IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

"INTEGRATED GEOHYDROLOGICAL ASSESSMENT OF GP-08 WATERSHED USING GEOLOGY, REMOTE SENSING AND GIS FOR SUSTAINABLE GROUNDWATER MANAGEMENT"

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Abstract

The GP-08 watershed in the Sanjul area of Phulambri Taluka, Chhatrapati Sambhajinagar District, Maharashtra, experiences recurring water scarcity during the summer season. The problem affects domestic requirements, agriculture, livestock and the local rural economy. The present study examines the geohydrological characteristics of the watershed by integrating geological observations with remote sensing and Geographic Information System (GIS) techniques. The study area lies between approximately 20°10′05″ N and 75°20′10″ E and has an elevation range of about 610–645 m, giving a relief difference of approximately 35 m. The reported average annual rainfall in the source study is 750 m; this value should be verified in the final field-based manuscript for the appropriate rainfall unit.

The watershed is mainly underlain by Deccan Trap basalt, with associated red boles, lateritic and inter-trappean materials, together with recent black cotton soil and limited alluvial deposits. The basalt flows show important vertical and lateral variations in lithology and secondary porosity. Compact basalt is generally hard and massive, whereas vesicular, amygdaloidal and weathered portions can provide pathways for groundwater movement. Joints, fractures, flow contacts and weathered zones are therefore important hydrogeological controls. Tachylytic basalt and volcanic breccia also occur locally and may influence permeability and groundwater storage depending upon their degree of weathering, fracturing and matrix characteristics.

Remote sensing provides spatial information on lithology, geomorphology, land use/land cover, drainage and lineaments, while GIS allows these layers to be integrated for groundwater-prospect and recharge-site assessment. The methodology adopted in the study consists of primary and secondary data collection, preparation of thematic maps, comparison with field observations, GIS analysis, groundwater-zone delineation and selection of suitable recharge locations. The study further considers groundwater development through dug wells and dug-cum-bore wells, with site-specific investigation required before construction.

The results indicate that groundwater development in the watershed must be planned according to the geological and hydrogeological characteristics of the basaltic terrain rather than by assuming uniform groundwater availability. Artificial recharge measures such as check dams, percolation tanks and subsurface interventions may be considered where site conditions are favourable. Scientific well-site selection, seasonal monitoring, controlled groundwater abstraction, soil and water conservation and community participation are essential for sustainable watershed development. The study demonstrates the usefulness of integrating geology, remote sensing, field observations and GIS for micro-level groundwater and watershed planning in basaltic regions of Maharashtra.

Keywords

Watershed; Geology; Deccan Trap; Basalt; Hydrogeology; Groundwater; Remote Sensing; GIS; Aquifer Recharge; Watershed Management.

Introduction

Water is one of the most important natural resources for rural development, agriculture, domestic use and ecological sustainability. In semi-arid and seasonally water-stressed parts of Maharashtra, groundwater provides an important source of water during periods when surface-water resources become inadequate. However, groundwater is not uniformly distributed. Its occurrence, movement, storage and accessibility are controlled by geological formation, weathering, fractures, joints, geomorphology, soil thickness, drainage characteristics, rainfall and land use.

The GP-08 watershed in the Sanjul area experiences recurring summer water scarcity. The original study identifies inadequate surface-water resources and increasing dependence on groundwater as important reasons for undertaking a detailed geohydrological assessment. Increasing extraction without understanding aquifer characteristics can result in declining water levels, unsuccessful wells and deterioration of groundwater resources. Hence, micro-level planning is required to match groundwater development with the actual hydrogeological potential of the watershed.

The Deccan Trap terrain presents a special challenge for groundwater development. Basaltic rocks may appear massive and continuous at the surface, but groundwater commonly occurs in secondary openings such as joints, fractures, weathered zones, vesicular horizons and flow contacts. Consequently, two wells located relatively close to each other may have very different yields. Geological mapping and spatial analysis are therefore essential before selecting groundwater-development or recharge sites.

Remote sensing and GIS are particularly useful because they permit rapid assessment of large areas and integration of several spatial factors. Satellite imagery can assist in identifying drainage patterns, lineaments, land-cover conditions and geomorphic features. GIS provides a framework for storing, overlaying and analysing these data together with topography, geology and field observations. The objective is not to replace field investigation but to improve the identification and prioritisation of areas requiring detailed investigation.

The present work therefore focuses on the integrated assessment of GP-08 watershed using geological interpretation, remote sensing and GIS, with special emphasis on groundwater occurrence, recharge possibilities and sustainable groundwater development.

Objectives

The principal objectives are:

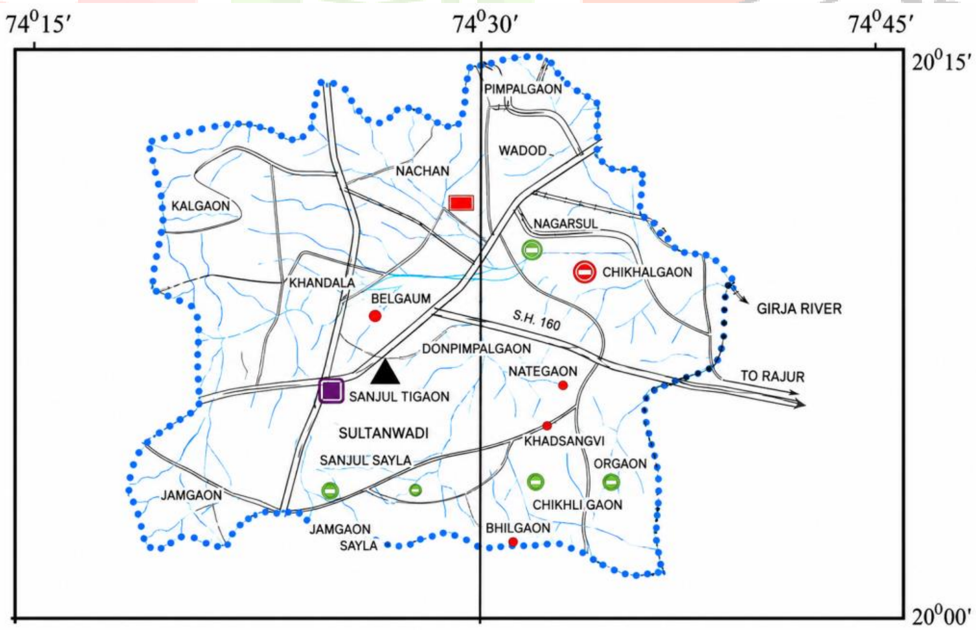
1. To study the geological and geohydrological characteristics of the GP-08 watershed.
2. To understand the influence of Deccan Trap basalt flows, weathering, joints, fractures and flow contacts on groundwater occurrence.
3. To use remote sensing information for identifying lithological, geomorphological, drainage and structural features.
4. To integrate thematic information using GIS for groundwater-prospect assessment.
5. To identify suitable areas and principles for artificial groundwater recharge.
6. To examine suitable groundwater-development options such as dug wells and dug-cum-bore wells.
7. To recommend practical measures for sustainable groundwater and watershed management.

Study Area

The GP-08 watershed is situated in the Sanjul area of Phulambri Taluka, Chhatrapati Sambhajinagar District, Maharashtra. The source paper places the study area approximately between 20°10′05″ N and 75°20′10″ E. The elevation varies from about 610 m to 645 m, producing a relief difference of nearly 35 m. The watershed is therefore characterised by moderate topographic variation that can influence runoff concentration, drainage development and groundwater recharge.

The area receives seasonal rainfall, and the study identifies an average annual rainfall of 750 m. Since rainfall is normally reported in millimetres, the unit in the original manuscript should be checked against the original meteorological record before publication. The major water-related problem occurs during the summer season, when available surface water becomes inadequate and dependence on wells increases.

The location map and grid map show the watershed boundary and surrounding settlements and drainage features. These spatial references are useful for relating the geological observations to watershed-scale planning. The study is essentially a micro-level assessment in which geological characteristics are considered together with surface features and groundwater requirements.



Geological Setting

Sr. No.	Age	Formation	Lithology
1	Recent	Soil	Black Cotton Soil, kankar
2	Pliestocen	Alluvium	Alluvium comprising sand silt etc.
3	Upper CretaciousTo Lower Eocene	Deccan Trap	Basalt, red boles, lateritic and inter trappean

The study area forms part of the Deccan Trap volcanic province. The geological succession described in the original paper includes Recent soil, Pleistocene alluvium and Upper Cretaceous to Lower Eocene Deccan Trap formations. Recent deposits include black cotton soil and kankar. Pleistocene alluvium consists mainly of sand, silt and related unconsolidated material. The Deccan Trap is represented by basalt, red boles, lateritic material and inter-trappean horizons.

The Deccan Trap basalts are generally extensive and tabular. Individual compact basalt flows may range considerably in thickness, with the source study indicating approximately 7 to 120 m. The internal structure of a basalt flow is important because its different portions possess different hydrological properties. The upper portion may be vesicular and amygdaloidal and may contain hydrothermally altered material. The middle and lower portions are commonly more compact and massive. Cooling-related joints occur especially in the middle and lower portions and may provide secondary permeability.

A fresh vesicular or amygdaloidal top portion can behave as a relatively low-permeability unit when cavities are filled or when the rock is otherwise unconnected. In contrast, weathering and sheet jointing can substantially increase secondary porosity and permit infiltration. Therefore, weathering intensity and fracture connectivity are important considerations when evaluating groundwater potential.

Tachylytic basalt is described in the source as basaltic glass formed by rapid cooling and chilling of lava. It may occur as thin bands, pockets, lenses or irregular thin intrusions, commonly between lava flows or within the upper part of a flow. It may display red, green, brown or black colours, with red being common. Its closely spaced joints can influence the movement of groundwater where the fractures are open and interconnected.

Volcanic breccia consists of angular basalt fragments held together by a red tachylytic, zeolitic or grey lava matrix. Its hydrogeological behaviour depends on the matrix, degree of weathering, fracture development and presence of interconnected voids. Some zeolitic breccias may contain voids where zeolitic material is absent. These local variations demonstrate why a single permeability value cannot be assumed for the entire watershed.

Hydrogeological Characteristics

Groundwater occurrence in basaltic terrain is mainly governed by secondary porosity rather than primary pore space. The important water-bearing features in the GP-08 area are expected to include weathered basalt, joints, fractures, vesicular zones, flow contacts and locally favourable brecciated horizons. Compact massive basalt may restrict vertical movement unless it is fractured. Consequently, groundwater conditions can change considerably over short distances.

The upper weathered zone may temporarily store infiltrated rainfall and transmit water towards fractures and deeper openings. Flow contacts may become important because differences in texture, cooling characteristics and weathering can produce zones of enhanced permeability. However, not every flow contact is water-bearing. Its usefulness depends on whether it is open, weathered and hydraulically connected.

The source paper emphasises that the hydrogeological conditions of Deccan Trap rocks are not uniformly favourable for large groundwater storage. This helps explain why severe scarcity can persist even after average or above-average rainfall. Rainfall alone does not guarantee recharge to usable aquifers. Surface runoff, soil characteristics, slope, vegetation, evaporation, fracture connectivity and the storage capacity of the subsurface all influence effective recharge.

Groundwater development must therefore be based on the balance between recharge and abstraction. Where wells are concentrated, pumping should be regulated according to seasonal water-level behaviour. A well that gives water during one season should not automatically be considered capable of sustaining intensive year-round irrigation. Long-term groundwater development requires repeated monitoring of water levels and, where possible, discharge and quality.

Remote Sensing and GIS

Remote sensing is useful in hydrogeological investigations because satellite data provide spatial, spectral and temporal information over large areas. The original study identifies lithology and structure, geomorphology, soils, land use/land cover and lineaments as important information layers. These datasets can support groundwater exploration and recharge planning when interpreted together with field evidence.

Lithological interpretation helps distinguish different surface materials and geological units. Geomorphic interpretation can identify valleys, plains, slopes and depositional surfaces that influence runoff and infiltration. Drainage analysis provides information about terrain dissection and runoff behaviour. Lineaments may represent fractures, joints, faults or lithological boundaries and are therefore potentially significant for groundwater exploration. However, a remotely sensed lineament should not automatically be treated as a groundwater-bearing fracture; field verification is essential.

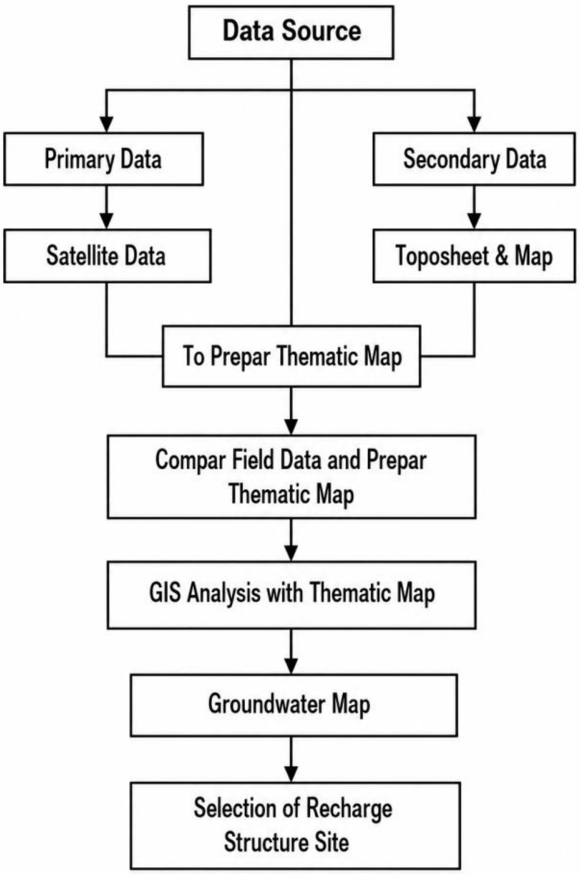
GIS provides an efficient framework for integrating thematic layers. A groundwater-prospect map can be developed by assigning logical or weighted conditions to factors such as geology, geomorphology, drainage, lineament concentration, slope, soil and land cover. The final classification should be validated using existing wells, field observations and, where available, yield and water-level data.

The methodology shown in the original paper follows a practical sequence: primary and secondary data are collected; satellite data and topographic maps are used to prepare thematic maps; field data are compared with the interpreted information; GIS analysis is undertaken; groundwater zones are delineated; and suitable recharge sites are selected. This workflow is appropriate for micro-level watershed planning because it connects spatial analysis with ground verification.

Methodology

The study methodology combines geological investigation, remote sensing, GIS analysis and groundwater-development planning. Primary data include field observations, geological characteristics, surface-water features and information from existing wells where available. Secondary information includes topographic maps and other available spatial data.

The first stage involves preparation of a base map and delineation of the watershed boundary. The second stage consists of preparing thematic information relating to geology, geomorphology, drainage, lineaments, slope, soil and land use/land cover. The third stage is field verification, during which geological exposures, weathering, joints, fractures, wells and other relevant features are observed.



The thematic layers are then integrated in a GIS environment. Areas showing favourable combinations of hydrogeological characteristics can be identified as priority zones. Recharge-site selection should additionally consider drainage position, slope, available storage, land availability, proximity to groundwater-use areas and the possibility of safely storing runoff.

Existing wells provide an important validation dataset. For each well, location, type, depth, seasonal water level, pumping arrangement and approximate yield should preferably be recorded. Repeated measurements are more useful than a single observation because groundwater levels fluctuate seasonally. The source paper proposes dug wells, dug-cum-bore wells and limited development of shallow wells according to geological conditions. These proposals should be implemented only after site-specific scientific investigation.

Groundwater Development Planning

The original study considers the shallow phreatic aquifer to be the principal groundwater-development target and proposes development through dug wells and dug-cum-bore wells. In basaltic areas, dug wells can utilise weathered and fractured shallow zones. Where a newly constructed dug well is unsatisfactory, a bore component may be considered to intersect deeper fractures, provided geological and geophysical investigations indicate a sustainable target.

The source paper gives indicative construction considerations including dug wells of approximately 6–8 m and 15 m depth in basalt and dug-cum-bore wells with a bore diameter of about 100–150 mm and a depth of about 30 m below the bottom of selected dug wells. These figures should be treated as planning guidance from the original study rather than universal design specifications. Actual dimensions and depths must be based on local geology, water levels, drilling results and technical investigation.

The study also notes that alluvial areas are limited and therefore have comparatively less scope for groundwater development. The proposed groundwater strategy should consequently favour structures suited to basaltic conditions and avoid indiscriminate drilling.

Bore wells require particular caution. A bore may intersect a productive fracture, but the fracture may have limited storage or poor recharge connection. Heavy pumping can therefore rapidly lower local groundwater levels. The original recommendations emphasise that bore-well sites should be scientifically investigated and that bore wells should preferably be reserved for drinking-water supply rather than uncontrolled irrigation in areas where sustainability is uncertain.

Artificial Recharge and Watershed Management

Artificial recharge should be regarded as part of an integrated watershed programme rather than as an isolated engineering activity. The basic objective is to slow runoff, increase infiltration where appropriate and improve the availability of groundwater without causing adverse impacts.

Potential measures include check dams, percolation tanks, contour-based soil and water conservation measures and subsurface recharge structures where geological conditions permit. The source study specifically identifies percolation tanks, check dams and subsurface dykes as possible interventions upstream of groundwater-irrigated areas so that stored water can support downstream wells.

Site selection is critical. A recharge structure should not be constructed merely because a drainage line is visible on a satellite image. The site must be checked for foundation conditions, permeability, storage space, catchment area, sediment load, land ownership, downstream effects and groundwater response. In basaltic terrain, recharge is more effective where water can enter weathered or fractured zones rather than remaining above an impermeable massive layer.

Soil conservation is equally important. Contour bunding, vegetative measures, reduction of unnecessary soil disturbance and appropriate agricultural practices can reduce runoff and erosion. Farm-level water harvesting can also reduce pressure on groundwater. The most suitable combination of measures depends on local topography, land use and the observed behaviour of runoff.

Community participation is essential because watershed structures require maintenance. Silt removal, repair of bunds, protection of recharge structures and regulated use of groundwater cannot be sustained entirely through one-time construction. Village-level institutions and local users should therefore participate in planning and monitoring.

Results and Discussion

The integrated interpretation indicates that the groundwater potential of GP-08 is spatially variable. The principal reason is the heterogeneous nature of the basaltic sequence. Massive compact basalt, vesicular basalt, weathered horizons, tachylytic bands, breccias and alluvial deposits do not have identical hydraulic properties. The presence of a geological unit alone is therefore insufficient to predict well success.

The 35 m relief difference across the watershed provides a topographic control on runoff and drainage. Lower-lying areas may receive concentrated runoff and sediment, whereas elevated and steeper surfaces may generate greater runoff and less direct infiltration. Valley zones and suitable gentle-slope surfaces may have better potential for recharge, but their actual suitability depends upon subsurface geology.

Lineaments and fracture zones are important targets for investigation. Where a lineament intersects a drainage feature, geological contact or another structural trend, the probability of enhanced secondary permeability may increase. Nevertheless, these areas must be verified by field observations and, where necessary, geophysical investigation.

The recurring summer scarcity suggests that groundwater demand is not fully balanced by available recharge and storage. Sustainable development should therefore combine limited and carefully selected new groundwater structures with recharge and demand management. Increasing the number of wells without controlling abstraction may provide only short-term relief.

Remote sensing and GIS are particularly valuable for prioritising field investigation. Instead of drilling randomly across the watershed, resources can be concentrated in areas where multiple independent indicators are favourable. This approach can reduce unsuccessful drilling and improve the scientific basis of groundwater development.

An important limitation of the present study is the absence of detailed quantitative datasets in the supplied manuscript, such as a complete well inventory, pumping-test results, seasonal groundwater-level series, aquifer-test parameters, laboratory water-quality data and measured recharge volumes. Therefore, the study supports a qualitative and planning-level interpretation rather than a numerical groundwater budget.

Future work should collect these datasets so that the GIS-based groundwater assessment can be calibrated and quantitatively validated.

Recommendations

1. Groundwater development should be undertaken only after considering the existing level of groundwater exploitation.
2. Geological and hydrogeological investigation should precede construction of new bore wells.
3. Dug wells should remain an important groundwater-development option in suitable weathered and fractured basalt.
4. Dug-cum-bore wells should be considered only where geological conditions indicate deeper fracture potential.
5. Groundwater abstraction for irrigation should be regulated according to seasonal groundwater availability.
6. Existing wells should be inventoried and monitored before additional wells are sanctioned.
7. Artificial recharge structures should be located using GIS analysis followed by field verification.
8. Check dams and percolation structures should be designed according to catchment size, runoff and foundation conditions.
9. Recharge structures should be maintained regularly and protected from excessive siltation.
10. Soil and water conservation should be integrated with groundwater development.
11. Water-quality monitoring should be included, particularly in areas with intensive agriculture and concentrated human activity.
12. Community participation should be promoted for monitoring, maintenance and responsible groundwater use.
13. Remote-sensing interpretations should always be validated through field observations.
14. The reported rainfall value and all location information should be checked against authoritative records before final publication.
15. A long-term groundwater-monitoring programme should be established to evaluate the effectiveness of recharge and abstraction measures.

Conclusion

The GP-08 watershed represents a typical basaltic watershed in which groundwater occurrence is strongly controlled by geological and structural heterogeneity. The recurring summer water scarcity demonstrates the need for systematic groundwater assessment and watershed-level planning. The Deccan Trap basalt sequence contains compact, vesicular, amygdaloidal, weathered and fractured portions, while tachylytic basalt and volcanic breccia occur locally. These units differ in their capacity to transmit and store groundwater.

The study demonstrates that geology, remote sensing and GIS can be effectively integrated for preliminary groundwater-prospect assessment. Remote sensing helps identify spatial features such as drainage, geomorphology, land cover and lineaments, while GIS provides the means to combine these factors and prioritise areas for field investigation. Geological and well observations remain essential for validating the interpretation.

The groundwater-development strategy should focus on suitable shallow aquifer zones, carefully selected dug wells and, where justified, dug-cum-bore wells. Uncontrolled bore-well development should be avoided because deeper fractures may not provide sustainable supplies. Artificial recharge through suitable check dams, percolation tanks and other watershed measures can improve the utilisation of seasonal runoff, provided that the structures are placed on scientifically suitable sites.

Ultimately, sustainable groundwater management in GP-08 requires a balance between recharge, storage and abstraction. The most effective approach is therefore an integrated one combining geological investigation, remote sensing, GIS analysis, field validation, water conservation, scientific well construction, seasonal monitoring and community participation. Such a framework can support more reliable groundwater planning in GP-08 and can also provide a useful approach for other basaltic watersheds of Maharashtra.

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