Management of Groundwater Resource: An Example from Nagukhedi-Dewas Area, Madhya Pradesh, India

Poonam Khare
Assistant Professor & Head,
Deptt.of Geology,
J. V. Jain College,
Saharanpur, U. P.

Pramendra Dev
Professor and Head (Ex)
School of Studies in Earth Science,
Vikram University,
Ujjain, M. P.

Abstract

Nagukhedi – Dewas area in Madhya Pradesh, is facing an acute problem of groundwater levels depletion resulting in shortage of water availability. The study area restricted to the vicinity of Nagukhedi and adjoining area, extending over 147 Sq. Km. in Dewas district of Madhya Pradesh. Physiographically, the area is characterised by typical topography of Malwa Plateau regions. Geologically, the area is occupied by different basaltic lava flows (Upper Cretaceous to Lower Eocene) and alluvium (Recent).Ten different types of lava flows have been recognised. The groundwater occurs under unconfined (phreatic) and confined conditions. The groundwater resources development and supply status is unacceptably low and needs a major transformation. With the rapid growth in population, urbanization, industrialization and competition for economic development, groundwater resource has become vulnerable to depletion and degradation. Management of this valuable resource is determined by its acceptability and value in terms of quantity and quality. Due to imbalance between demand and availability, the management approaches are facing various ethical problems.

Development of groundwater can be obtained by assessment of the groundwater potential and groundwater balance. The groundwater potential for development has been determined by using rainfall-infiltration and hydrodynamic methods. It indicates that the groundwater recharge is 952.56 x 10^4 m^3. The estimation of annual groundwater draft of the study area has been made as 2425.5 x 10^4 m^3, which exhibits overdraft of groundwater 1472.94 x $10^4 m^3$. The overdraft is causing the problem of depletion of groundwater levels in the area. The groundwater reserves can be augmented by implementing a plan of development of artificial recharge structures. Management of groundwater resource can be achieved; the groundwater levels may be augmented by increasing the precipitation through development of forestation, maintaining a balance between the withdrawal and recharge of aquifers.

Keywords: Development, Management, Groundwater, Nagukhrdi - Dewas, Madhya Pradesh, India.

Introduction

Groundwater has always been as an important resource for the sustenance of ecosystem. It is considered to be a readily available source of water for domestic, agricultural development, urbanisation and industrial use. Groundwater extracted for a variety of purposes has made a major contribution to the improvement of the social and economic circumstances of human beings. Inspite of bringing many benefits, with the increase in demand, this resource is being overexploited in many areas resulting in a permanent depletion of the aquifer system and associated environmental consequences like land subsidence and water quality deterioration.

The present investigation has been carried out in the vicinity of Nagukhedi - Dewas and adjoining areas extending over 147 sq. km. of Dewas district Madhya Pradesh in India (Figure 1) .Physiographically, the area is characterised by prevalence of typical topography of Malwa Plateau. The plateau tops rise to the elevation ranging from 510 to 680 m amsl (above mean sea level). These are covered by scrubby forest and have thin or almost lacking soil cover. The drainage pattern is of sub-dentritic nature. The Kshipra River flows mainly during monsoon season provide the main surface drainage. The average annual rainfall is 1044 mm. The temperature varies from 9.6^0 C to 44^0 C, whereas relative humidity ranges from 30 % to 88 % and wind velocity ranging from 7.1 to 27.0 km/hr.

Aim of the Study

The present work has been conducted with the main objective of development and proper management of ground water resource in the vicinity of Nagukhadi – Dewas for resolve the problem of shortage of water supply particularly during summer season.

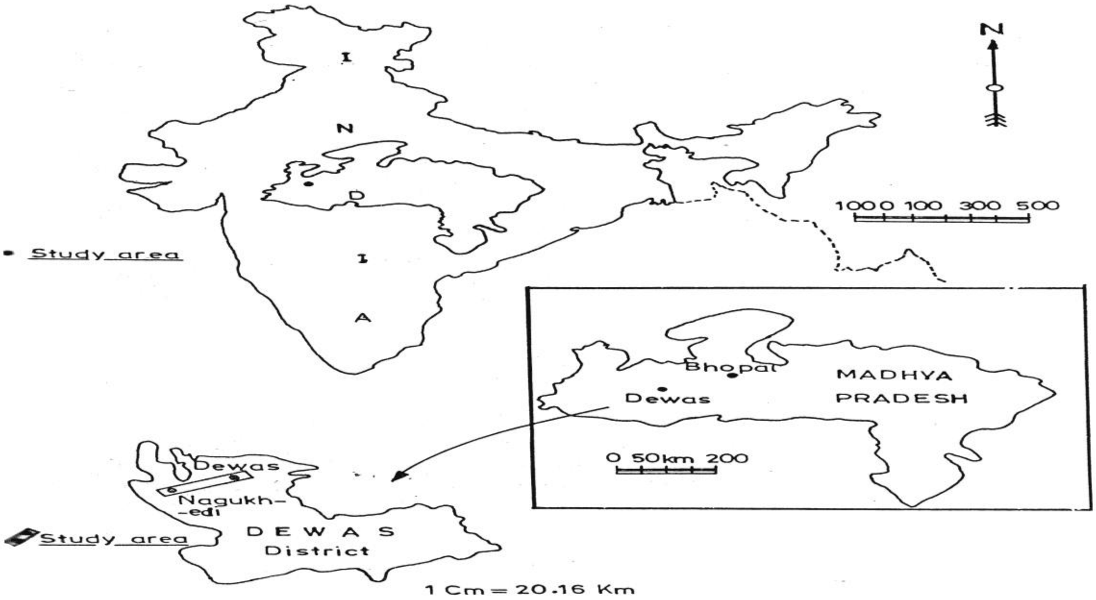
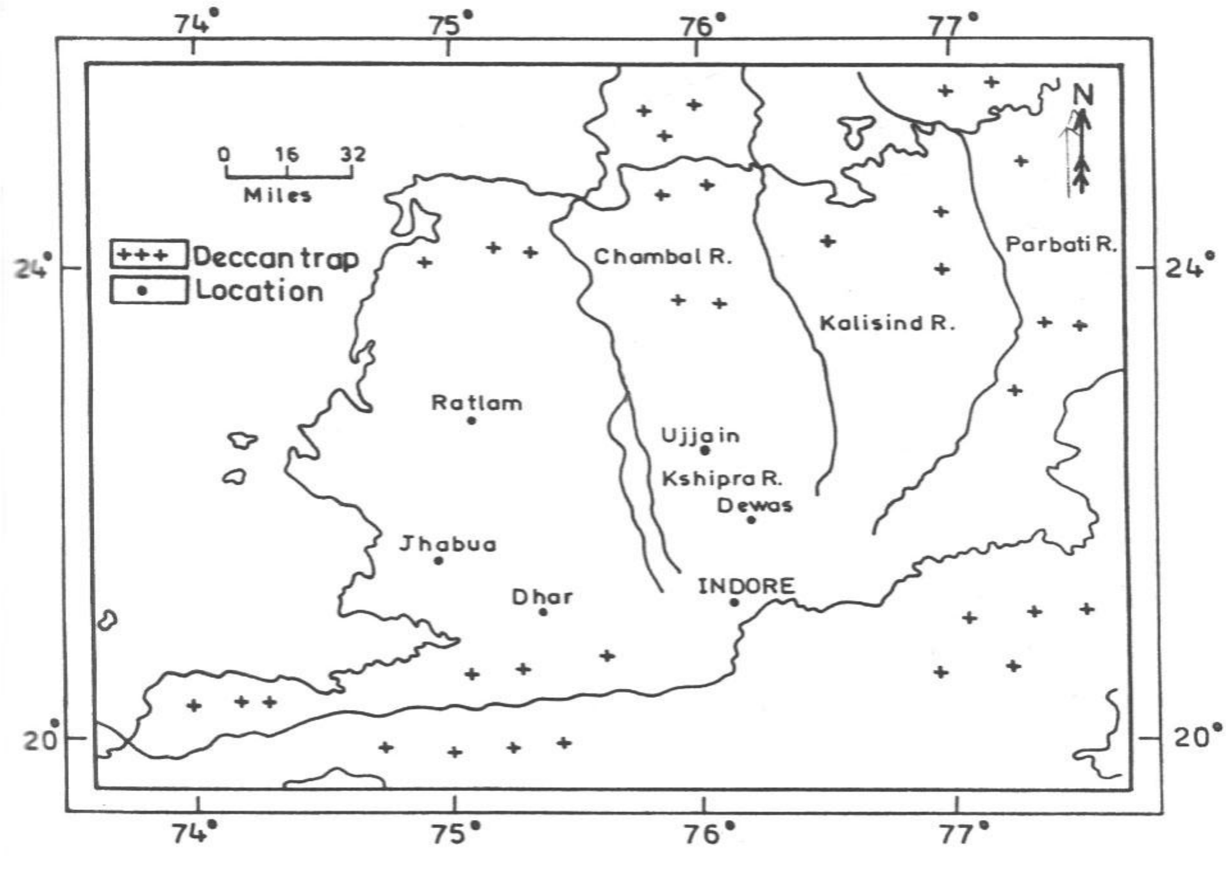


Fig 1 : Location map of Nagukhedi– Dewas district M.P.

Hydrogeologic Setting

The present investigating area in Dewas region, is occupied by basaltic lava flows of Malwa Plateau belonging to the Deccan Volcanic Province (Upper Cretaceous to Eocene). The Basaltic rocks are overlain by the lateritic Soil and alluvial formation (Recent) developed mainly along stream courses and their flood plains (Figure 2).

Figure 2 Extent of Deccan Volcanic Province of Malwa Region



The systematic hydrogeological survey shows that the groundwater occurs under unconfined and confined conditions. The monitoring of static water levels in dug wells indicates a range from 6.0 m to 18.5 m b.g.l (below ground level) and 4.17 m to 15.33 m b.g.l, during premonsoon and post monsoon seasons respectively. The seasonal fluctuation in groundwater levels has been observed within the range of 0.8 m to 5.5 m b.g.l. The groundwater movement is mainly towards the Kshipra River.

Concept of Development and Management

Sustainable development means to meet the needs of the present without compromising the ability of future generations to gather their own needs. It depends on the understanding of processes in the aquifer system, quantitative and qualitative monitoring of the resource and the interaction with land and surface water development.

The Occurrence of groundwater in basaltic terrain has been observed in almost all horizontal flows. The groundwater also occurs under artesian conditions in this terrain. The vesicular and weathered zones in basaltic lava flows have proved high potentiality of water bearing horizons (Adyalkar, 1984). The Deccan basalts serve as a moderate aquifers partly due to their vesicular nature and also due to their jointed and fractured character. Since the flows are horizontally disposed, and are piled one over the other, they constitute a layered aquifer system (Rajurkar *et al*, 1996).

Unmanaged Groundwater development can result in negative consequences, which are mostly the result of aquifer properties. They can be anticipated and taken into account by calculation and modelling. Undesirable effects include prolonged groundwater level drawdown, groundwater storage depletion, interference with springs, pumping induced stream – aquifer effects, subsidence and sometimes water quality deterioration.(Sophocleous, 2003). Groundwater development can generally be achieved at reasonable cost using affordable technology. Groundwater is also very important water resource for alleviating poverty, fighting malnutrition and famine and improving sanitary conditions (Burke and Moench, 2000; Moench 2003).

The examination and analysis of 35 open dug wells in Nagukhedi area reveals that groundwater occurs both under unconfined and confined conditions. The water table aquifers occur near the surface in weathered and jointed zone of massive basaltic lava flows and are being developed by dug wells. The confined conditions are established by more permeable deep aquifers.The monitoring of groundwater levels in the study area reveals a variation within the range 0.5 to 5.5 m (b.g.l). from postmonsoon to premonsoon season. The groundwater levels indicate a decreasing trend which may be described to several reasons including overdraft and or changing rainfall trend, which in turn, affecting groundwater recharge.

The water resource management map has been prepared. It is an integrated version of slope, landuse / land cover and hydrogeomorphological features. It provides valuable clues for selecting appropriate sites for harvesting rainwater (Figure 3, Table 1). It has been possible to pin–point sites for development of rainwater harvesting structures to enhance the groundwater in storage in order to obtain regular water supply. The following structure have been suggested for construction:

Pits and Trenches

These structures can be considered at higher slopes, where contours are closely spaced forming steep slopes for water and soil conservation. Monsoon runoff is collected in these trenches, which retain moisture for longer period to facilitate the plant growth.

Nala Bunding

Small bunds near Karnakheri can be developed for arresting the monsoon water flow.

Stop Dams

The favourable sites for construction of stop dams for irrigation and drinking water supply may be selected near Achlukheri, Rasulpur, Chandana, Lohariya, Mareti and River Kshipra.

Percolation Tanks

The potential sites can be suggested near Anwatpura and Babria with a view to divert the surface runoff to the aquifer. The surface water conserved after monsoon in the reservoir should percolate to aquifer adjacent to river stream course.

Subsurface Dykes

Subsurface dykes are meant for arresting the groundwater flow in downstream. This type of structure can be established near Anwatpura and south of Binjana. The subsurface dykes can be constructed upto 5- 8 m bgl. by excavation across the stream bed.

Loose Boulder Structure

This type of structure is generally constructed in upper reaches or high lands in an area. These structures can be considered particularly in the south – eastern part of the study area.

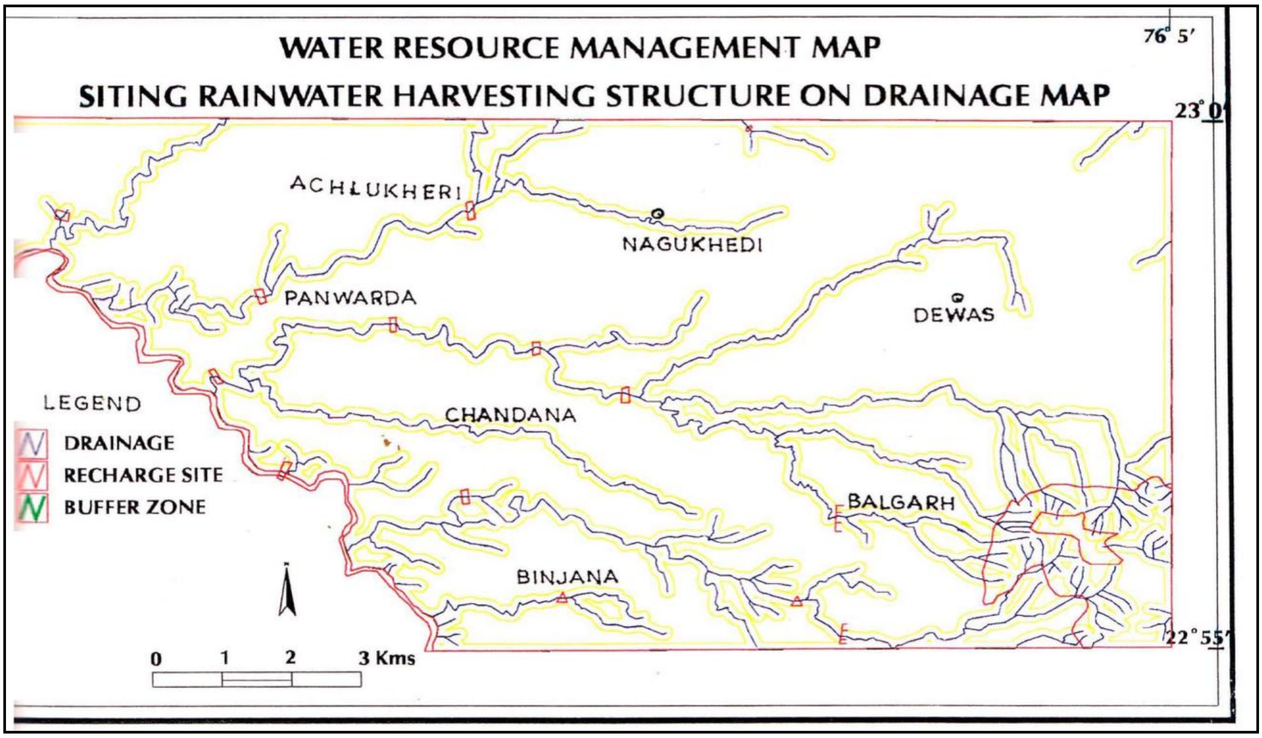


Figure 3 Water Resource Management map for siting Rainwater Harvesing structure on Drainage map.

Table:1 Parameters used for Siting rainwater Harvesting Structures

Hydrogeomorpic unit (Hgm)	Landuse/Landcover units (LS/LC)	Slope	Drainage	Suggested Rainwater Harvesting structures
UDP, MDP Alluvium	2.1 , 2.2 4.4	Very gentle	2nd and 3rd order stream	Stop Dams
UDP, MDP	2.1 , 2.2	Very gentle	1st and 2nd order stream	Sub-surface dykes
UDP	4.4	Very gentle	2nd order stream	Nala bunds
HDP	3.3 , 4.5	Moderate & moderately steep slopes	1st order stream	Loose boulder structures
HDP	3.3	Gentle to moderate	1st order stream	Pits and trenches

Abbrebiations

UDP - Undissected Plateau,
MDP - Moderately Dissected Plateau,
HDP - Highly Dissected Plateau.

2.1 Cultivated Land
2.2 Present Agriculture
3.3 Degraded Forest
4.4 Land with or without scrub
4.5 Barren Rocky / Stony Sheet

Groundwater Potential Estimation

The estimation of groundwater potential is very essential for planned development of the area. (Jeyaram *et. al*. 1996). Groundwater potential of an area has been estimated by Rainfall Infiltration, Hydrodynamic and Groundwater balance. These methods are based on the appreciation of rainfall data, aquifer parameters obtained through aquifer analysis. The relationship of rainfall and infiltration dertermines the groundwater recharge of an area.

Rainfall Infiltration Method

The Groundwater recharge is calculated as follows –

GWR = Area X Rainfall Infiltration Index (RII) X Average annual rainfall

= 147x 10^6x (10 /100) x 1.044m = 1534.68 x $10^4 m^3$.

Hydrodynamic Method

Central Board of Irrigations and Power (CBIP, 1976) and Adyalkar and ShrihariRao (1979) considered that hydrodynamic method provides more reliable values for computation of groundwater recharge, because it takes into account variation in water levels which reflects a lead picture of groundwater regime.

Groundwater recharge = Area x water level fluctuation x specific yield.

= 147x 10^6x 2.16x (3/100) = 952.56 x $10^4 m^3$.

Ground Water Balance

The total groundwater in storage has been calculated by using the average saturated thickness of the aquifers derived from the well inventory studies.

Ground Water Storage = Area x Average satutated thickness x Sp, Yield

= 147x 10^6 x 22.0 x (3/100).= 9702x$10^4 m^3$.

The groundwater draft of the study area has been estimated by observing the average decline in water levels from postmonsoon to premonsoon period.

The annual groundwater draft of the study area has been computed by following formula.

Annual draft = Area x Decrease in water level from post to premonsoon x specific yield.

= 147 x 10^6 x 5.5 x (3x 100) = 2425.5 x $10^4 m^3$

Strategy for Groundwater Development

Water Resource Management is one of the critical universal problem which involves the determination of technique of managing the water supply and water use for human population. The management of groundwater resource objective involves geologic, hydrologic, economic, legal, political and financial considerations (Todd, 1980). In other words, the groundwater management involves the extraction of maximum cost. Duckestein et al (1985) stated that the management or decision making refers to actions affecting the whole complex water resource system based on data collection, forecasting activities, which predict the behaviour of the system.

The water resource management can be completed through surface and groundwater management. Surface water management is a planned development or utilisation of land and water resource for optimum and sustained productions with the minimum of hazard to natural resource and environment. The development operations involve optimum utilisation of natural resources such as soil and water conservation and socio- economic programmes namely ravine reclamation, drought prone areas, tribal welfare and runoff farming (Chakraborti, 1992).

The groundwater can be augmented by employing techniques of artificial recharge. Augmenting the natural movement of surface water into underground formations by some method of construction by spreading of water, or by artificially changing natural conditions termed as Artificial Recharge. It is a planned augmentation of water storage in the ground water reservoir by suitable recharge techniques, which are beneficial for reducing overdraft, conserving surface runoff and increasing available groundwater supplies.

The main sources of recharge to groundwater storage are precipitation.Surface flow and subsurface outflow. Numerous criteria for selection of artificial projects have been suggested by various workers (Todd, 1959, 1980, Charlu and Dutt, 1982: Chaudhary, 1993, Karanth, 2003 and others). Some suggested favourable artificial recharge methods in the investigating area are discussed herein.

Water Spreading Method

It involves releasing water over the ground surface in order to increase the quantity of water infiltration into the ground and then percolating to the water table.

Basin Method

Water is impounded in or released into smaller basins formed by excavation or the construction of bunds. The formation required for basin method is aquifer with limited storage capacity.

Recharge Pit, Injection and Connector Well Methods

The regions, where shallow subsurface strata restrict the downward movement of water, pits penetrating such layers can supply water directly to the underlying materials with higher infiltration rates (Karanth, 2003).

Injection wells or tube wells are used for recharging deep confined aquifers. The recharging water is carried through the confining impermeable layer into the underlying confined aquifer or group of aquifers.

Areas adjacent to perennial rivers the natural recharge to these semiconfined aquifers is so low that it can not meet the water demand. In such areas connector well can help in recharge of the deeper over drafted aquifer.

Induced Method

Induced recharge method can be performed by locating wells/ tubewells parallel to the bank of river or lake. This method is effective in permeable formations and aquifer with limited storage capacity.

The area under investigation constituting a part of Deccan Traps is characterised by topography comprising of plain area or gently undulating area, plateau region, foot hill zone and forested area. In this basaltic terrain, the suitable basaltic structures, which can be considered for increasing groundwater storage are suggested in Table

Management Strategy of Groundwater

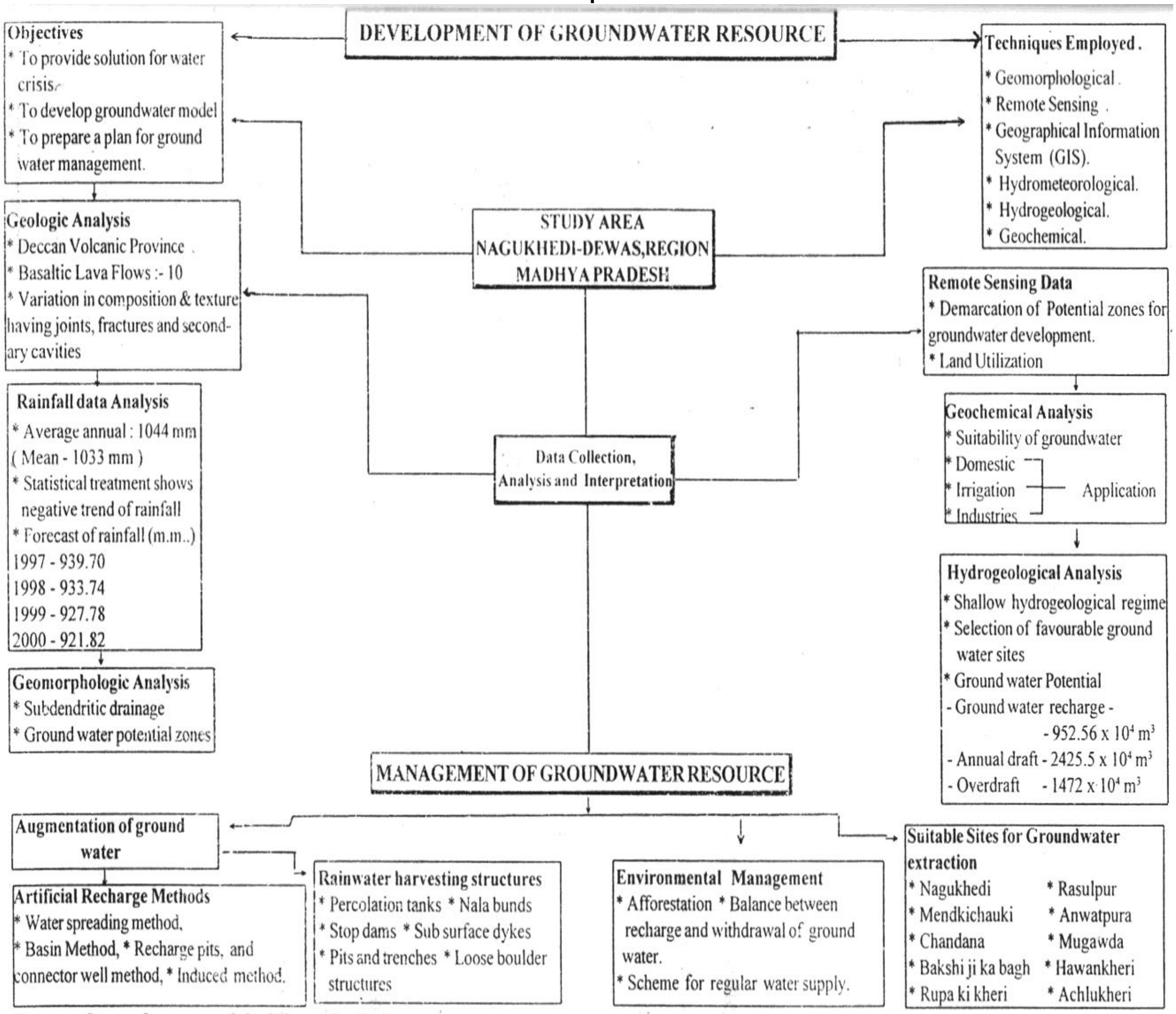
The management of groundwater resource refers to a programmes of development and utilization of subsurface water for specified purpose usually of social and economic nature (Burt,1967).Groundwater management studies have been recognised into four levels and generally not all are required (Amer. Soc, Civil Engrs. 1972: *vide* Todd 1980.. p.358). These are Preliminary Examination, Reconnaissance, and Feasibility and define project. The water resource development can be obtained by conjuctive use which involves the coordinated and planned operation of both surface water and groundwater resources to meet water requirements in a manner whereby water is conserved. Management by conjuctive use requires physical facilities for water distribution, recharge and pumping (Todd, 1980).

The estimated values of groundwater recharge (952.56x104m3) and annual draft (2425 x 104m3) reveals that there is an overdraft of groundwater by 1472.94 x 104m3. The overdraft is causing the problem of depletion of the groundwater levels in the area.

An attempt has been completed to formulate a groundwater model in respect of Nagukhedi area by using Remote Sensing Data and Geographical Information System (GIS). to simulate model (Figure 4) These techniques have been employed through integration of map information and followed by a few selected field verifications. ARC / INFO software has been used for GIS analysis to develop a groundwater model of Naghukhedi area.

Satellite imagery data and application of GIS technique has enabled in visualizing a data base ground water development model. The formulated model has been displayed by graphic representation technique (Figure 4).

Figure 4 Groundwater Model of Nagukhedi – Dewas Area, M.P. based on Integrated Remote Sensing Technique



Conclusion

Groundwater is a finite but renewable resource that is intrinsically linked to surface water and other natural resources. It is generally a more reliable freshwater resource than surface water that can be readily developed to meet human needs and agricultural demands. The strategy of groundwater development and management has been discussed. The groundwater can be augmented by the construction of artifical structures and phenomen of rainwater harvesting.

Acknowledgement

The authors are sincerely thankful to the authorities of Vikram University, Ujjain, for providing necessary research facilities. Sincere thanks are due to Mr. Dayaram Solanki for generous assistance.

References

1. *Amer. Soc. Civil Engrs.(1972) Groundwater Management. Manual Engg.Practice,40, 216 p.*
2. *Burt, O. (1967) Temporal allocation of groundwater, Water Resources Research, vol. 3 p. 45-56.*
3. *Burke, J.J. & Moench, M.H. (2000). Groundwater and Society: Resources, Tensions and Opportunities. ST/ESA/265, United Nations: New York, 1–170.*
4. *CBIP (Central board of Irrigation and Power),(1976). Manual on Groundwater and Tubewells.Govt. of India, New Delhi, Unpublished Report 411 p.*
5. *Chakraborty A.K. (1992). Strategies for Watershed Management using remote sensing techniques. Nat. Symp. "Remote Sensing for Sustainable Development" Lucknow, p. 1-8.*
6. *Chaudhary, K.K. (1993). Planning and design of Artificial Recharge structures in basaltic rock aquifers with case histories. Workshop "Artificial Recharge of groundwater in basaltic and sedimentary rock aquifers" , Indore.*
7. *Charlu, T.G.K. and Dutt, D.K. (1982). Groundwater Development in India. Rural Electrification Corporation New Delhi, Tech Ser. No. 1,228p.*
8. *Gorelick, S., (1983) "A review of distributed parameter groundwater management modelling methods", Water Resources Res., vol. 19, no 2, p. 305-319.*
9. *Duckstein, L., Ambus, S. and Davis, D.R. (1985).Management forecasting requirements.In Hydrological Forecasting, Edited by M.G. Anderson and T.P. Burt, John Wiley and Sons Ltd., New York, p. 559-585.*
10. *Karanth, K.R. (2003). Groundwater Assessment, Development and Management.Tata Mc – Graw Hill Publ. Co. Ltd., New Delhi, 720 p. (Reprint, 1987, 1994).*
11. *Jeyaram, A., Mohabey, N.K., and Krishnamurthy, Y.V.N. (1996).Groundwater Potential using Remote Sensing and Geographical Information System, "Mineral and Groundwater Resources of Vidarbha". Deptt.Geology, Nagpur Univ. Nagpur, Symp.Vol. p.257-267.*
12. *Rajurkar, S.T,; Ayyangar, R.S.; Khare, Y.D. and Bedekar, R.N. (1996). Vidarbha from Space: A Geoinvironment Appraisal. "Mineral and Groundwater Resources of Vidarbha". Symposium vol., Nagpur, p. 269-291.*
13. *Sophocleous, M. (1997). Managing water resources systems: why "safe yield" is not sustainable. Ground Water, 35 (4), 561.*
14. *Todd, D.K.(1959,1980). Groundwater Hydrology, John Wiley and Sons Inc., NewYork.535 p.*