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Evaluation of Ground Water Resources: A Review Paper on Ground Water Development

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ABSTRACT- This is a review paper for researching the groundwater development of different Indian regions with the help of some references and government data available. The need for the groundwater development management is very important for this era as the water consumption in both drinking and irrigation purposes is going out of bounds due to many factors i.e. population, geographical changes, crop demand, the soil pollution, the low rain factor and many other also.

KEYWORDS- Groundwater development, Aquifers, Sodicity, Toxicity and Sustainability Evapotranspiration, Transmissivity.

I. INTRODUCTION

The Indian republic is country made up of different types of physiological divisions which have given it the name **subcontinent**. It almost has different types of soil formations available which are used for different kinds of crops. The ground water resources are also different on every places. For example the water resources of Rajasthan are quite different from the water resources of Uttar Pradesh or Punjab. So, the crop duty of these states are different from the every other states. The situation of ground water is different of all these states. We will be studying these developments via different reports given by governments and many other case studies by renowned researchers. On the basis of their research we will provide our verdict on whether the ground water development of a certain area needs some maintaining or it needs to remove the excess water from its table.

Groundwater resources are a critical source of water supply for communities around the world. Due to increasing demand and pressures on this resource, it is important to evaluate and manage groundwater resources sustainably. This research paper presents an overview of groundwater resources evaluation, including methods for assessing groundwater availability, quality, and sustainability. The paper also discusses the importance of groundwater monitoring, data collection, and modeling in groundwater resources evaluation.

GROUND WATER – Ground water is a critical component of the water cycle, providing water for drinking, irrigation and industrial uses. It is estimated that approximately 30% of freshwater supply is stored in groundwater aquifers. Sustainable management of groundwater resources is therefore essential to ensure a reliable and sustainable water supply.

GROUNDWATER RESOURCE EVALUATION- Groundwater resource evaluation involves assessing the availability, quality and sustainability of groundwater resources. The following methods are commonly used in groundwater resource evaluation:

1. Groundwater Availability Assessment
2. Groundwater Quality Assessment
3. Groundwater Sustainability Assessment

Groundwater Availability Assessment –This can be done through aquifer testing which involves pumping water from a well and measuring the rate at which the water table in the surrounding aquifer is falling. The total annual groundwater recharge is 437.60 billion cubic kilometers and the annual groundwater exploitation is 239.16 billion cubic meters.

- About 87% of the total groundwater withdrawal is used for irrigation.
- Only 30.69 bcm was used for domestic and industrial purposes, representing about 13% of the total extraction. The total national groundwater exploitation stage is 60.08%.
- Haryana, Punjab, Rajasthan, Dadra and Nagar Haveli and the states of Daman and Diu have very high groundwater levels exceeding 100%.In other states,

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the groundwater extraction stage is less than 60%.

- According to the level of groundwater, the country is divided into three categories: overexploited, critical and semi-critical. The first refers to groundwater that is withdrawn more than it is recharged, i.e. the withdrawal exceeds 100%.Critical where the water taken out is 90-100% of what's recharged and semi-critical where extraction rate is 70-90%.
- As per "National compilation on Dynamic Groundwater Resources of India, 2020" of CGWA, out of the total 6965 assessment units (Blocks/Mandals/Talukas) in the country, 1115 units in various states(16%) have been categorized as 'Over Exploited', 280 units(4%) are 'critical', and 1045 are semi-critical units(15%) and 4458 units have been considered as safe (64%), there are 70 units (1%) which have been categorized as 'Saline'.
- Southwestern monsoon is the major source of groundwater recharge. India is one of the few countries engaged in a detailed assessment of the dynamic component at regular intervals since 2005.
- The resource is assessed for each block/taluka/firka for all states and union territories in a joint endeavour by states and the centre under the supervision of the Central Ground Water Board(CGWB).
- The assessment calculates recharge and withdrawal from the aquifer to determine the stage of groundwater development (development/resource).
- The lower the SOD (Stage of Development), the better the aquifer or area. Dynamic resources and SOD are widely used in policy and management, such as the prioritization of government funding for programs or the issuance of NOCs by central groundwater authorities for groundwater abstraction by sector. However, the recharge of deep aquifers and the withdrawal of deep aquifers are not part of this mandate.
- In overexploited areas, the increased depletion of static resources leads to the permanent destruction of aquifers.
- Static components should be used in emergency situations such as drought. Efforts should be made to assess static resources nationally.

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DRINKING WATER STANDARDS AND PROBABLE EFFECTS OF HUMAN HEALTH
(BIS: IS: 10500, 1991)

S. No.	Parameters	Prescribed limits		Probable effects
		Desirable	Permissible	
1	COLOUR (HAZEN UNIT)	5	25	Aesthetically undesirable.
2	ODOUR	Essentially free		Aesthetically undesirable.
3	TASTE	Agreeable		Aesthetically undesirable.
4	TURBIDITY (NTU)	5	10	Indicates pollution/ contamination.
5	pH	6.5	8.5	Affects taste, corrosivity & supply system.
6	HARDNESS, as $CaCO_3$, mg/l	300	600	Causes scaling, excessive soap consumption, calcification of arteries.
7	IRON, as Fe , mg/l	0.30	1.00	Causes staining of laundry and porcelain. In traces it is essential for nutrition.
8	CHLORIDE, as Cl , mg/l	250	1000	May be injurious to heart or kidney patients. Taste, indigestion, corrosion & palatability are affected.
9	RESIDUAL CHLORINE, only when Water is chlorinated	0.20	-	Excessive chlorination causes asthma, colitis & eczema
10	TOTAL DISSOLVED SOLIDS, mg/l	500	2000	May cause gastro-intestinal irritation, corrosion and laxative effect to new users.
11	CALCIUM, as Ca, mg/l	75	200	Excessive Cause incrustation, deficiency causes rickets, essential for nervous, muscular, cardiac functions and in coagulation of blood.
12	MAGNESIUM, as Mg, mg/l	30	100	Its salts are cathartics and diuretic. Excessive may cause laxative effect; deficiency causes structural and functional changes. It is activator of many enzyme systems.
13	COPPER, as Cu, mg/l	0.05	1.50	Beneficial in human metabolism, deficiency results in nutritional anaemia in infants. Large amounts may result in liver damage, causes central nervous system irritation & depression. Enhances corrosion of Al in water supply systems.

GROUNDWATER QUALITY ASSESSMENT-

Groundwater quality can be assessed through water sampling and analysis. Common water quality parameters include pH, dissolved oxygen, total dissolved solids and various ions such as chloride, sulphate and nitrate. Groundwater quality can be impacted by many natural causes and factors including geographical and artificial situations.

There are also few factors which define how much standards are used for the agricultural water and for the irrigation purposes. Generally salinity, sodicity and toxicity of specific ions are considered for assessing suitability of waters used for irrigation purposes. Use of waters exceeding the maximum permissible limits of these parameters will affect the soil structure and decrease the yield of the crops grown. Recent studies have shown that some heavy metal in low concentrations in irrigation waters also affect the crop yields.

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EFFECTS OF WATER QUALITY PARAMETERS ON IRRIGATION WATER

(AFTER AYERS R.S. AND WESTCOTT.D.W.1985)

S. No.	Parameters	Prescribed limits		Probable effects
		Desirable	Permissible	
1	Salinity/EC in Mmhos/cm at 25^0c	Sensitive crops <1500 Semi-tolerant 1500-3000 Tolerant >3000		Plant growth is retarded with stunted fruits, leaves and stem in high salinity
2	SODICITY/SAR	SAR<10 10-18 18-26 >26	Excellent Good Medium Bad	Causes deflocculation of soil, restricting free movement of water
3	R.S.C meq/l	<1.25 1.25-2.5 >2.5	Excellent Good Bad	Result in increase of Sodium causing adverse effects.
4	SODIUM (NA) %	No Guideline		Increase total salinity, has adverse effect on sodium sensitive species such as stone fruit trees and avocados
5	CHLORIDE, (cl) mg/l	No Guideline		May have direct toxic effect with sodium.
6	NITRATE, (NO_3) mg/l	No Guideline		An essential plant nutrient but its excess may delay maturity and seed growth in some plants
7	BORON, (B) mg/l	Sensitive crops <1.0 Semi-tolerant 1.0-2.0 Tolerant 2.0-4.0 Unsatisfactory for most crops>4.0		An essential plant nutrient at low concentration but high conc. are toxic to plant
8	COPPER, (Cu) mg/l	0.20^a	5.00^b	Essential for plant as micronutrient. Deficiency may cause crop damages, chlorosis also leading to dieback of plant.
9	LEAD, (Pb) mg/l	5.20^a	10.00^b	Some plants accumulate it that may have harmful effect on human health. Very high concentration may reduce root growth.

Groundwater Sustainability Assessment – Groundwater sustainability is the development and use of groundwater resources to provide current and future beneficial uses without unacceptable environmental or socio-economic consequences. Certain points at which groundwater sustainability is determined are called multiple influencing factors. The indicators are –

1. Climate change
2. Groundwater abstraction (extraction)
3. Groundwater quality
4. Groundwater vulnerability
5. Public participation
6. Legal framework
7. Water productivity
8. Professions related to groundwater.

The durability of groundwater determination varies with different types of geographical conditions in Indian regions. There are simpler regions, coastal regions, mountain regions, desert regions, and hard rock regions. Demand and consumption vary considerably with land quality.

1.**Climate variability** – Gradual or sudden changes in weather patterns in or around areas that have profound effects on groundwater conditions. If it warms up, surface water evaporates and groundwater begins to rise by convection. Human disturbances are a major cause of climate variability.

2**. Groundwater abstraction** - Excessive use of groundwater for daily living and irrigation purposes results in too large differences in the calculation of assessment data.

Groundwater pumping involves extracting excess water from underground. Water extraction is mainly done by pumping. This pump is mainly used for irrigation purposes. But if people use it for their daily use and needs, it will lead to huge waste of water resources, which will guide the calculation of groundwater development.

3.**Groundwater Quality** - Groundwater quality is the largest part of the assessment, showing water use and processes to improve groundwater quality. Groundwater can be contaminated by many types and conditions. Therefore, for greater sustainability of water resources, we need to conduct quality assessments as efficiently as possible.

4.**Groundwater vulnerability** - Groundwater vulnerability depends on the environmental and soil conditions nearby.
It can be divided into 4 types, from top to bottom.
HIGH areas are those that readily transfer pollution to groundwater due to soil leaching effects and lack of low permeability surface sediments. The middle zone provides some groundwater protection, and the low zone provides the greatest groundwater protection from contamination due to the presence of low permeability surface sediments. Groundwater Vulnerability Unproductive areas consist of rocks that have negligible impact on water supply or base flow of rivers. It has a layer of soil deposits above the flow-permeable surface deposits.

5. **Public Participation** – The most important factor in groundwater assessment is public participation. Without their support, we would not have been able to collect data as easily as we had hoped. The public also plays an important role in the sustainability of water sources, as they are fully aware of where the water is taken from and who is polluting it. So if we can involve them and tell them the consequences of not protecting the water, they can and will support our campaign.

6**.Legal framework** – Legal barriers are sometimes the cause of most water allocation problems. With so many laws passed by the government, people can easily find the right to use water and not abuse it to their advantage. The legal framework is sometimes so confusing that people don't understand it. So the government. It is imperative to explain to people their plans and the use and loss of water resources.

7.**Water Productivity** - Sustainability often focuses on understanding water productivity in a particular sector, region or region. Factors that predict and give water productivity values indicate whether there is enough water in the area. The increase or decrease in water productivity over a period of time was also considered in the assessment.

8**. Professions related to groundwater** - There are many professions directly related to groundwater. There are geotechnicians, field analysts, microbiologists and many others directly responsible for ground water determination

II. LITERATURE REVIEW

There are many research references that we can pick up on to help our review thesis on the ground water resources. The review work mainly is based on the reports of the Indian government yearly assessments and on the research papers on the some main parts of the Indian regions. There are many papers which are as follows:

1. GROUND WATER ASSESSMENT REPORT BY GOVT. OF INDIA-

This report is the basis of our data. Based in this report we have collected our data and calculated the ground water development of certain regions of India. The report indicates that The groundwater extraction in overall India is lowest since 2004, where it was 231bcm. The another major factor is if we calculate state-wise the overall stage of groundwater extraction in the country is 60.08%. India is the largest user of groundwater with a fourth of the total global withdrawal. Indian cities take 48% of their water supply form groundwater. The rapid growth of industrialization, over population and also the unregulated extraction of groundwater are the major facts that are the concerning field for the governments to look into for the preserving of the water resources.

2. An overview of groundwater quality in Tamil Nadu by R. Kuttimani, A. Raviraj, B.J. Pandian and Gouranga Kar-

This research reports shows us the data of the groundwater quality and quantity in Tamil Nadu state of India. The main districts of Tamil Nadu are a flourishing industry units of tannery, textiles, dyeing, pulp and paper producing industries. They have a major source of water known as river CAUVERY. The states of Tamil Nadu, West Bengal and Uttar Pradesh together have 88% of the tannery units of the country. About 55% of the total leather processed in the country is from Tamil Nadu. The groundwater quality in the few districts of Tamil Nadu which are COIMBATORE, VELLORE, DINDIGUL, TIRUCHIRAPALLI and CHENNAI. They have the standards of groundwater which are below the desired value. The main reason for this cause is the pollution in the NADU NOYYAL river in the COIMBATORE, the most number of tanneries which are filling the groundwater from Hardness, Salinity, Calcium Chloride and Fe are in the VELLORE district, the value of Fluoride, Dissolved Oxygen, biological oxygen demand and chemical oxygen demand are exceeding the permissible limit in most of the groundwater samples in the DINDIGUL district.

3. Status of groundwater resources in Haryana and its dynamics and spatial pattern by Dr P.K Sharma-

Groundwater is the key resource input in India's agriculture and food security in recent years. At present tube wells accounts for over 60% of the irrigated area in the country. Currently in Haryana about 85% of total cultivated area is irrigated. According an assessment made in a NASA study, during 2002 to 2008 three agriculturally developed states (Punjab, Haryana and Rajasthan) together lost about 109 cubic km of water leading to a decline in water table to the extent of 0.33 m per annum. In 1995 in Haryana net availability of groundwater was 724.84 thousand ha-m which increased to 1029.67 thousand ha-m in 2013, recording an increase of about 42 percent. In 1995 the groundwater development in the state of Haryana was 84%. That mean that the sates as a whole pumped out 16% less water than the annual recharge. But in 2013 the level of groundwater development changed from 845 to 135%. About 78.62% of area of the state experience the over-exploitation of groundwater. That shows us the excess of groundwater use in the Haryana state.

4. Depleting Groundwater resources of Rajasthan State and Its Implications by SURESH KUMAR, B.L DHYANI and RAMAN JEET SINGH-

Rajasthan has only 1.15% of its water resources supporting 5.67% of human population and 10.53% cattle population of the country. The groundwater development in the state of Rajasthan is 125%. It is the largest state in India covering the area up to 34.22 Million hectares. Water table in the state is continuously falling over the years and the blocks under the critical and over-exploited categories are increasing at alarming rate. Over-exploitation of groundwater leads to reduction in water yield in wells. The groundwater management rather than development is the major challenge facing the water resources, particularly in the dry land areas like Rajasthan.

Methodology

To calculate the groundwater development (the increase and decrease in water table)

There have been many methods and types to calculate the water resources emergence and depletion. In the case of Indian regions there are various areas where conventional formulas don't give satisfying results. So we will use various types of formulas for the specific regions of country as well as with conventional formulas.

1. **Groundwater Balance Equation-**

The groundwater balance equation is written as-

$R_r+R_c+R_i+R_t+S_i+I_g=E_t+T_p+S_e+O_g+\Delta S$

where,

R_r = recharge from rainfall

R_c = recharge from canal seepage

R_i = recharge from field irrigation

R_t = recharge from tanks

S_i = influent seepage from rivers;

I_g = inflow from other basins;

E_t = evapotranspiration from groundwater;

T_p = draft from groundwater;

S_e = effluent seepage from rivers;

O_g = outflow to other basins; and

ΔS = change in groundwater storage.

this equation can be used as the main calculating standard for the groundwater development calculation. The components given in the equation are the basis of what the groundwater resource estimation is all about.

Estimation Of Groundwater Components

The components showing various inflow/outflow of the groundwater balance equation are suitable for a region if estimated through appropriate empirical relationships suitable for a region according to the norms of Groundwater Estimation Committee (2015).

1. Recharge from rainfall (R_t)

The rainfall is variably different in almost every region of India, so we use many empirical formulas to determine the rainfall quantity suitable for the specified region.

a. Chaturvedi Formula: This formula is suitable for the regions of Ganga-Yamuna doab, developed in 1936. It shows the empirical relationship to arrive at the recharge as a function of annual precipitation.

$R_r = 2(P\text{-}14)^{0.4}$

Where P is the annual precipitation in inches.

Later in the next years this formula was modified by the U.P Irrigation Research Institute, Roorkee and the modified formula is

$R_r = 1.35(P\text{-}14)^{0.5}$

There are certain cases where the rainfall will be zero, then we will put the value of P=14 and increase upto 18% at P=28inches and again decrease.

b. KUMAR & SETUPATHI(2002): They found out in their research that as the rainfall increases, the quantity of recharge also increases but the increase is not linearly proportional. The recharge coefficient was found to vary between 0.05 to 0.19 for the study area. The formula is-

$R_r = 0.63(P\text{-}15.28)^{0.76}$

This formula is considered to be better than the Chaturvedi formula as it has less relative errors.

c. AMRITSAR FORMULA: For certain doabs in Punjab, the Irrigation and Power Research Institute, Amritsar, developed the following formula in 1973.

$R_r = 2.5(P\text{-}16)^{0.5}$

d. KRISHNA RAO: Krishna Rao gave the following empirical relationship in 1970 to determine the groundwater recharge in limited climatological homogeneous areas:

$Rr = K(P\text{-}X)$

This equation is specially designed for the various parts of Karnataka where K and X are to be determined as the standard values variating on the basis of rainfall parameters.

2. Recharge from Canal Seepage (R_c)

Seepage refers to the process of water movement from a canal into and through the bed and wall material. This loss often constitute a significant part of the total recharge to groundwater system. The actual seepage will also be controlled by the width of canal(B), depth of flow(D), hydraulic conductivity of the bed material(K) and depth to the water table.

a. Knowing the value of B and D, the range of seepage losses (R_{c_max} and R_{c_min}) from the canal may be obtained as-

$R_{c\_max} = K(B+2D)$

$R_{c\_min} = K(B\text{-}2D)$

b. For unlined canals in Uttar Pradesh, the seepage can be computed by using the formula:

Losses in cumecs/km = $C/200(B+D)^{2/3}$

where C is a constant value with 1.0 as the intermittent running channels and 0.75 for continuous running channels.

c. For lined canals in Punjab, the following terms are used for estimation of seepage losses:

$R_c = 1.25Q^{0.56}$

There are many other methods that can be used for the seepage calculations such as

- Inflow-Outflow method
- Seepage meter method
- Ponding method

3. Recharge from Field Irrigation (R_i)

During the irrigation process, a part of the water applied to the irrigated field crops is lost in consumptive use and the balance infiltrates to recharge the groundwater. The water that percolates into the soil constitutes a major part of the groundwater recharge. For a correct assumption of the quantum of recharge by applied irrigation, studies are required to be carried out on experimental basis.

The recharge due to irrigation return flow can also be estimated based on these factors-

- Source of irrigation (groundwater or surface water)
- The type of crop (paddy, non-paddy)
- Depth of water table below ground surface.

To find out various values we use the norms provided by Groundwater Resource Estimation Committee(2015).

4. Recharge from Tanks (R_t)

The groundwater recharging done by the tanks is mainly with the help from the seepage done on the check dams and nala bunds made on the rivers. These structures hold almost 50% of the total recharge from tanks. The seepage from percolation is also of a significant rate.

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Groundwater resource estimation committee has also stated that the recharge from when the tank has water in it will be 1.4mm/day otherwise 60% of the maximum water spread area would be used instead of total average of water spread area.

5. Influent and Effluent Seepage (S_i and S_e)

This type of seepage can be seen with two water sources like a river and an aquifer. If the river provides water to the aquifer then the flow will be known as influent and if the aquifer provides the water to the river effluent. The effluent or influent character can vary from season to season. Both these types of flow will cause some changes in the bank storage and we will need to monitor it. The contribution of one source to the other source will be from both ends to/from the source. The contribution from each side can be separated by the following method-

Contribution fromleft bank = $(I_L T_L / (I_L T_L + I_R T_R)).Q_g$

Contribution from right bank = $(I_R T_R / (I_L T_L + I_R T_R)).Q_g$

In these equations I_L and T_L are the gradient and transmissivity on the left side and so are the right side denoted in the same pattern.

6. Inflow from and Outflow to Other Basins (I_g and O_g)

The flow into and out of a region below surface or above surface participating in groundwater recharge are based on a water level data from and outside the study area. The flow mostly depends upon the gradient and the transmissivity of the aquifer of another source participating. Every other data contemplated in the equation is used from the contour level chart of the specified place from where the seepage is happening. The inflow/outflow is determined by this following equation-

$$I_g \text{ or } O_g = \sum T\ I\ \Delta L$$

In this equation I is the hydraulic gradient averaged over a length ΔL of contour line and T is the transmissivity.

7. Evapotranspiration from Groundwater (E_t)

In short terms, evapotranspiration is the combination of evaporation + transpiration. Transpiration is done by plant roots and vegetables and evaporation is done by the soil and environment. Evapotranspiration generally happens in water logged areas where water is in abundance and nowhere to go. So, plant roots absorb the water then leave it into the ground to let it percolate into the soil sub-surface to boost the water table. The forests are considered the most potential place for the consistent evapotranspiration. The potential evapotranspiration from such areas can be computed using standard methods. The equation used in determining the evapotranspiration are-

$E_t = P.E_t * A$

If $h > h_s$

$E_t = 0$

If $h < (h_s - d)$

$E_t = P.E_t * A(h-(h_s-d))/d$If $(h_s-d) \leq h \leq h_s$

In these equations,

$E_t$is the evapotranspiration in volume of water per unit time

PE_t = max. rate of evapotranspiration volume of water per unit area per unit time $[L^3\ L^{-2}\ T^{-1}]$;

A = surface area $[L^2]$;

h = water table elevation [L];

h_s = water table elevation at which the evapotranspiration loss reaches the maximum value;

d = extinction depth. When the distance between h_s and h exceeds d, evapotranspiration from groundwater ceases [L]

8. Draft from Groundwater (T_p)

Draft means the amount of water lifted from the sub-surface sources such as wells for the irrigation and other purposes. We can estimate these activities by an inventory of wells, tube-wells and open wells. In every case we will need the running hours of that body and discharge velocity and number of operation in a season. We can easily get this data from the government agencies. We can also collect the data from private tube-wells by conducting a simple survey of groundwater drafting.

In absence of survey data we can also estimate the draft indirectly from the net crop requirement which is always based upon the cropping patterns and irrigated areas under various crops. The consumption of water is different in each crop groups so the water demand will be different each season. So the groundwater draft can be estimated by subtracting canal water released for the crops from the net crop water requirement.

9. Change in Groundwater Storage (ΔS)

The groundwater storages show changes rapidly during the change of seasons. In the monsoon period the storages are at almost full level. The recharge is more than the extraction, therefore the change in groundwater storage between the beginning and end of the monsoon season indicates the total volume of water added to the groundwater reservoir. The change in storage is computed as follows;

$$\Delta S = \sum \Delta h \, A \, S_y$$

In this equation,

Δh = change in water table elevation during the given time period;

A= area influenced by the well; and

S_y= specific yield.

The values of specific yield can also be approximately determined from the soil classification triangle showing relation between particle size and specific yield(Johnson, 1967).

III. CONCLUSION:

- Groundwater balance study is the easy way to evaluate the groundwater resources and also the groundwater development. We have to find out a way to keep track of the groundwater consumption and pollution as well keeping tab in how to increase the quantity of the table.
- With groundwater balance equation, we can easily estimate the data we need. The equation can be factually correct but in case of season change or pre-monsoon and post-monsoon period we will need to check the coefficient factors again.
- We will always need to exploit the groundwater resources be it in any case(drinking, irrigating, industrial use), so we just to do it smartly and considering the fact that we will not disrupt the balance that has been created by the nature.
- This study is as important for the present as it is for the future, so we should provide some sustainable solutions that can prevent the over-exploitation of groundwater table.
- Water balance approach, essentially a lumped model study, is a viable method of establishing the rainfall recharge coefficient and for evaluating the methods adopted for the quantification of discharge and recharge from other sources. For proper assessment of potential, present use and additional exploitability of water resources at optimal level, a water balance study is necessary. It has been reported that the groundwater resource estimation methodology recommended by Groundwater Resource Estimation Committee (2015) is being used by most of the organisations in India.
- Non-conventional methods for utilisation of water such as through inter-basin transfers, artificial recharge of groundwater and desalination of brackish or sea water as well as traditional water conservation practices like rainwater harvesting, including roof-top rainwater harvesting, need to be practiced to further increase the utilisable water resources.

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