RATIO	REMARKS
	I ORDER	166	120.83		The drainage pattern is dendritic drainage pattern.
	II ORDER	43	57.19	0.259	
	III ORDER	12	33.27	0.279	
	IV ORDER	4	19.02	0.333	
	V ORDER	1	4.71	0.25	

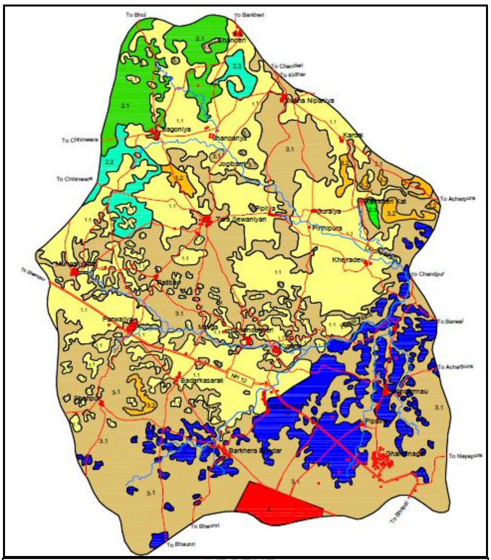
Figure 2: Drainage Map



LEGEND

MAP UNIT	SLOPE CATEGORY	AREA in SQ. KM.	%OF AREA	POTENTIALITY OF EROSION
I	Nearly Level (0-1%)	109.46	79.76	Slight
II	Very Gently Sloping (1-3%)	19.972	14.6	Slight
III	Gently Sloping (3-5%)	2.545	1.8	Moderate
IV	Moderately Sloping (5-10%)	2.86	2.1	Moderate
V	Strongly Sloping (10-15%)	1.55	1.12	High
VI	Moderately steep to steep (15-35%)	0.049	0.04	Sever
VII	Very steep (>35%)	0.799	0.58	Sever
	TOTAL	137.23	100%	

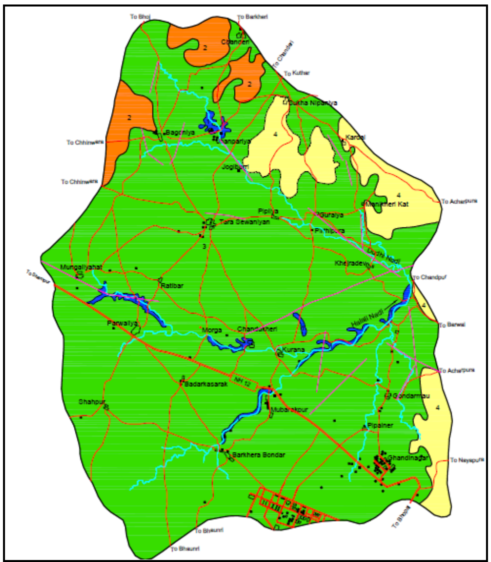
Figure 3: Slope Map



LEGEND

MAP UNIT	LANDUSE CATEGORIES	AREA in SQ. KM.	%OF AREA	REMARKS
1.1	SINGLE CROP	49.84	36.32%	Land used for production of food,fibre, etc.
1.2	DOUBLE CROP	12.62	9.196%	
2.1	DENSE FOREST	6.41	4.67%	-
2.2	DEGRADED FOREST	3.53	2.57%	-
2.3	FOREST PLANTATION	0.2	0.146%	-
3.1	STONEY WASTE LAND	60.01	43.73%	Wastelands have potential for development of vegetative cover but are lying unused due to different constraints.
3.2	UNDULATING UPLAND WITH OR WITHOUT SCRUB	2.07	1.51%	
4	SETTLEMENTS	2.55	1.86%	
	TOTAL	137.23	100%	

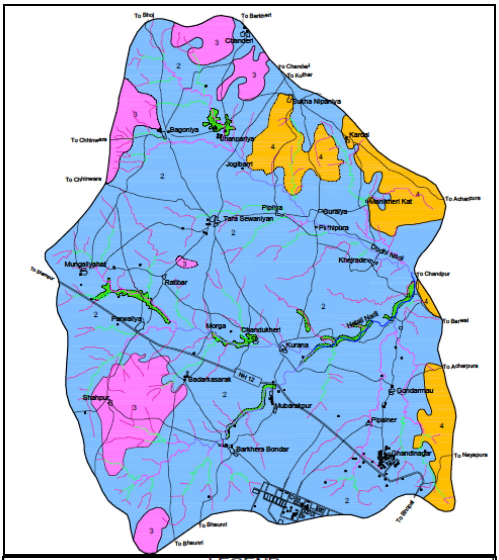
Figure 4: Landuse-Landcover Map



LEGEND

MAP UNIT	GEOLOGICAL UNIT	AGE	AREA in SQ. KM.	%OF AREA	REMARKS
1	ALLUVIUM	Recent	1.78	1.3%	Alluvium, comprising sand, silt, clay, graval, etc.
2	LATERITE	Cenozoic	5.13	3.7%	Laterite cappings on top of basalt.
3	BASALT FLOWS	Upper cretaceous to Lower Eocene	118.72	86.5%	Basalt Sandstone Cherty, Limestone
4	UPPER BHANDER SANDSTONE	Upper Proterozoic	11.61	8.5%	Shales, Sandstone & Limestone.
	TOTAL		137.23	100%	
	MAJOR LINEAMENT				
	MINOR LINEAMENT				

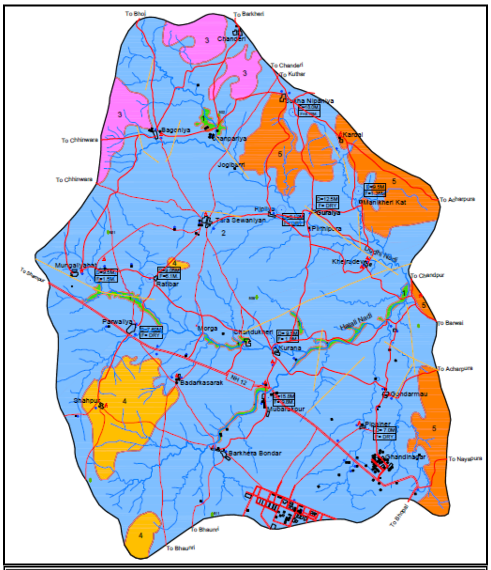
Figure 5: Geology Map



LEGEND

MAP UNIT	GEOMORPHIC UNIT	AREA in SQ. KM.	%OF AREA	REMARKS
1	VALLEY FILLS	1.78	1.3	A valley (high moisture zone & thick vegetative cover) is filled by loose unconsolidated sediments.
2	BURIED PEDIMENTS	111.97	81.6	These are the areas between hills & plain.
3	RESIDUAL HILLS	11.88	8.7	These hills are erosion remnants. Generally Leterite forms these hill. Basalt,occurs in isolation, rising above general level of pediplain.
4	STRUCTURAL HILLS	11.6	8.4	Generally massive Vindhyan sandstone forms structural hill.
	TOTAL	137.23	100%	

Figure 6: Geomorphology Map [8]



LEGEND

MAP UNIT	HGM UNIT	LANDFORM	LITHOLOGY	AREA in SQ. KM.	%OF AREA	REMARKS
1		Valley fills	Alluvium	1.779	1.3%	Groundwater condition along the Lineaments is very good.
2		Buried pediments	3-basalt flows	111.97	81.6%	
3		Residual hills	Laterite	11.6	8.4%	
4		Residual hills	3-basalt flows	6.754	5%	
5		Structural hills	Upper Bhander Sandstone	5.126	3.7%	
	TOTAL			137.23	100%	
	MAJOR LINEAMENT					
	MINOR LINEAMENT					

Figure 7: Hydro-geomorphology Map

Criteria weights and map scores

One of the classic problems in decision theory or multi-parameter analysis is the determination of the relative importance (weights) of each parameter with respect to each other. This is a problem, which requires human judgment supplemented by mathematical tools. As all parameters cannot be weighted equal for the suitability assessment, it is essential that a weighted method needs to be employed where the relative importance of the parameters defines the weights. Class wise code and weight value (Table 3 to 8) were assigned for different thematic maps.

Table 3: Slope

S. No.	Map unit	Slope category	Rating code
1	I	Nearly Level	20
2	II	Very Gently Sloping	12
3	III	Gently Sloping	8
4	IV	Moderately Sloping	6
5	V	Strongly Sloping	3
6	VI	Moderately steep to steep	1
7	VII	Very steep	0

Table 4: Landuse-Landcover

S. No.	Landuse/landcover category		Map unit	Rating code
1	Crop land	Single Crop	1.1	9
		Double Crop	1.2	15
2	Forest cover	Dense Forest	2.1	5
		Degraded Forest	2.2	4
		Forest Plantation	2.3	6
3	Waste land	Stony Waste land	3.1	2
		Undulating Upland with or without Scrub	3.2	4
4	Built-up land	Settlements	4	5

Finally all the parameters are combined in order to get final integration of all the parameters influencing groundwater movement and occurrence in the region. The output thus generated as a final weighted map which is further classified into five classes (Table 9).

Table 5: Geology

S.No	Geology	Prospects for Groundwater	Rating Code
1	Alluvium	Excellent	15
2	Laterite	Moderate to poor	5
3	3 basalt flows	Moderate to Good	10
4	Upper bhander	Poor	1

Table 6: Geomorphology

S.No	Map Unit	Geomorphic Unit	Rating Code
1	1	Valley fills (vf)	18
2	2	Buried pediments	10
3	3	Residual hills (rh)	1
4	4	Structural hills (sh)	1

Table 7: Hydro-geomorphology

S. NO.	Map Unit	HGM Category	Remark	Rating Code
1	1	VF-1	Excellent	50
2	2	BP-3	Moderate to Good	30
3	3	RH-2	Poor	6
4	4	RH-3	Poor	10
5	5	SH-4	Poor	4

Table 8: Lineament

S.No.	Lineament category	Rating Code
1	Major	25
2	Minor	15

Table 9: Weight Values for Groundwater potential zones

S.	Class	Weight Values
1	Excellent	>70
2	Very good to good	60-70
3	Good to moderate	50-60
4	Moderate to poor	30-50
5	Poor	<30

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Results & Discussion

Based on the various iteration carried out during analysis on variables undertaken for present study, the results have been discussed. The study requires further detailed investigations on the field to be able to implement some of the recommendations. The results of whole study has been categorized in three steps, i.e. i) Groundwater Potential Zone Map; ii) Water resource Action plan; and iii) Water Quality improvement measures.

Groundwater Potential Zone Map

Groundwater potential map (Figure 8) of Halali and Dudhi mili-watershed was prepared integrating various thematic maps such as geology, geomorphology, slope, landuse-landcover, and lineament in GIS. The whole study area is divided into five categories for Groundwater potential development i.e. excellent, ii) very good to good, iii) good to moderate, iv) moderate to poor, and v) poor.

Excellent

The excellent groundwater potentials areas in the watershed are intersection points of lineaments and valley fills marked on the map especially in Deccan Trap area, where slope is nearly level to gentle. These are contributing to form good aquifer zones. This is also realized by well inventory and field observation at villages Mugaliyahat and Kurana where artesian condition of some of the wells has been noticed. The area is characterized by presence of loose and unconsolidated material.

Very good to good

This zone is specially considered for buried pediments of Deccan trap having gentle slope and double crop area. Wells observed in this unit are having less water table fluctuation. The area is characterized by vesicular and basalt with considerable depth of weathering.

Good to moderate

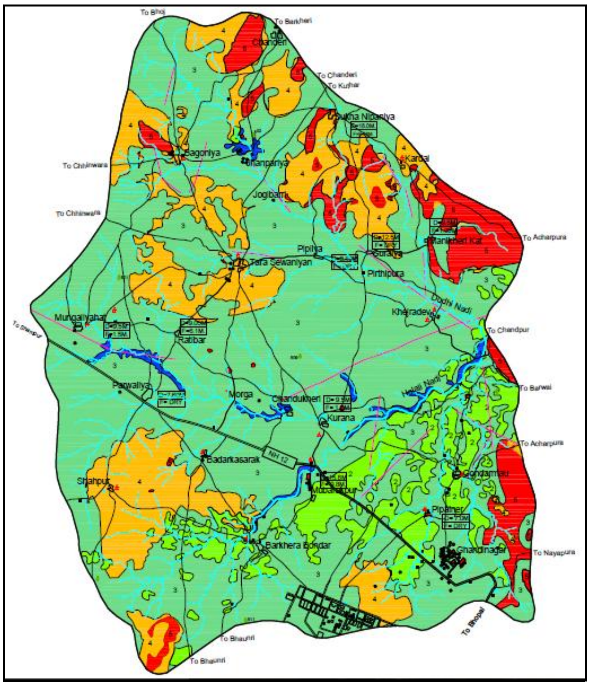
This zone is found mainly in the central portion of the watershed, covered by weathered vesicular basalt filled with secondary fillings having gentle slope. Geomorphologically the area is marked as buried pediment, which is almost flat with little undulations and maximum cultivation.

Moderate to poor

This zone is mainly confined to areas having moderate slopes and minor lineaments, which are playing major role to develop the semi confined conditions. Mesa tops, Vindhyan sandstones are coming under this category and water is moderately available only along lineaments. Scanty cultivation is seen over the area.

Poor

Northern and Southwestern boundary of watershed is emerged as poor zone for groundwater potential. Residual hills and structural hills of Vindhyan's sandstone come under poor potential. All these hills are covered by dense forest and scanty scrubs.



LEGEND

MAP UNIT	GROUND WATER PROSPECT	AREA in SQ. KM.	% OF AREA	REMARKS
1	EXCELLENT	1.713	1.25%	Groundwater condition along the Lineaments is very good.
2	VERY GOOD TO GOOD	12.69	9.25%	
3	GOOD TO MODERATE	89.47	65.2%	
4	MODERATE TO POOR	23.65	17.22%	
5	POOR	9.71	7.08%	
	TOTAL	137.23	100%	

MAJOR LINEAMENT
MINOR LINEAMENT

Figure 8: Groundwater potential map [2]

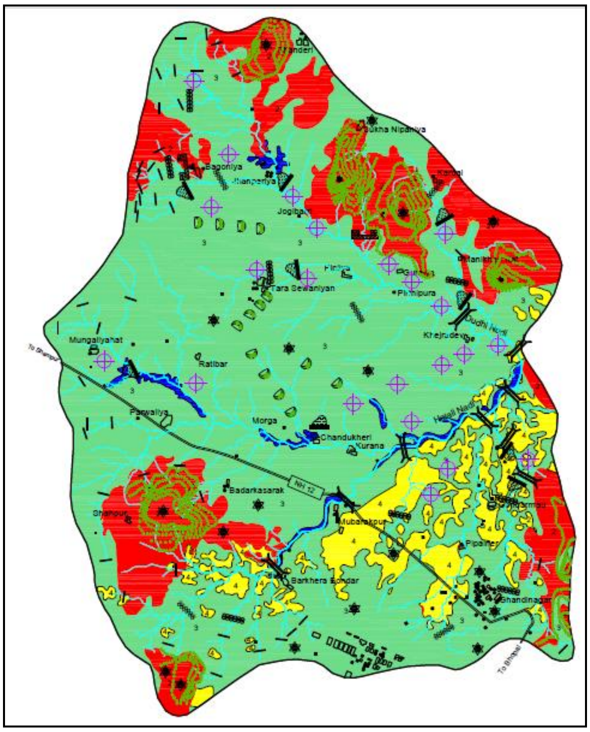
Water Resource Action Plan

The water Resource Action Plan (Figure 9) highlights different measures of conservation and artificial recharge of groundwater along with other developmental activities. The recommendations are finalized based on the regional guidelines of development region and also site-specific resource information like water demand, rainfall, surface and groundwater availability, geology, lineament, and hydro-geomorphology.

The action plan includes different recharge structure sites and water harvesting structure sites, environmental aspects like soil reclamation and de-siltation and suggested groundwater exploitations in the study area.

Suggested Groundwater Exploitation for Halali & Dudhi Mili-Watershed

The entire study area was divided into various zones for exploitation of groundwater resources i.e. Zones of exploitation through shallow tube/bore wells; Zones of exploitation through large diameter open dug wells; Drilling sites; and Areas for soil conservation.



LEGEND

MAP UNIT	RECOMMENDATIONS	AREAin SQ. KM.	%OF AREA	REMARKS
1	Area recommended for exploitation by shallow tube wells.	1.713	1.25%	Area covered by alluvium & valleyfills.
2	Area recommended for soil conservation.	23.65	17.2%	Hilly, steep slope areas.
3	Area recommended for exploitation by dug wells.	99.177	72.3%	Area with shallow weathered thickness with joints & fractures
4	Area recommended for taking no action.	12.69	9.25%	Double crop area.
	Drilling sites	-	-	based on lineament intersection.
	Proposed Rainwater Harvesting & Artificial recharge structures.	-	-	-

Figure 9: Water Resource Action Plan

Zones of exploitation through shallow tube/bore wells

Areas covered by shallow thickness of alluvium, valley fills, and moderate weathered zones, with fractures and joint have been recommended for exploitation through shallow tube/bore wells.

Zones of exploitation through large diameter open dug wells

Areas with shallow weathered thickness with joints and fractures and terrain, where storage capacity of wells can compensate the slow rate of recoupment have been recommended for exploitation through large diameter open dug wells.

Drilling Sites

After demarcating the different exploitation zones, exact site locations are fixed based on detailed hydrological study and lineament intersection points to understand the subsurface distribution of aquifer system.

Areas for soil conservation

Considerable thickness of soil is also important for Groundwater recharging. Soil can retain good amount of water and moisture for a longer duration. Areas for soil conservation are also suggested in the map. These are the areas, where soil erosion is severe during rainy season. Afforestation and artificial recharge structures may help to prevent soil loss up to appreciable extent.

Rainwater harvesting and Artificial Recharge structures

In the study area the geology and structural setup do not provide a sustained supply of groundwater to the human kind for domestic and agricultural purposes. It therefore, calls for immediate attention and remedial measures to be undertaken. In the current study rainwater harvesting and artificial recharge structures [1] for augmentation of groundwater resources have been proposed on the basis of the drainage pattern, geology, geomorphology, slope, lineament, landuse-landcover and hydro-geomorphological conditions of the study area.

Through map overlays in GIS suitable sites have been identified for various rainwater harvesting and artificial recharge structures such as Loose Boulder check, Percolation Tanks (PT)/Spreading Basin, Gabion Structure, Nala Bunds and Small Check Dams, Recharge pit, Subsurface Dykes, Dabries and Contour trenching.

Loose Boulder check

The main purpose of this structure is to delayed surface run-off of rain water and to minimize erosion, thus results in increased recharge in the wells located down stream of the area.

Loose Boulder check structure consists of placing the boulder in a nala at suitable location up to the height of 75% of nala depth. The downstream slope of the structure is normally kept as 2.5:1 or 3:1 (horizontal: vertical). In upstream of structure a reverse filter is provided. The reverse filter consists of 6"-8" thick soil, 6"-8" thick sand and 6"-8" thick metals arranged in direction of flow of nala. The reverse filter helps to prevent the passing of soil within the structure. Thus, soil in the runoff is prevented at the upstream of the structure and runoff water passes from free board of the structure.

Percolation Tanks (PT)/Spreading Basin

These are the most prevalent structures in India as a measure to recharge the groundwater reservoir both in alluvial as well as hard rock formations. The efficacy and feasibility of these structures is more in hard rock formation where the rocks are highly fractured and weathered.

These are suggested on lower order streams (up to III order) with medium slopes. These are proposed, where water table fluctuation is very high. It reduces runoff velocity thereby

minimizing erosion and secondly allows the rainwater to percolate and thus results in increased recharge in the wells located down streams of the structures.
In the States of Maharashtra, Andhra Pradesh, Madhya Pradesh, Karnataka and Gujarat, the percolation tanks have been constructed in plenty in basaltic lava flows and crystalline rocks.

Gabion Structure
This is a kind of check dam being commonly constructed across small stream (1st or 2nd order streams) to conserve stream flows with practically no submergence beyond stream course. The boulders locally available are stored in steel wire. This is put up across the stream's mesh to make it as a small dam by anchoring it to the streamside. The height of such structures is around 0.5 m and is normally used in the streams with width of about 10 to 15 m. The excess water overflows this structure storing some water to serve as source of recharge. The silt content of stream water in due course is deposited in the interstices of the boulders to make it more impermeable.
The structure helps in checking the soil erosion, creates small storage's which can be utilizes to reclaim the wasteland area around it. This also helps to conserve the soil moisture condition of the surrounding area, which results in growth of vegetation. These structures are common in the State of Maharashtra, Madhya Pradesh, and Andhra Pradesh.

Nala Bunds and Small Check Dams
These structures are suggested across nala (streams) for checking velocity of runoff, increasing water percolation and improving soil moisture regime. Nala bunds are less expensive, smaller in dimension and constructed using locally available material whereas percolation check dams are larger and more expensive. A series of small bunds or weirs are made across selected nala sections such that the flow of surface water in the stream channel is impeded and water is retained on pervious soil/tock surface for longer body. Nala are constructed across the bigger nalas of second order streams in areas having gentler slopes. A nala bund acts like a mini percolation tank.

Recharge Pit
This structure is suggested mostly at the water divide areas, where rainwater does not stay because of slope and impervious rocks at the top. Pits of 1 to 2 m. diameter are excavated which penetrate impervious strata and connect it to the aquifer, or up to the pervious strata by means of drilling. These pits are filled with coarse pebble and sand to recharge water.

Subsurface Dykes
These structures are proposed to arrest the lateral groundwater flow (base flow in the stream). These structures are suggested at areas having 2 to 5 m. thickness of weathering mantle. Before constructing the subsurface dykes, the parameters such as thickness of loose material, degree and extent of weathering and depth of bedrock need to be studied. The structure is to be constructed up to the bedrock depth.

Dabri (Dug Pit)
These structures are proposed at suitable places flowing water is blocked to have surface storage up to certain level and then it is allowed to overflow. Such structures are useful to provide a long time stay of water and to have sufficient percolation. These structures are also useful to have water for irrigation purpose. Care should be taken while construction earth embankment that the all soil requirement to construct the bund must be lifted from the dabri (Dug Pit). The tree planting on the bund will control the soil erosion.

Erosion Control Measures

Contour Trenching
In this method, trenches are excavated along the contour. The contour bunds along the contour trench act as barrier to the flow of water thus reducing amount and velocity of surface runoff and hence soil erosion is controlled. Tree planting on the contour bunds will control the soil erosion. These provide closed canopy, improve infiltration of moisture, and provide organic matter making the soil fertile.

Vegetative Stripes
Filter stripes to be created along the river and places of the diversion of drain in order to direct the overflow of the seasonal river channels and thereby to check the soil erosion. Vegetative filter stripes prepared by locally available grasses like muja and other shrubs.

Water Quality Improvement Measures

The result found nitrate pollution in Guraiya village, however in controlled stage. It may increase if proper care is not taken. Farmers are advised to use chemical fertilizers in their optimum quantity. Excessive use of fertilizers leads to Groundwater pollution and loss of money. It is recommended that the animal and domestic wastes should not be dumped in depressions as these leads to Groundwater pollution. In the villages there is no proper sewage system. The septic tanks are not constructed scientifically. Civic bodies should take proper care for disposal of domestic waste including sewage.

The recommendations in the current study are purely on scientific and technical basis that can be attempted in future for similar studies. Due to time constraints PRA (Participatory Rural Appraisal) technique could not be conducted in the area before final recommendations are made which could have derived better output.

Conclusion

Remote Sensing and GIS have introduced a new dimension in the field of watershed management [7]. Data integration through GIS plays very important role in order to get right perspective of the terrain conditions. It is difficult visually comparing two or three maps. Hence GIS approach can be accepted as a standard methodology in watershed management for targeting groundwater prospective zones. The remote sensing techniques help to derive significant information on the geology, lineament, geomorphology, landuse-landcover, soil, slope, drainage and recharge condition, which ultimately define the groundwater regime through visual interpretation of satellite data with limited field checks.

The final output of groundwater prospects map and the proposed water resource action plan for Halali and Dudhi mili-watershed will be helpful in utilizing the land according to its capability, mitigating soil erosion, improving the socio-economic condition of people, and fulfilling the demand of water. The recommended treatments in the project are purely on scientific and technical basis that can be attempted in future for similar studies.

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