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# **WATER RESOURCES DEVELOPMENT ACTION PLAN FOR SASTI WATERSHED, CHANDRAPUR DISTRICT, MAHARASHTRA USING REMOTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM**

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## **ABSTRACT**

Today the world is facing the biggest crisis for water. The available both surface and groundwater resources are not sufficient to meet all the water requirements for all purpose. The optimal and sustainable development of the resource is a prerequisite so that it is assessed reliably to avoid any future problems regarding its qualitative and quantitative availability. The interpretation of remote sensing data in conjunction with ancillary data and sufficient ground truth information makes it possible to identify and outline various ground features such as geological structures, geomorphic features and their hydraulic characters, that may serve as direct or indirect indicators of the presence of ground and surface water. Remote sensing and Geographical Information System (GIS) have emerged to meet ever-increasing demand for more precise and timely information. These techniques permit rapid and cost effective natural resource survey and management. Remotely sensed data provides unbiased informations on geology, geomorphology, structural pattern and recharging conditions, which logically define the groundwater regime and help to generate water resources development action plan. The present study is an attempt to prepare a water resource development action plan for Sasti watershed of Chandrapur district, Maharashtra using remote sensing and GIS.

## **Introduction**

Our very own survival on earth essentially

depends on water, nature's valuable gift to mankind. Water resources are extremely limited but renewable exhibiting diversity in their quality and quantity.

Many parts of India experienced acute shortage of water for different purposes and the problem of water crises is likely to become more severe and serious and will continue well into the 21<sup>st</sup> century (Biswas, 1991). As groundwater is the largest available source of fresh water lying beneath the ground it has become crucial not only for targeting of groundwater potential zones, but also monitoring and conserving this important resource. Besides targeting groundwater potential zones it is also important to identify suitable sites for artificial recharge usage cycle. When the natural recharge rate cannot meet the demand for water, the balance is disturbed and hence calls for artificial recharge on a country wise basis (Rokade, 2003).

Remote sensing with its advantages of spatial, spectral and temporal availability of data covering large and inaccessible areas within short time has become a very handy tool in assessing, monitoring and conserving groundwater resources. Satellite data provides quick and useful baseline information on the parameters like geology, geomorphology, land use/land cover, lineaments etc. controlling the occurrence and movement of groundwater (Saraf and Choudhury, 1998; Singh *et al.*, 1993). Thematic layers generated using remote sensing data like geology, geomorphology, land use/land cover, lineaments etc., can be integrated in a Geographic Information system (GIS) framework and analyzed using a model developed with logical conditions to derive groundwater potential zones. By combining the remote sensing information with adequate field data, particularly well inventory and yield data, it is possible to arrive at prognostic models to predict the ranges of depth, the yield, the success rate and the types of wells suited to different lithounits under different hydrogeological domains. Based on the status of groundwater development and groundwater irrigated areas, artificial recharge structures such as percolation tanks, check dams, recharge-cum-discharge wells and rainwater harvesting structures can be recommended upstream of groundwater irrigated areas to recharge the wells

in the downstream areas so as to augment groundwater resources.

The main objectives of the study are to collect ancillary data and generate different thematic maps from satellite data and to prepare implementable water resources development action plan on 1: 50,000 scale supported by various thematic maps like - Base map, Drainage map, Geological map, Geomorphological map, Land use/Land cover map and Groundwater potential map.

The suitable sites and structures for groundwater exploitation and for water harvesting are suggested in consideration with physical and cultural parameters of the area to fulfill the increasing demands of water for irrigation and drinking purposes. The study revealed that after the implementation of the proposed plan, peoples can make optimal use of water and farmers of the watershed will be able to take double crops.

## Results and Discussion

In the present study, topographical maps (56 M/1, M/2, M/5 and M/6) prepared by Survey of India on 1:50,000 scale, IRS-1C LISS III digital data (Path 100 and Rows 58 and 59) dated October 28, 2001, IRS-1C PAN digital data (Path 100 and Rows 58 and 59) dated December 7, 2001 were used. Secondary data on hydrology, well data, recharge conditions, type of aquifers and depth of weathering were collected from Groundwater Survey and Development Agency (GSDA, Chandrapur) as well as during the field visits. Geological map published by Geological Survey of India on 1: 250, 000 scale was also used.

The IRS- 1C LISS III and PAN data were registered to SOI topographical maps on 1 : 50, 000 scale in ERDAS IMAGINE 8.4 image processing software using map to image registration algorithm. The digitally rectified images (LISS III and PAN) were merged by Principal component analysis based

image fusion techniques (Prasad *et al.*, 2002). The False Colour Composite (FCC) was generated from green, red and near-infrared (NIR) spectral bands (2, 3 and 4). Linear, equalization and root enhancement techniques have been followed in analyzing the satellite imagery for better interpretation of the geological, geomorphological, structural and land use/ land cover information.

The different thematic layers on geology, geomorphology, lineaments and hydrology (waterbodies, streams etc.) are generated on the basis of their image characteristics (tone, texture, pattern, shape, size, association and drainage characteristics). Geographic Information System (ARC/INFO 8.0.1) has been used for digitization, editing and topology creation. Final integration of multi-thematic information, overlaying, analysis, correlation and generation of groundwater potential map was also carried out in ARC/INFO 8.0.1. GIS modelling was done to demarcate the zones of suitable groundwater exploitation structures and artificial recharge structures by using Boolean logical operators like AND, OR, NOT and XOR. Tentatively generated water resource developmental action plan was discussed with progressive farmers, school and college teachers and with policy makers. Their suggestions are incorporated, which have given birth to final water resources developmental action plan.

### Geology of the Area

On the basis of interpretation of satellite data, fieldwork and subsurface borehole data obtained from the Central Mining and Power Development Institute (CMPDI, Nagpur) the area has been mapped. The Vindhyan sediments, Lower Gondwana sediments, Deccan Traps, alluvium and soil mainly constitute the geology of the area. Percentage wise distribution of the different litho-units is shown in the Fig. 1. The Geological map prepared from satellite data, ancillary data followed by field checks is shown in the Fig. 2.

In study area, Vindhyan sediments are represented by limestone, shale and shaley limestone. About 62% area of the watershed is constituted of Vindhyan sediments. Lower Gondwana sediments (rocks of the Talchir, Barakar and Kamthi Formations) occupy 23% area of the watershed. Gondwana sediments are represented by sandstones, shale, carbonaceous shale and coal. Deccan traps are encountered towards the southern part of the Sasti watershed. It is represented by black, compact, fine grained basalt with vesicular structures. An examination of sections of dug wells at Tumriguda and Kolamguda villages indicates that the zone of weathering extends down to a depth of about 2 - 5 m below ground level. Wardha River and its major streams have developed the flood plains along their banks. It comprises sand, silt and clay. Black cotton soil and sandy soil deposits are generally at the average height of 5 m to 10 m above the stream level. In case of Wardha River, at some places it may be at the height of 15 m these deposits are generally situated about 100 - 300 m wide along the course of major stream.

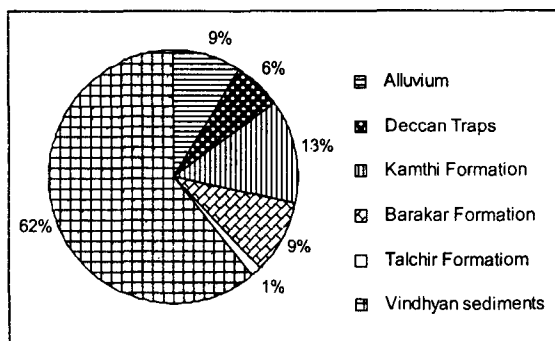


Fig. 1. Pie diagram showing percentage of different litho-units in the area.

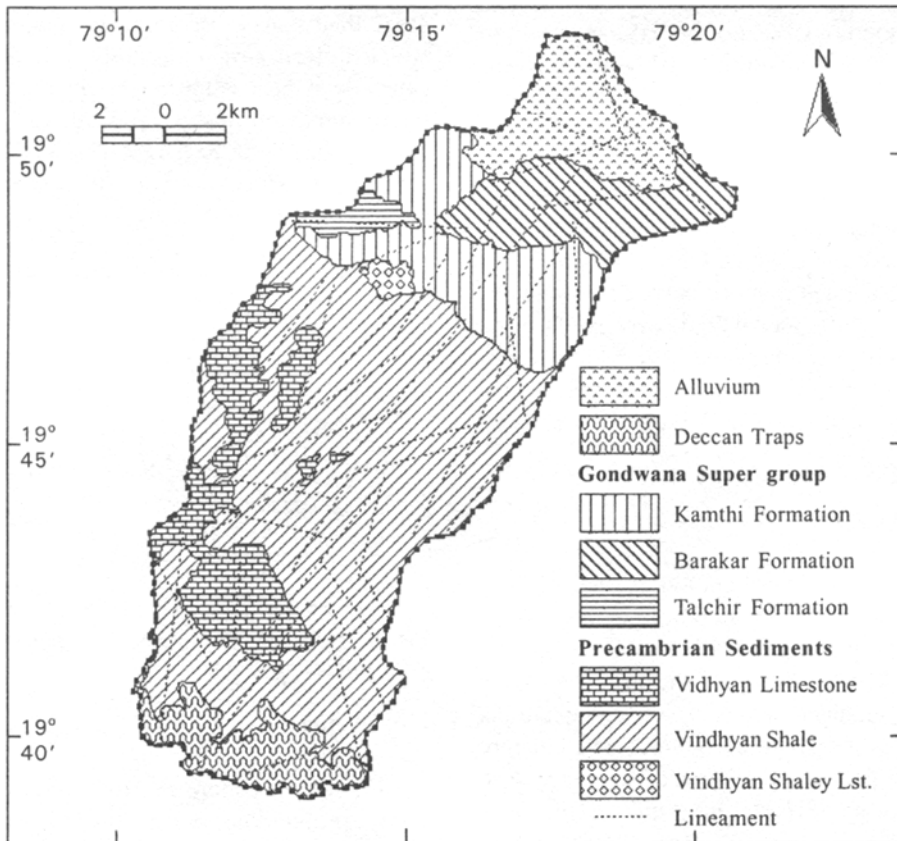
### Lineaments

Lineaments mapped from satellite data are natural straight lines or curvilinear features that can be correlated to faults, fractures, joints, bedding traces, lithological contacts, unconformities etc. The study area is characterized by major NE- SW,

ENE-WSW, E-W and NW-SE trending lineaments (Fig. 2). The dominant trend of the lineaments is NE-SW. Vindhyan sediments are characterised by NE-SW, E-W and NW-SE whereas the Lower Gondwana sediments show E-W, NE-SW and ENE-WSW trends of the lineament. According to the report published by Western Coalfields Limited, in between Ballarpur and Sasti area there is local swing of dip towards southeast because of angular unconformity between Kamthi Formation and Barakar Formation. Gondwanas show minor undulations and various faults with throw of about 8 m to 30 m with NW-SE, NE-SW and WNW-ESE strike directions. The surface evidence of these faults are not observed within watershed.

### Geomorphology of the Area

Geomorphological expressions exert tremendous control on the groundwater regime. The relief, slope, depth of weathered material, types of the weathered material and the overall assemblage of different landforms play an important role in defining the groundwater regime more particularly in hard rock areas and as well in unconsolidated formations (Karanth, 1997). On the basis of interpretation of satellite image, SOI Toposheets, field visits and well data it is clear that geomorphology of the area comprises of plateau, piedmont slope, pediment, pediplains and flood



**Fig. 2.** Geological Map of the Sasti watershed, Rajura Taluka, Chandrapur District (MS).

plain of Wardha River. The geomorphology of the area is as shown in Fig. 3.

**Plateau:** Plateau is the table like land. It is broad, elevated, and almost level. It covers southern part of the watershed along the watershed divide. This landform is easily identifiable in the satellite data due to flat top, occupying the higher altitude of 509 m above MSL. Drainage originating from this area shows trellis drainage pattern. This geomorphic unit is predominantly covered by open forest.

**Piedmont Zone:** Piedmont Zone is the area between plateau and plains. It is characterized by very high runoff and poor groundwater recharge region. In study area it is marked by presence of piedmont slope and pediment. Piedmont slope is found to

occur from 300 to 400 m above MSL and occupies the southern part of the watershed. It is covered by open forest. Pediments are broad, extensive and gently sloping areas of rock cut surfaces, which spread as aprons around the bases of mountains and it is characterised by very high runoff and poor groundwater regime.

**Plains:** Plains are the area between piedmont zone and the main river. In this area plains are represented by the presence of pediplains and flood plain of Wardha River. In Sasti watershed, it is divided into shallow pediplains and deep pediplains. Shallow pediplain has a flat surface with a weathered zone that extends up to a depth of 10 m. Groundwater availability is believed to be poor to moderate in view of their elevated ground compared

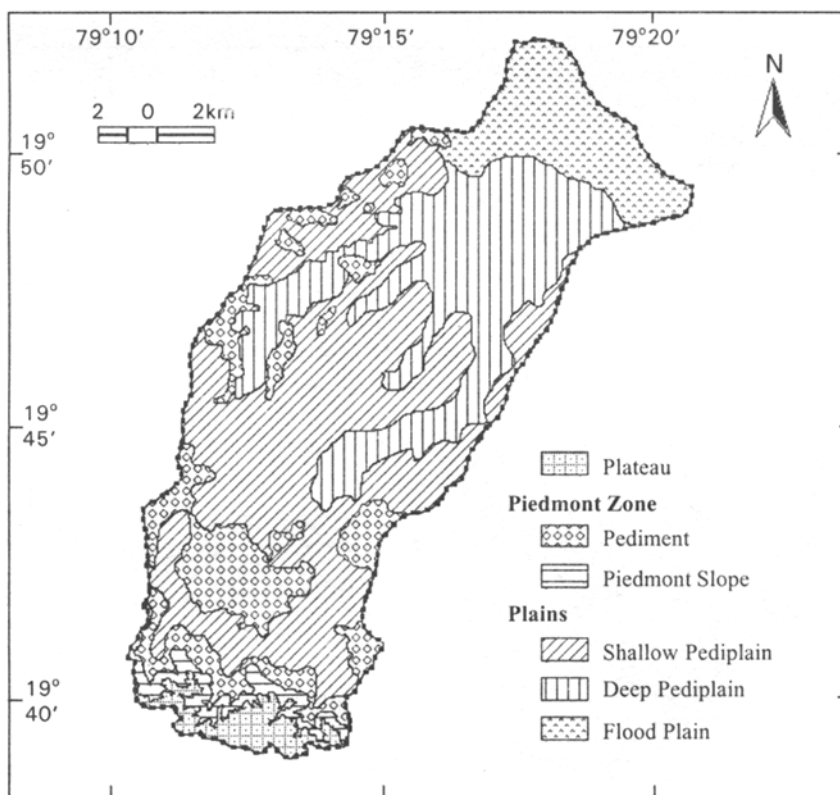


Fig. 3. Geomorphological Map of the Sasti watershed.

to the deep pediplain. Similarly deep pediplain has a flat surface with a weathered zone that extends up to depth more than 10 m. In study area these units are found to be near Pauni and Gauri villages.

In studied area flood plain is formed due to the course of Wardha River. It is the lowest and youngest geomorphic unit lies at less than 200 m above MSL. Flood plain is comprises of sand, silt and clay and facilitates channel bed infiltration. It is a highly permeable zone helping the partial bank recharge and subsurface flow of groundwater occurs with shallow water levels. Groundwater prospects in flood plains are almost invariably found to be good. This geomorphic unit occupies an area of about 2% of total area of the watershed and is mostly under cultivation for paddy, wheat, gram and vegetables.

### Land Use/Land Cover

Land use describes how a parcel of land is used such as for agriculture, settlements or industry, whereas land cover refers to the material such as vegetation, rocks or water bodies that are present on the earth surface (Anderson *et al.*, 1976). Information on land use and land cover is necessary for assessment of groundwater availability and its management. Agriculture is the major activity of peoples in area. About 58% area of the watershed is under agriculture. The analysis of the rabi and kharip season's land use/ land cover characteristics reveals that majority of area is under single cropping system. The area under single crop accounts for about 52% because of its monsoonal climatic conditions and rainfed cropping system (Fig. 4). The double-cropped area occupies the flood plain of

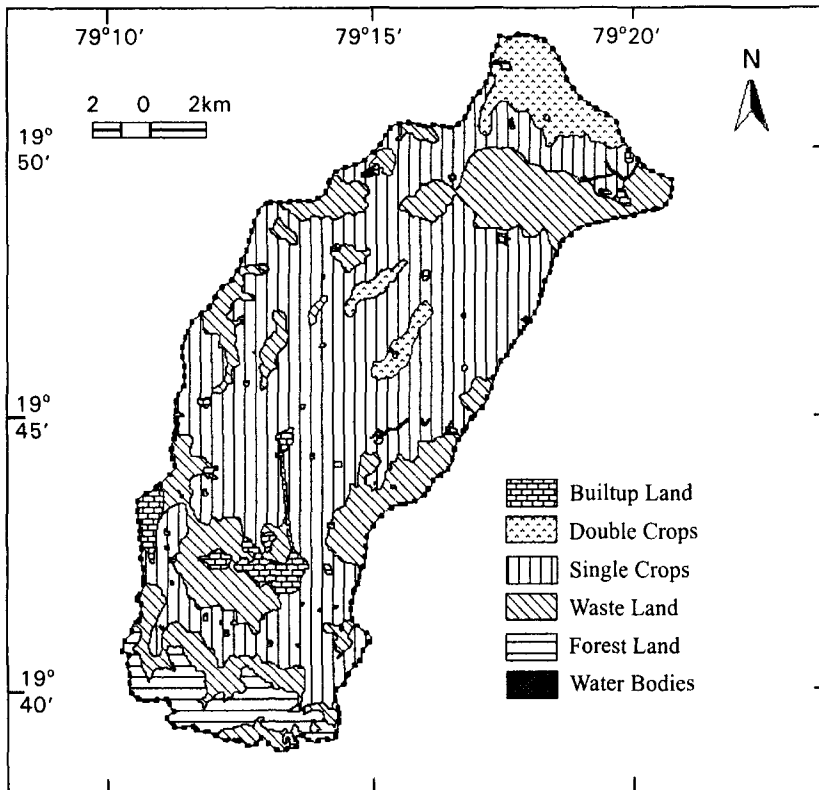


Fig. 4. Land use/Land cover map of the study area.

Wardha river and it accounts for about 6% of the area. The crops are generally soyabean, cotton and tur in kharip and wheat, grams, jawas and vegetables in rabi seasons. In study area, wasteland comprises of land with scrubs, land under mining activities and barren rocky land. The scrubland is more common on pediments and it accounts for 18% of the total area. About 11.5% area of the watershed is under mining activities, about six opencast and two underground coal mines are working. About 2.7% area is covered by barren rocky land and is mainly restricted to plateau. The thick deciduous forest is restricted to plateau side drainage and occupies nearly 6.5% area. Area covered by streams, percolation tanks and ponds is only 0.5% and 2.8% area is occupied by built-up land i.e. area covered by villages and cement factories (Ambuja Cement Factory and Manikgarh Cement Factory).

### Groundwater Potential of the Area

The groundwater potential zone map (Fig. 5) generated through GIS modelling was verified with the yield data to ascertain the validity of the model developed. The verification showed that the groundwater potential zones demarcated through the model are in agreement with the bore well yield data. Four groundwater potential zones (Very High, High, moderate and low) have been identified in the studied area. In each zone, the prospect of groundwater has been described in relation to its geomorphology and hydrogeological characteristics.

**Very High Groundwater Potential Zone:** The major geomorphic unit in this zone is flood plain of Wardha River. This zone is mostly influenced by

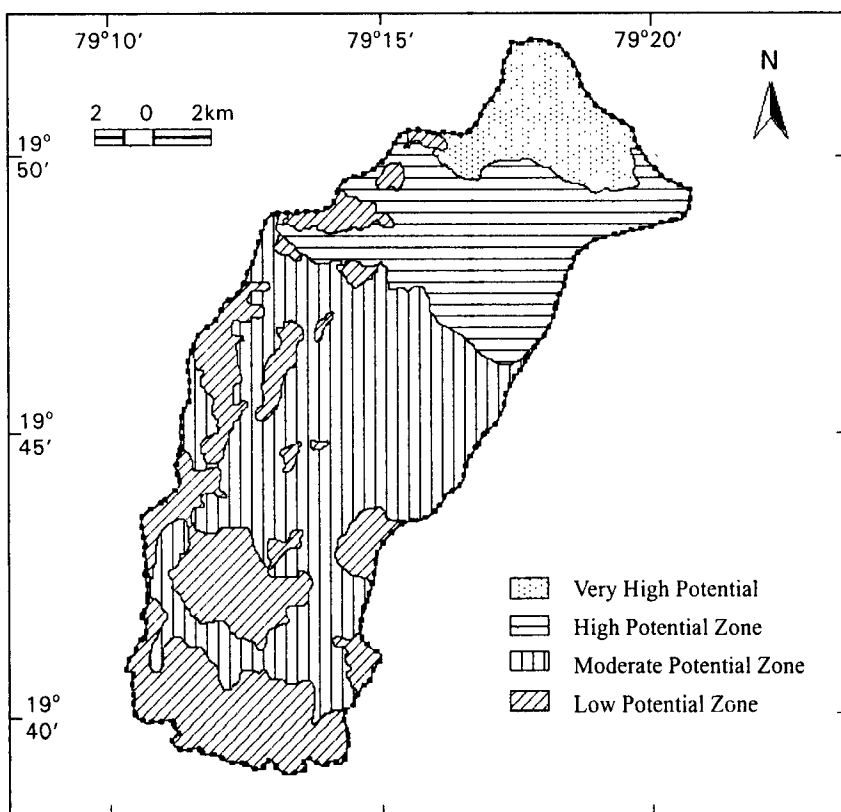


Fig. 5. Map showing groundwater potential zones of the study area.

Quaternary sediments. Major part of this zone exists in North-Eastern part of the watershed. In majority of cases, the static water level (SWL) value ranges between 3 - 15 m bgl with good recharge conditions. Expected yield of wells from this zone is greater than 4000 lph.

**High Groundwater Potential Zone:** This zone is mainly dominated by geomorphic unit like deep pediplain. This zone is mostly influenced by Kamthi and Barakar sandstones. Because of the favorable hydrogeological conditions this zone is suitable for groundwater exploration. The expected yield of wells from this zone is between 1000 - 1200 lph.

**Moderate Potential Zone:** This zone is dominated by shallow pediplain, mostly developed under Kamthi sandstone, Talchir sediments and shales and limestones of Vindhyan age. The formations are mostly confined to weathered and fractured rocks that influence the water table. In majority of cases, the static water level (SWL) value ranges between 3 - 15 m below ground level. The recharge conditions are moderate to good. Expected yield of wells from this zone is between 700 - 1000 lph.

**Low Potential Zone:** This is mainly a rocky terrain dominated by pediment zone, plateau and piedmont slope which occupies about 26% of the total area. This zone is mostly influenced by limestones, shaley limestones, and red shales of Vindhyan age and Deccan Basalts. Due to favorable slope conditions and surface characteristics, this zone is ideal for runoff generation. The groundwater recharge conditions are either limited or moderate. The aquifer material is mostly weathered and fractured. The depth weathering is also low and not uniform. Therefore these aquifers are characterised by low yield, low homogeneity and low to moderate rate of success. In majority of cases, the static water level (SWL) value ranges between 3 - 20 m bgl. Expected yield of wells from this zone is between 300 - 600 lph.

## **Water Resources Development Plan and its Implementation**

The principal recharge of groundwater body in Sasti watershed is through monsoon precipitation. The development of water resources is needed to meet the water requirements of domestic, irrigation and industrial sectors. The water resources development plans of the area have been prepared on the basis of geology, geomorphology, drainage, surface water bodies, groundwater potential and present land use/land cover in the area. This plan prepared for the area clearly depicts the exploitation of prospective zones by suitable exploitation structure and artificial recharge of groundwater by percolation tanks, check dams, recharge-cum-discharge wells and rainwater harvesting.

**Groundwater Exploitation Structures:** The choice of groundwater exploitation structures mainly depends upon the topography, geological conditions of the underlying strata, depth of the groundwater table, and the quantity of water required. In Sasti watershed zones of different exploitation structures have been delineated by generating GIS model for borewell, normal dug well, large diameter dug well and dug-cum-bore well.

The zone of large diameter dug well is mainly occupied by Talchir shales with shallow pediplain having poor groundwater potential. This zone is mainly confined to second and third order streams near Sakhari, Hirapur and Nimni villages. The diameter of these wells is mostly 6 - 9 meters. The slow rate of recuperation and low permeability of the terrain force to go for large diameter dug wells.

The zone of normal dug well is mainly occupied by the Vindhyan shales with deep pediplain and it is characterized by moderate to high groundwater potential, flat topography resulting less than 1% slope. The study of existing wells indicates that the diameter of these wells should be between 4 - 6 meters.



Major part of the Kamthi and Barakar sandstone with deep pediplain is suitable for bore well exploitation. This area is characterized by very high and high groundwater potential, flat topography resulting less than 1% slope. Groundwater occurs in this terrain mainly in between pore spaces of sandstone and along its bedding plains. The thickness of weathered zone is greater than 10 m. Since the terrain possesses very high groundwater potential, high groundwater fluctuations, very high groundwater yield and more thickness of weathered zone, the area is highly suitable for bore wells.

The area suitable for dug-cum-bore well is occupied by Vindhyan shales with shallow pediplain. The existing dug wells can be converted into dug-cum-bore wells by drilling a bore up to depth of 20 - 25 m from the bottom of the wells. In this zone dug wells are not suitable because the water table fluctuation is more, possessing poor to moderate groundwater potential.

**Artificial Recharge Structures:** In Sasti watershed by considering local topography, lithology, land use/land cover and availability of surface and groundwater potentials, zones of the suitability of the different recharge structures like percolation tanks, check dams, Roof top rain water harvesting and runoff rain water harvesting structure have been delineated.

Percolation tank is a small tank, which stores the available runoff during monsoon and allows it to percolate gradually to recharge the surrounding groundwater body. Major part of Deccan basalts and Vindhyan shales and limestones can recharge artificially by percolation tanks. This area is characterised by poor groundwater potential with yield of wells ranges from 300 - 600 lph and land use/land cover is scrub land. The augmentation through percolation tanks recommended in this area will enhance the groundwater potential of the area. The expected recharge from percolation tanks will vary from 28% to 61% of stored water.

In Industrial area like Ambuja Cement Factory and Manikgarh Cement Factory the monsoon runoff can be harnessed to recharge the groundwater reservoir through roof top rain water harvesting and by conserving storm runoff during monsoon. Vindhyan limestones with pediment mainly occupy this zone. This area is characterised by poor groundwater potential. This zone is mainly confined to the area 500 m away from Ambuja Cement Factory and Manikgarh Cement Factory. Rain water captured from roof, roads and campus of the cement industries can be diverted to storage. Storage like dug wells; recharge shafts can be constructed around the Industry. The augmentation through this modern techniques recommended in this area would enable to fulfill the shrinkage of recharge area caused by constructional activities and asphaltting of roads etc.

Check dams are constructed across small streams having gentle slope and are feasible both in hard rock as well as in alluvial formations. Check dams are constructed to serve as storage reservoir for agricultural purpose and to check the soil erosion. The area suitable for check dams is underlain by Kamthi sandstone, Vindhyan shales and limestones with shallow and deep pediplain. This zone is characterised by moderate to high groundwater potential. The thickness of weathered zone is greater than 5 m and land use/ land cover is kharip only. The artificial recharge through check dams would increase the groundwater level of this zone and may be helpful to take double crops.

**Renovation Activities:** Renovation activities like conversion of village tanks into percolation tanks, desilting and cementing of silted and damaged recharge structures, deepening of drinking water source and modification of irrigation technology are necessary in the watershed.

**Implementation of Plan:** The implementation of water resources development plan sometimes results in environmental degradation and imbalance of ecology if there is no clear understanding of

hydrologic behavior of the watershed considering all the relevant parameters during the planning stage itself. Multisectoral efforts are needed to minimize the wasteful uses of groundwater and environmental degradation e.g. conjunctive use of surface and groundwater, restriction of overdraft by suitable legislation, involvement of NGOs, women participation, mass awareness programme, selection of appropriate pumps, adoption of high tech irrigation etc.

### Conclusion

This study has demonstrated an integrated remote sensing and GIS based methodology for preparation of water resource developmental action plan. Study area is divided into four groundwater potential zones (Very High, High, Moderate and Low). Flood Plain of Wardha river has very high groundwater potential whereas Kamthi and Barakar sandstones gives high groundwater potential. We have suggested the suitable structures for proper exploitation of groundwater. Recharge structures like percolation tanks, check dams and roof top rainwater harvesting and runoff rainwater harvesting are also suggested in area to improve the groundwater conditions. Desiltation and cementation of the existing recharge structures, deepening of drinking water source and modification of existing village tanks into percolation tanks is necessary.

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