IOSR Journal of Applied Chemistry (IOSR-JAC)
e-ISSN: 2278-5736. Volume 3, Issue 5 (Jan. – Feb. 2013), PP 16-23
www.iosrjournals.org

Ground Water Resource Assessment: A case study on Murthal Block of Sonipat District

Rajesh Bhagwat Jadhao
[1]*(Sr. Assistant Professor, Department of Applied Science and Humanities, Faculty of Engineering and Technology, Jamia Millia Islamia,New Delhi, India)*

ABSTRACT: *This paper deals with the groundwater resource assessment of Murthal block in Sonipat District. The hydrogeological and geophysical techniques are used to excavate information about ground water in the area. It is completely based on primary research conducted on the area.*
Key Words: *Geophysical Investigation, Hydrogeological techniques, Groundwater Assessment*

I. INTRODUCTION

Optimum economic development of water resources in an area requires an integrated approach that coordinates the use of both surface water and groundwater resources. After evaluation of total water resources and preparation of alternative management plans, action decisions can then be made by the bodies that are going to utilize the water resources of the area in future.

The management of groundwater basin in an area implies a program of development and utilization of subsurface water for some stated purpose. For groundwater extraction water wells are drilled and it is presumed that production of water will continue indefinitely with time. This only happens if there exists a balance between water recharged to the aquifers from the surface sources and water pumped from the aquifers by wells. Typically, the development of water supplies from groundwater begins with a few pumping wells scattered all over the area. With the passage of time, more wells are drilled and the rate of extraction increase, as a result the aquifer discharge increases to its recharging capability. Continued water extraction without a management plan could eventually deplete the groundwater resource.

By regulating inflow and outflow from the basin, an underground reservoir can be made to function beneficially and indefinitely just as a surface water reservoir. Forecasts of future water demand suggest that mismanagement or lack of management of major groundwater resources cannot be permitted if adequate ongoing water supplies are to be provided

GROUND WATER QUALITY

Groundwater quality studies are conducted by collecting groundwater samples from the area. The samples were analyzed in the laboratory following the IS-10500 norms.

GROUNDWATER QUANTITY

Depth to Water Level: The depth to water level in the study area is shallowest in the southern part and deeper water tables occur near the northern boundary. The shallowest water table occurs at a depth of 10 – 12 m below the existing ground level. The deepest water table occurs at the depth of 13 m b.g.l.

Water Level Fluctuation: The maximum water fluctuation of 2.7 m. is seen in northern side of the area. From north to south, the fluctuation gradually decreases showing the least value in the southern most part.

Groundwater Movement: The groundwater flow in the study area is from north to south.

Groundwater Potential: The groundwater potential is the capacity of the aquifer or groundwater reservoir to discharge water. The tube wells have been located in the high groundwater potential zone and are shown on the layout plan.

Groundwater Availability in the area: The existing tube wells in working condition within the sites are two in numbers. Two more tube wells are proposed around the site. Two tube wells can serve the water requirements. The draw down and discharge of the existing tube wells are given in Table The Geophysical sounding data at the area and Terrameteric Investigation for tube well site selection is given in Table given Below . The proposed tube well sites are given in Layout Plan.

The gross recharge of the area is calculated as follows:

Location of the study area

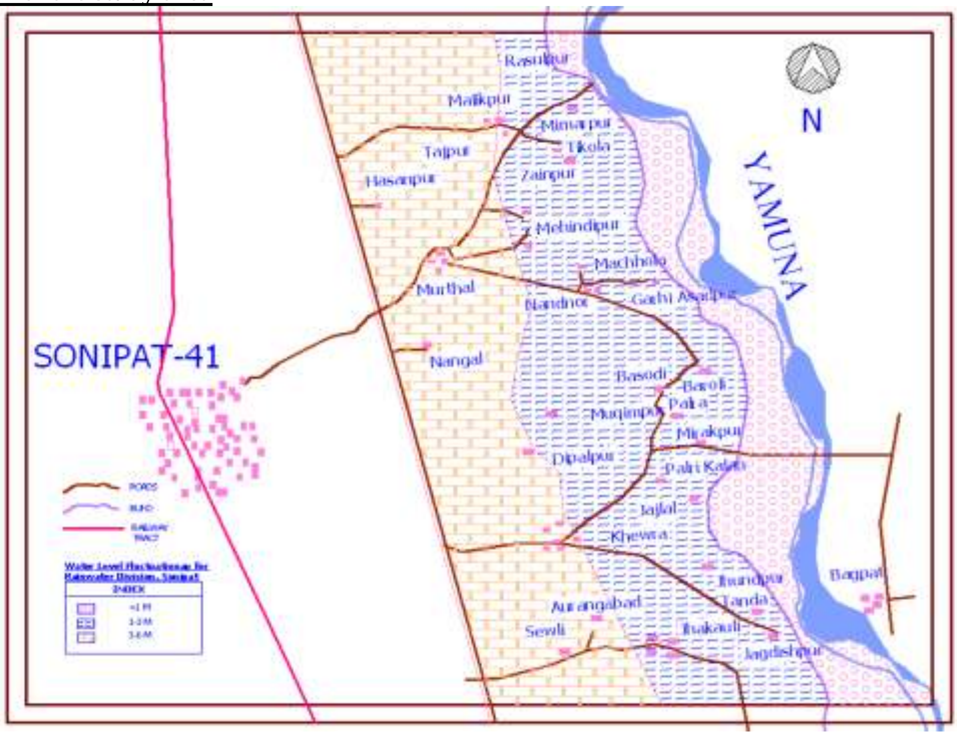

Table 1: Present Groundwater Development Status in the area of influence when the groundwater has been withdrawn nominally from the area by means of hand pumps, shallow tube wells etc for 365 days in one year.

Area (m^2)	Sp.yield (%)	WLF	Gross Recharge Q=A*S*WLF (m^3)	Recoverable recharge I=70%Q (m^3/year)	Draft O (m^3/d)	SWD (O/I)%	Category
24000000	0.2	5	24000000	65753.42	46027.40	11.51	White

The recoverable recharge I i.e. 70 % of the gross recharge (Q) is calculated in the same table. The hand pumps and minor shallow tube wells have been considered for draft in the area under the influence of proposed tube wells groundwater regime. 2 tube wells are proposed in the area, which will run only for 300 days in the year. The Stage of Groundwater Development (S.W.D) = O/I % are also calculated.

S.W.D <= 65% White category
S.W.D 65%-85% Grey category.
S.W.D > 85% Black category.

Hence the area under the influence of tube wells falls under the White category.
5 Ranney Wells are proposed in the area. The withdrawal from one Ranney Well is 13 MLD. Hence from 5 such Ranney wells, the total withdrawal will be 65 MLD.

Table2: Terrameteric Investigation for the proposed tube well site selection.

S.No.	Tubewell No.	Bore well dia (inches)	Depth (m)	Water Quality	Discharge (Liters/hr)	Machine
1	L1-L60	18 – 22	35 - 40	Moderately Hard & Alkaline	15000-20000	Reverse Rotary

Recommended Locations: Except tube well numbers L45 To L52 all the tube wells are in good quality zone.
The above discharge will be maintained after adaptation of Designed Rainwater Harvesting System in the area

GROUND WATER QUALITY AND QUANTITY

GROUND WATER QUALITY
The Groundwater Quality were tested as per IS: 10500 the recommended code for Drinking Water Standard by the Indian Standard Bureau. Table 4.1 below gives the ideas about the Maximum and the Minimum concentration in the area.

Table 3: Groundwater Quality at Sector 9 Kundly , Sonipat

S. NO.	PARAMETERS	UNIT	RESULT	PROTOCOL FOLLOWED IS :10500
PHYSICAL PARAMETERS				
	Colour	Hazen Unit	1.6	5.0
	Odour	Unobjectionable	Unobjectionable	Unobjectionable
	pH	Nil	5.7-8.5	6.5 – 8.0
	Turbidity	N.T.U.	1.5	5.0 N.T.U.
CHEMICAL PARAMETERS				
	Total Hardness	Mg/l	450-750	300 –600
	Nitrate	Mg/l	11-25	10-45
	Chloride	Mg/l	50-500	200 – 300
	Fluoride	Mg/l	0.11-.15	1.0 – 2.0
	Sulphate	Mg/l	76-100	100 – 200
	Iron	Mg/l	0.3-0.5	0.3 – 1.0
	T.S.S.	Mg/l	Nil	No Relaxation
	T.D.S.	Mg/l	130-800	500-2000
	Oil	Mg/l	Nil	No Relaxation
	Phosphate	Mg/l	10	10 – 20
BIOLOGICAL PARAMETER				
	Coli form	MPN/100ml	Nil	<2.0

T.S.S. : Total Suspended Solids, T.D.S. : Total Dissolved Solids

REMARK: The water may be used after treatment by R.O.for Domestic but can be used directly for Horticulture purpose with the amendment like Filtration and Coagulation. In case of absence of other alternative it may create Scaling action in the Air Condition due to excessive pH ,Hardness and Total Dissolved Solids. Almost all the parameters eg. TDS and Hardness were found within Maximum permissible limits of IS: 10500 but requires treatment like Ion Exchange or Reverse Osmosis in the sensitive areas like Residential areas and Air Condition units.

Hydro geological Investigations: These are conventional methods and widely adopted by different organizations. These include apart from borehole lithology, depth to water level, water level fluctuation, groundwater movement direction, dispersion rate of the strata, general quality of groundwater (through electrical conductivity) and discharge from tube wells etc.

II. CONJUNCTIVE USE OF WATER

The conjunctive use involves the coordinated and planned operation of both surface water and groundwater resources to meet water requirements in a manner whereby water is conserved. Coordinated use of surface water and groundwater does not preclude importing water, as required, to meet growing needs. The basic difference between the usual surface water development with its associated groundwater development and a conjunctive operation of surface water and groundwater resources is that the separate firm yields of the former can be replaced by the larger and more economic joint yields of the latter.

Management by conjunctive use requires physical facilities for water distribution, for artificial recharge, and for pumping. The procedure does require careful planning to optimize use of available surface-water and groundwater resources.

A conjunctive use management study requires data on surface water resources, groundwater resources, and geologic conditions; data on water distribution systems, water use, and waste water disposal are also necessary.

This conjunctive use management plans in the area requires the data regarding:

i) Water Requirement of the study area
ii) Water Availability in and around the study area

Factors Affecting the Rate of Water Demand

The demand for water varies from town to town and factors which may affect the rate of demand of water are as follows:

- Climatic Conditions
- Habits of People
- Efficiency of the Water System
- Quality of Water

Climatic Conditions: The consumption of water depends upon the climatic conditions of the place. In warm countries like India and particularly Delhi, water required in summer will be much more than in winter as more watering of gardens, more bathing, more air-conditioning, more watering of parks and fountains etc. would be done. Therefore, the consumption increases in summer season.

Habits of People: The consumption of water depends upon the economic status of the consumers and will differ widely in different localities in the same city. In posh localities, like in case of site, the consumption per capita will be high while in slum areas, a common tap may serve several families and thus the consumption per capita would be low.

Efficiency of the water supply system: Efficiency of the waterworks will affect consumption. Leaks in mains, unauthorized connections, etc., increase losses and hence the consumption.

Quality of Water: The consumption of water varies directly with the quality of water. If the quality is good, then the consumption will be high while the consumption will be low if the water has an unpleasant odor or taste, such that in case of saline water or sewage water leakages in the main water supply.

Water Requirements

The consumption of water can be divided into the following categories:

i) Water Supply for Human Consumption
ii) Institutional/Hospital requirements
iii) Horticulture and Landscaping
iv) Intermittent Requirement

Geophysical Investigations: To carry out Terrameteric Investigations at the site at two levels, i.e., Macro Level grid using 'Uni-Pole' method and Micro Level Grid using 'Dipole' method. Through this detailed field investigation a clear profile of sub-soil strata such as aquifer is known. The trough and the crest of the aquifers strata and their qualitative characteristics are delineated. The orientation and dimension of the fracture zones and their depth are to be analyzed. The data generated through this investigation is hereby used in proposing the installation of Infiltration wells for rainwater Restoration and tube wells, especially suited for the strata.

Hydrogeological Studies: The hydro-geological studies for the study of the depth to water level, water level fluctuation and groundwater movement direction as well as groundwater quantity and quality potential are to be studied in order to locate the infiltration wells. The groundwater movement direction is to be known in order to locate the Infiltration wells in the upstream areas and the tube wells in the downstream areas. Quantity and quality wise, comparatively higher quantity and quality zones are to be considered for tube well installations and the medium to low potential areas for the injection wells.

Methodology Adopted

1. The study area is divided into different zones as macro and micro- level grid pattern according to the physiographic condition.
2. The Terrameteric Investigation is carried out at the Macro level grid using the Uni-Pole method and at the Micro level grid using the Dipole method. The Macro level study is done for general vision of the sub-surface strata and the Micro level is for the localized details.
3. The data are analyzed using the Geomac III field analyzer and the Configuration was used as Schlumberger using the RESIX V.2 software.
4. The aquifer system is delineated with the Terrameteric Interpretations and the trough and the crest of the aquifers is located in the field for the locations of the Infiltration wells and tube wells.
5. The orientation, dimension and the location of the fractures are analyzed.
6. The Meteorological Department's rainfall data were used for the rainfall intensity and pattern calculations in and around the study area.
7. The isohytal maps, which represent the points of equal rainfall, were also taken into consideration in order to establish the relation between Rainwater Restoration Potential and rainfall in the study area.
8. The average rainfall of the study area is integrated at the rooftop area and open space areas of different zones in monsoon months for rainfall restoration.
9. The Hydrogeological studies related to the depth to water level, groundwater movement directions are done by the Terrameteric study and interpretations. The water level fluctuation in the area is studied through the data available from CGWB Delhi. The groundwater quantity and quality potential is also studied through the Geophysical investigations in the area.
10. Water Quality Testing by collecting water samples from the study area as per the IS-10500.

Geophysical Methods: Geophysical techniques in soil-water research form an important component of Water Resources Development and Management, which is defined, as is the logical compulsory approach to explore and assess the available water in the light of its withdrawal and recharge. The widely used geo-electrical method is helpful in analyzing sub-surface lithology, soil salinity, groundwater exploration, ground water quality and aquifer characteristics. Geophysical techniques work on the basic concept of determining and understanding the physical contrast in the soil-water systems. These contrasts are expressed by measurable physico-chemical parameters such as electrical resistively or conductivity of the sub-surface configuration. Information on general geology and hydro-geological conditions are essential to arrive at meaningful conclusion from the geophysical data at a given location.

Principles of artificial recharge of groundwater: Artificial recharge is the process by which the groundwater reservoir is augmented at a rate exceeding that under natural conditions of replenishment. Any man made scheme or facility that adds water to an aquifer may be considered to be an artificial recharge system.

There are many reasons why water is deliberately placed into storage in groundwater reservoir. A large percentage of artificial recharge water projects are designed to conserve water for further use.

From the point of view of artificially storing water for future, use, the basic requirement is to be able to obtain water in adequate amounts and at the proper times in order to accomplish this goal. Some schemes involve the impoundment of local storm runoff, which is collected in ditches, basins or behind dams, after which it is placed into the ground .In other localities; water is sometimes brought into the region by pipeline or aqueduct. In the latter case, the water is an import and represents an addition to whatever natural water resources occur in the region. A third approach is to treat and reclaim used water being discharged from sewer systems or industrial establishments. In certain coastal area of the world, notably in Israel, the Netherlands and the western part of the United States of America (California), artificial recharge systems are in operation in order to block inland encroachment of sea water. Most of these schemes rely on the injection of fresh water through wells in order build up a pressure barrier that will retarded or reverse encroachment of salty water that has resulted from excessive withdrawals from the wells. In schemes of this type, most of the injected water is not directly available for reuse, but serves as hydraulic mechanism to allow a better use of existing groundwater reserves.

In a few places, where heavy withdrawals of the groundwater has resulted in subsidence of the surface of the land, attempts have been made to overcome the problem by forcing water under pressure into groundwater reservoirs. The success of re pressuring to stop subsidence is inconclusive.

Disposal of liquid wastes is another means of artificial recharge. Sanitary sewage, for example may be filtered, chlorinated or otherwise treated, and then allowed to filter into the ground through spreading areas or special passing and pits. Sometimes, streams of this kind are adopted simply to avoid the cost of constructing long sewer mains. A similar type of operation takes place on many industrial sites, where liquid plant wastes may be placed into artificial recharge facilities. Storm water is collected in some places, as a means of artificial recharge to reduce the cost that otherwise would be incurred in transporting the water to distant areas of disposal.

Another deliberate type of groundwater recharge, which is often overload because it is not correctly concern the water supply, is the injection of the waters into wells to speed up extraction of oil. In this approach, which is referred to technically as “secondary oil recovery”, oil is forced through the ground towards producing wells by the hydraulic head of water build up around artificial recharge wells. In other words, forcing water into an injection well creates a recharge cone, and the head of the injected water raise the oil through the geological formation towards an oil production wells.

However, as noted above, man plans most artificial recharge projects for the specific purpose of saving or storing fresh water for subsequent use. Among these projects some may serve the dual purpose of eliminating objectionable amounts of water at the land surfaces and, at the same time putting this water into reserve for eventual extraction.

Two hydraulic effects are generated by artificial recharge, as a result of the head, which is applied in the recharge area and the mass of the water, which is introduced into the aquifer through the recharge area, the Piezometric effect and the volumetric effect. The Piezometric effect results in a rise in the Piezometric surface in the unconfined aquifers and /or a rise of the artesian pressure in the confined aquifers. The Piezometric effect is related to three main factors. First, it is related to factors which create a damping effect is related to shape of the Piezometric surface to the geological and hydraulic boundaries of the aquifer and to the type of location of the recharging device secondly, it is related to quotient T/C (T= Transmissivity coefficient; C= Replenishment coefficient which is equivalent of storage coefficient).Thirdly, it is related to the artificial recharge yield and the duration of operation. Other factors such as capillary forces water temperature and presences of air bubbles in the aquifers also have in impact on the Piezometric effect.

The volumetric effect is related to specific yield, replenishment coefficient, the transmissivity coefficient and the boundary coefficient model studies that were checked through filled experiments have demonstrated that the bulk of the recharge water move according to the two systems of flow .One results in a spreading out effect, with a speed related to the recharge flow; the other in the sliding effect, with a speed related to ground water flow.

A thorough and detailed knowledge of geological and hydrological features of the area is necessary for adequately selecting the sites and the type of recharge .In particular, the following features, parameters and data are to be considered geological boundaries; hydraulic boundaries inflow and outflow of waters; storage capacity; porosity; hydraulic conductivity; transmissivity; natural discharge of springs; water resources available for recharge; natural recharge; water balance; litho logy; depth of aquifer ; and tectonic boundaries

Aquifers best suited for artificial recharge are those aquifers, which absorb large quantities of water and do not release them too quickly. Theoretically this will imply that the vertical hydraulic conductivity is high, while the horizontal hydraulic conductivity is moderate. These to conditions are not often encountered in nature. Among the hydro geological structures that are most frequently utilized for artificial recharge schemes, the following deserve special mention. Carbonate Karstic ranges and plateaus can absorb large amount of water, but often release these waters shortly after their infiltration through large springs fed by fast flowing underground springs. In some region well below the level of the outlets can minimize the volume of discharge after recharge. Examples of such groundwater reservoirs can be found in the Mediterranean region. However most of the existing recharge areas are located in alluvial plains, as such structures are favourable to groundwater storage both from the point of view of the availability of infiltration waters and from the point of view of the transmissivity of the aquifer. However, adverse conditions are often associated with these structures, namely limited storage capacity; low amplitude of fluctuations; and lack of storage availability owing to high water table levels when recharge water is abundant. In fact in many alluvial valleys a lowering of the water table generated by high yield pumping is often a prerequisite for an artificial recharge operation.

Under temperate humid climates, the alluvial areas which best lend themselves to artificial recharge schemes are the ancient alluvium, the buried fossil river beds and the interlinked alluvial fans of main valleys and there tributaries. In the arid zone, recent river alluvium may sometimes be more favourable then in humid zones, because the water table is subjected to pronounced natural fluctuations. Coastal dunes and deltaic areas are often very favourable for artificial recharge schemes. In addition, dense urban and industrial concentrations in such areas may render artificial recharge schemes necessary. Artificial recharge is planned with double purpose of increasing the availability of water supply and protecting the aquifers against sea water intrusion.

Large sedimentary hydro geological basins dominantly contain artesian aquifers, which store large volumes of water. Artificial recharge schemes are the exception in such areas. In general, the areas, which are the first selected for artificial recharge projects, are those where water table levels are substantially lowered as a result of an over draught or as a result of a deficit in natural recharge.

Rainwater harvesting in the study area

It is expected that out of the total area of **8176.96 sq.m.** the built up area may be 50 % (**4088.48 sq.m**), Road area may be 20 % (**1635.39sq.m**) and rest 30% (**2453.08 sq.m**) area will be Open Green Hence Using the Formula

Q= CIA

The rainwater potential of the areas in the site is given in Table 4

Table showing Rainwater Harvesting at Site

The following factors have been considered for the total plot area =**24000000 sq.m**. which is

a. 40% Building = 9600000 sq.m
b. 20 % Roads = 4800000 sq, m.
c. 40 % Open Space = 9600000 sq. M

Table 4 Rainwater Harvesting calculation for the study area.

Type	**Area(m^2)**	**Co-efficient of runoff**	**Intensity of rainfall (m)**	**Quantity of rainfall (m^{3}/year)**
Roof top	9600000	0.85	0.6	4896000
Roads	4800000	0.75	0.6	2160000
Open area	9600000	0.3	0.6	1728000
Total				**8784000**

Hence the Rainwater Harvesting can further add **8784000** m^3/year and total groundwater potential works out to be sum of recoverable recharge and that available through rainfall is and therefore we can get 70093.15 m^3/day.

Conclusions and Recommendation: The study area is situated near Murthal &Rai Block of Sonipat Haryana. The total area of proposed is 24 Sq.Km. The average annual rainfall is about 600 mm, falling mainly during July and August.

The water requirement of the the area can be described under the following heads:

Water Supply for Human Consumption
Commercial requirements
Horticulture and Landscaping

On the basis of gross recharge including Rainwater Harvesting 60 tube wells have been recommended for the area with 16 hour duration without Rainwater Harvesting.

In general the area has medium Hard Water upto depth of investigation 50-65 meters.

The area requires 400 MLD of Water for the supply. Apart from 60 tube wells working for 16 hours a day and discharge of 15000-20000 G P H(1 MLD /tube well),5 Ranney Wells have also been proposed. About 60 MLD of water can be withdrawal from the proposed tube wells.65 MLD can be withdrawal from 5 Ranney Wells at the rate of 13 MLD per Ranney well. The remaining water can be withdrawn from the canal. The only remedial measure to the areas is Designed Rainwater Harvesting System. The study area shows the discharge of tube well will be in medium range. This is found in general that the aquifers in this area are in unconfined to semi confined and confined condition. The strata may yield medium discharge on a continuous basis. The expected water quality will be Moderately hard with a discharge capacities varying from 15000-20000 Gallons/hour.

The appropriate drilling technique with suitable drilling may be undertaken for the installation of the tube-wells.

The drilling depth may be taken as 50-65 m for recommended Site Location in general. However the Lowering Depth including the design of the Tubewell assembly must be decided on the basis of Geo-Physical Logging, in order to avoid salinity.
In order to develop Groundwater Potential and to improve the quality and quantity of Groundwater and as well as the life of the tubewell, Rainwater Harvesting System may be adopted for recharging and dilution of salinity.

- ✧ As per pump Test data analysis it is found that the uniform and continuous discharge with sand free water is 15000 – 20000 liters / hr for the area .
- ✧ Taking the aquifer parameters and field conditions 3-5 H. P. KSB submersible pump may be installed with the specification as per stage. However, the stage may vary as per the distribution system.
- ✧ Lowering depth of the pump found to be 17-27 m from the Ground Level.
- ✧ The pump should be installed in the Blind Pipe zone/Rocky Strata in order to avoid cracks in Filter. This may be verified with the assembly given in the Logging Report.

Specific Recommendation

1. 60 Tube wells and 5 Ranney Well can be proposed in the area.
2. The Designed Rainwater Harvesting System will improve the Salinity by Dilution method.

REFERENCES

[1] Abrahim Philip (1998) Watershed Management – Objectives and Strategies (Proceedings of Int. Conf. Watershed Management), CBIP, New Delhi (91-98).
[2] Ala Eldin M.E.H., Sami Ahmad M., Gurunadha Rao, Dhar R.L. (1998) Groundwater Modelling In Parts of Central Ganga Basin, Uttar Pradesh, India. Technical Report. No. AMU/NGRI-1, Collaborative Project between Remote Sensing Centre Application for Evaluation and Geo-Engineering, Aligarh and NGRI.
[3] American Public Health Association, 1975, Standard Methods for the Estimation of Water and Water Waste, 14th Ed., APHA, Washington, D. C.
[4] Armstrong & Armstrong, "Measurement & Modeling of Oxygen Release from Roots of Reeds". Proceedings of the International Conference on Constructed Well and Water Pollution Control.
[5] Babu Rao P., Sreenivas Prasad P., Iftekhar Ahmad S. (1998) Watershed Management and Consequential Conservation / Augmentation to Groundwater Resources (Proceedings of Int. Conf. Watershed management 8 –10 Dec. 1998), CBIP, New Delhi (259-268).
[6] Back, W. and Hansaw, B. B. (1965) Chemical Geohydrology, Ad., Hydrscience, 1, 49-109.
[7] Baweja, B. K. and Karanth, K. R. (1980) Groundwater Recharge Estimation in India, tech. Sr. H., Bull. 2, Central Groundwaer Board.
[8] Boom A.G., Report of a visit by memebers & staff of WHO to Germany to investigate Root Zone Method, Steve UK, 1985.
[9] Bouwer, H., Groundwater Hydrology, McGraw –Hill, New York, 480 pp., 1978.
[10] Chaturvedi, R. S., and Pathak, P. M. (1964) Flow of Groundwater Towards Pumping Wells and the Optimum Yoeld under Varying Geohydrological conditions, C.E. Univ. of Roorke.
[11] Christensen S., Rasmussen K. R., Moller K., (1998), Prediction of Groundwater Flow to Streams, Groundwater, vol. 36, No. 2 Mar-April 1998 (351-360).
[12] Chopra, S. (1990) A Geological Cum Geomorphological Framework of Haryana and Adjoining Areas for Landuse Appraisal Using LANDSAT IMAGERY. Photonirvachak, Jour. Ind. Soc. Of Remote Sensing, Vol. 18 No. 12. pp. 15-22.
[13] Chow, V. T.(1964) Handbook of Applied Hydrology, Mc Graw – Hills Co., New York, 4, 39-76.
[14] Daubenmire, R. F. (1974) Plants and Environment, Willey Eastern Pvt. Ltd. , New delhi
[15] Field Manual on Watershed Management by Central Research Institute for Dryland Agriculture, Hyderabad (1998).
[16] Geiger, W. F. et al (1987) Manual on Drainage in Urbanised Areas. Vol. 1., Planning and Design of Drainage System, UNESCO.
[17] Gooper, Pf., Hubson J. A. & Joens. Sewage Treatment by Reed Bed Systems, Journal of the Insititute of Water & Environment Management.
[18] Hantush M. S.(19660 Analysis of daa from Pumping Test in Leaky Aquifers, Trans. Am. Geophysics Union, 35, 468-470.
[19] Hjelmfet, A.T., Cassidy, J. J. (1975) Hydrology for Engineers and Planners
[20] Horton, R. E., 1932, Drainage Basin Characteristics
[21] Hyden, H. H. , 1913, Relationship of Himalayas to Indo-Gangetic Plains and the Indian Peninsula, Roc. Geol. Surv. Ind. Pt. 2, 43, 138-167.
[22] I.C. M. R., 1975, Manual of Standards of Quality for drinking water Supply. ICMR, New Delhi.
[23] Indian Standard, 1983, Drinking Water Standard Table-1, Substances on Characteristics Effecting the Acceptability of Water for Domestic Use.
[24] Kamalam Joseph, Jose K. I. (1998), A Study of the Watershed Development Programme – Lessons Learned and Suggestions for Future, (Proceedings of Int. Conf. Watershed Managemnt 8-10 Dec. 1998), CBIP, New Delhi (234-241).
[25] Konikow Leonard F., Reilly Thomas E. (1996) Handbook of Groundwater Engineering, U. S. G. S. Publication.
[26] Krishnan, M. S., 1968, Geology of India and Burma, Vth ed., Higginbothamas Pvt. Ltd. Madras.
[27] Miles, C. W.N. and Seabrook, W. (1977) Recreational Land Managemnt , E. & F. N. Spon. , London.
[28] Mittal S.P., Sharma J. S., (1998), watershed Mangemnt Experinces of Siwalik Foot Hill Region of North India (Proceedings of Int. watershed managemnt 8-10 Dec. 19980, CBIP, New delhi (287-295).