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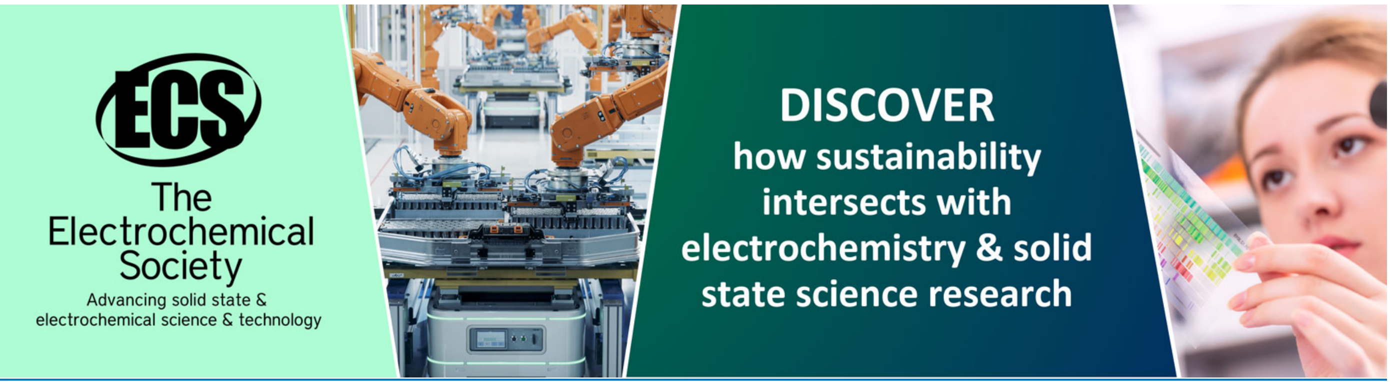

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Groundwater Resource Assessment of an alluvial aquifer in parts of Varanasi and Sant Ravidas Nagar Districts, Uttar Pradesh, India using GRE-2015

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Abstract. The importance of groundwater in India can be realized from the fact that the 85% of rural drinking water supply is dependent on groundwater. There has been paradigm shift from surface to ground water in view of poor quality and reduction in river flow/discharge in the recent past. The concept of micro and sustainable irrigation may be achieved efficiently through groundwater. Therefore, the groundwater resource assessment is essential to make the development plan for meeting out the drinking and irrigation demand for any groundwater unit. An attempt has been made to evaluate the groundwater resource using the latest Ground Water Resource Estimation (GRE-15) of an area that has gone through extensive irrigation using groundwater so that the groundwater stress areas can be sustainably managed. The present research is based on the Groundwater Resource Estimation methodology- 2015 to evaluate the groundwater availability and the stress conditions occurring in the study area. The stage of groundwater development inferred after the study shows that Araziline block of Varanasi and Bhadohi block of Sant Ravidas Nagar district of Uttar Pradesh are falling under the critical category while Sevapuri block of Varanasi district of Uttar Pradesh falls under the semi-critical category. The current estimation warrants the immediate need for proper management of groundwater resources.

Keywords: Groundwater, GRE, Availability.

1. Introduction

Due to the deficiency of surface water resources in semi-arid regions and the pressure from the uncontrolled increase in population, agricultural expansion, rapid urbanization, and modern industrial activities, there is a higher demand for groundwater [1]. Groundwater meets nearly 55 % irrigation, 85 % of rural and 50 % of urban and industrial needs [2, 3]. India's groundwater resources are becoming scarce due to the rampant use of this natural resource without proper scientific planning and management [4]. In the past few decades, many parts of India experienced a rapid decline in groundwater level due

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to over-extraction for various purposes [5]. The study area forms a part of Indo Gangetic alluvial plains which are the most fertile and prolific aquifer in India but unplanned overdraft of groundwater resource is posing a serious threat to the aquifer systems in terms of quantity as well as quality [6].

A serious groundwater crisis currently prevails in India due to excessive over-extraction and groundwater contamination covering nearly 60% of all districts in India and posing a risk to the population's drinking water security [3]. In addition to over-extraction, biological and chemical contamination and water logging are also severe problems in many regions, impacting the livelihood security of large society sections. It is necessary to acknowledge groundwater's hydrogeological characteristics and its integral link to land, vegetation, and surface water resources and perceive it as a 'resource' rather than a 'source' [3]. Proper management of groundwater resources requires knowledge of recharge processes and discharge associated with a groundwater basin [7]. The basic objective of groundwater resource evaluation is to estimate the total quantity of groundwater resource available and their future supply potential to predict possible conflicts between supply and demand and provide a scientific database for rational water resource utilization [8].

After Ground Water Estimation Committee (GEC)-2015 [9] recommendations, aquifer-wise groundwater resource assessment have been adopted. Groundwater resource comprises basically two components - Dynamic Resource in the zone of water table fluctuation, which reflects seasonal recharge and discharge of aquifer and Static Resource below this zone which remains perennially saturated. In India, dynamic groundwater resources are estimated by updated groundwater resource estimation methodology - 2015 (GEC- 2015). In this study we have used this methodology for evaluation of the Groundwater resource in the area.

Groundwater overdraft and developmental activities, under the scenarios of changing climate in the region are leading to the decline of this resource in some parts of the Uttar Pradesh; therefore, it is necessary to identify the groundwater potential of semi-arid regions to efficiently manage this resource to meet the future water demand of the area sustainably. The present study aims to identify the groundwater availability of an alluvial aquifer of parts of districts Varanasi and Sant Ravidas Nagar, India using GRE-2015.

2. Geology

The study area is geologically characterized by quaternary alluvium consisting of older and younger alluvium of Pleistocene to Recent age [3]. The Vindhyan sandstones are exposed in the southern part of the area. According to geological characteristics the area constitutes of the following three formations describe here it from older to younger:

Kaimur sandstones: The Kaimur sandstone is compact, fine to medium grained, arkosic in nature and generally of greyish white shade in colour. These are generally bedded horizontally or have northerly dips upto 10°. Current bedding is a prominent feature of the sandstone.

Older alluvium: The Older alluvial consists mainly of the back-swamp and meander-belt deposits associated with Ganga River's earlier. The meander-belt deposits comprise medium to coarse grained sand, thin lime cemented sand lenticels and minor amounts of clay and poorly stratified clays having thin lenticular bands of fine grained sand.

Newer alluvium: The Newer alluvium occurs mostly belts along with the courses of major streams in the area. This consists mainly of fine to medium-grained sand, silt and a minor amount of clay. The thickness of the newer alluvium in the area is unknown, but the thickness did not exceed 10 metres wherever it was examined.

2.1. Sub-surface Geology

Sub-surface geology of the district has been inferred based on exploratory boreholes drilled by [5]. The thickness of quaternary alluvium increases from East to West. It ranges from 06 to 44 m. On a regional scale, on single aquifer system is seen extending down to the drilled depth of 149 m. The thickness varies between 40.25 and 90.00 mbgl [5]. The sediments forming the aquifer in the study area are mainly composed of fine to coarse-grained.

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2.2. Hydrogeological Setup

Groundwater occurs both in the consolidated rocks of the Kaimur sandstone and the unconsolidated alluvial sediments. Groundwater conditions in these two hydrogeological units are discussed here below separately:

*2.2.1. Groundwater conditions in Vindhyan rocks***.** The occurrence, movement and availability of groundwater in Vindhyan sandstone is controlled by the size, depth persistence, spacing and degree of interconnection of planes of weakness such as joints, bedding planes, fractures and fissures. The availability of groundwater in wells will depend on the number of such planes of weakness exposed in the well section The depth to water level in the sandstone varies from 1.28 to over 20 metres level. The wells range in depth from 2.40 to 20.80 metres [10].

2.2.2. Groundwater conditions in alluvium. The geological setting is quite similar near surface throughout the study area are sandy lenses surrounded by clay-silty deposits. This sandy lenses form the shallow aquifers (25-40 m depth below surface, [11, 12] with the unconfined condition, which is the main water supply of most part of the city. The lateral length of these lenses can be up to some 1000 m. The clay-silty layer lies in fine-coarse sand deposits, representing the deeper aquifer (60-70 m depth below surface) [12].

The Central Ganga Alluvial Plain is underlain by the Quaternary Alluvium comprising of fine to coarse grained sand, clay and clay with Kankar. The alluvium belongs to the Quaternary Group of Pleistocene System of the recent geological age. To be precise, the Older Alluvium is Middle to Upper Pleistocene and the Newer Alluvium is recent [13].

3. Study Area

The study area falls under state of Uttar Pradesh Varanasi district which is covered by alluvial sediments of river basins, coastal and deltaic tracts constitute the unconsolidated formations. These are most significant groundwater reservoirs for large-scale and extensive development [14]. The study area comprises the parts of Varanasi and Sant Ravidas Nagar Districts of the Uttar Pradesh, India. Situated on the Ganga banks, Varanasi is the tract of holy land lying between the rivers Varuna and Assi, which flows into the Ganga. It is the fast-developing city of heavy, light, and cottage industries, local handicrafts and other small scale industrial units. It is lying between E 82°28'30″ to E 82°55'00″ longitude & N 25°9'45″ to N 25°27'45″ latitude with an area of about 620.82 km^2. The study area has low relief features with an average elevation of 80.71 amsl.

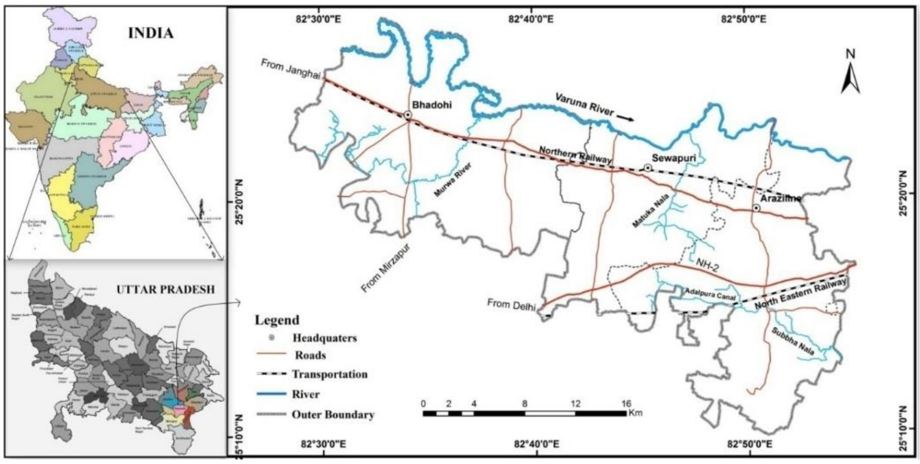

Figure 1. Study Area Map showing well locations

4. Material & Method

The assessment of groundwater includes the assessment of dynamic and in-storage groundwater

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resources. The development planning should mainly depend on dynamic resource only as it gets replenished every year. Changes in static or in-storage resources reflect the impacts of groundwater mining. Such resources may not be replenishable annually and may be extracted only during exigencies with proper recharge planning in the succeeding excess rainfall years [9].

Assessment of Annually Replenishable or Dynamic Ground Water Resources:
The methodology for groundwater resources estimation is based on the principle of water balance as given below [9]:

Inflow – Outflow = Change in Storage (of an aquifer)

It could be further elaborated as:

$$\Delta S = RRF + RSTR + RC + RSWI + RGWI + RTP + RWCS \pm VF \pm LF - GE - T - E - B$$

Where,

ΔS – Change is storage	RRF – Rainfall recharge
RSTR- Recharge from stream channels	RC – Recharge from canals
RSWI–Recharge from surface water irrigation	RGWI- Recharge from ground water irrigation
RTP- Recharge from Tanks& Ponds	RWCS– Recharge from water conservation structures
VF – Vertical inter aquifer flow	LF-Lateral flow along the aquifer system (through flow)
GE-Groundwater Extraction	T- Transpiration
E- Evaporation	B-Base flow

4.1. Rainfall Recharge
It is recommended that groundwater recharge be estimated on groundwater level fluctuation and specific yield approach since this method considers the response of groundwater levels to groundwater input and output components. It is proposed that there should be at least three spatially well distributed observation wells in the assessment unit, or one observation well per 100 sq. Km. Water level data should also be available for a minimum period of 5 years (preferably 10 years), along with corresponding rainfall data. Two water level readings, during pre and post monsoon seasons, are the minimum requirement regarding frequency of water level data. In units or subareas where adequate data on groundwater level fluctuations are not available as specified above, groundwater recharge may be estimated using rainfall infiltration factor method only. The rainfall recharge during the non-monsoon season may be calculated using the rainfall infiltration factor method only [9].

4.1.1. Groundwater level fluctuation method. The groundwater level fluctuation method is one of the most widely used techniques for estimating groundwater recharge over a wide variety of climatic conditions [15, 16 & 17]. The use of the method requires knowledge of specific yield and changes in groundwater levels over time. [18] have attributed the wide use of this method to the abundance of available groundwater level data and the simplicity of estimating recharge rates from temporal fluctuations or spatial patterns of water levels.

The groundwater level fluctuation method is to be used to assess rainfall recharge in the monsoon season. The groundwater balance equation in non-command areas is given by [9]:

$$\Delta S = RRF + RSTR + RSWI + RGWI + RTP + RWCS \pm VF \pm LF - GE - T - E - B$$

Where,

ΔS – Change is storage	RRF – Rainfall recharge
RSTR- Recharge from stream channels	RSWI–Recharge from surface water irrigation (Lift Irrigation)

RGWI-Recharge from ground water irrigation
RTP- Recharge from tanks& ponds
RWCS–Recharge from water conservation structures
VF – Vertical inter aquifer flow
LF-Lateral flow along aquifer system (through flow)
GE-Groundwater Extraction
T- Transpiration
E- Evaporation
B-Base flow

Whereas the water balance equation in command area will have another term i.e., Recharge due to canals (RC) and the equation will be as follows:

$$\Delta S = RRF+RSTR+RC+RSWI+RGWI+RTP+RWCS \pm VF \pm LF-GE-T-E-B$$

It is important to bear in mind that while estimating groundwater extraction quantum, the depth from which groundwater is being extracted should be considered. One should consider only the draft from the same aquifer for which the resource is being estimated.
The change in storage can be estimated using the following equation:

$$\Delta S = \Delta h * A * SY$$

Where,
ΔS – Change is storage
Δh - Rise in water level in the monsoon season
A - Area for computation of recharge
Sy - Specific Yield

4.1.2. Rainfall Infiltration Factor method. The rainfall recharge estimation based on Water level fluctuation method reflects actual field conditions since it takes into account the response of groundwater level. However the groundwater extraction estimation included in the computation of rainfall recharge using water level fluctuation approach is often subject to uncertainties. Therefore, it is recommended to compare the rainfall recharge obtained from the water level fluctuation approach with that estimated, using rainfall infiltration factor method. Recharge from rainfall is estimated by using the following relationship [9]:

$$Rrf = RFIF * A * (R - a)/1000$$

Where,
Rrf= Rainfall recharge in ham
A = Area in Hectares
RFIF = Rainfall Infiltration Factor
R = Rainfall in mm
a = Minimum threshold value above which rainfall induces groundwater recharge in mm.

The relationship between rainfall and groundwater recharge is a complex phenomenon depending on several factors like runoff coefficient, moisture balance, hydraulic conductivity and Storativity/Specific yield of the aquifer etc. The threshold limit of minimum and maximum rainfall event which can induce recharge to the aquifer is to be considered while estimating groundwater recharge using rainfall infiltration factor method. It is suggested that 10% of Normal annual rainfall may be taken as minimum rainfall threshold and 3000 mm as maximum rainfall limit. While computing the rainfall recharge, 10% of the normal annual rainfall is to be deducted from the monsoon rainfall and balance rainfall would be considered for computation of rainfall recharge [9].

4.2. Percent Deviation

After computing the rainfall recharge for normal monsoon season rainfall using the groundwater level fluctuation method and rainfall infiltration factor method these two estimates have to be compared with each other. A term, Percent Deviation (PD) which is the difference between the two expressed as a percentage of the later is computed as [9]:

$$\mathrm{PD} = \frac{\mathrm{Rrf\ (normal, wtfm)} - \mathrm{Rrf\ (normal, rifm)}}{\mathrm{Rrf\ (normal, rifm)}} \times 100$$

Where,
Rrf (normal, wlfm) = Rainfall recharge for normal monsoon season rainfall estimated by the groundwater level fluctuation method.
Rrf (normal, rifm) = Rainfall recharge for normal monsoon season rainfall estimated by the rainfall infiltration factor method.

The rainfall recharge for normal monsoon season rainfall is finally adopted as per the criteria given below:

- If PD is greater than or equal to -20%, and less than or equal to +20%, Rrf (normal) is taken as the value estimated by the groundwater level fluctuation method.
- If PD is less than -20%, Rrf (normal) is taken as equal to 0.8 times the value estimated by the rainfall infiltration factor method.
- If PD is greater than +20%, Rrf (normal) is taken as equal to 1.2 times the value estimated by the rainfall infiltration factor method.

4.3. Stage of Ground Water Extraction
The stage of groundwater extraction is defined by:

$$\textbf{Stage of Groundwater Extraction}\ (\%) = \frac{\textbf{Existing gross groundwater extraction for all uses}}{\textbf{Annual extractable groundwater resources}} \times \mathbf{100}$$

The existing gross groundwater extraction for all uses refers to the total of existing gross groundwater extraction for irrigation and all other purposes. The groundwater extraction stage should be obtained separately for command areas, non-command areas, and poor groundwater quality areas [9].

4.4. Validation of Stage of Ground Water Extraction
The assessment based on the stage of groundwater extraction has inherent uncertainties. The estimation of groundwater extraction is likely to be associated with considerable uncertainties as it is based on indirect assessment using factors such as electricity consumption, well census and area irrigated from groundwater. It is desirable to validate the 'Stage of Ground Water Extraction' with long term trend of ground water levels. Long term water level trends are to be prepared for a minimum period of 10 years for both pre-monsoon and post-monsoon period. The water level trend would be average water level trend as obtained from the different observation wells in the area [9].
In interpreting the long-term trend of groundwater levels, the following points may be kept in view. If the pre and post monsoon water levels show a fairly stable trend, it does not necessarily mean that there is no scope for further ground water development. Such a trend indicates that there is a balance between recharge, extraction and natural discharge in the unit. However, further ground water development may be possible, which may result in a new stable trend at a lower ground water level with associated reduced natural discharge. Suppose the ground water resource assessment and the trend of long term water levels contradict each other. In that case, this anomalous situation requires a review of the ground water resource computation and the reliability of water level data. The mismatch conditions are enumerated below [9]:

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In case, the category does not match with the water level trend given above, a 'reassessment' should be attempted. If the mismatch persists even after reassessment, the sub unit may be categorized based on Stage of Ground Water Extraction of the reassessment. However, the subunit should be flagged for the strengthening of observation well network and parameter estimation [9].

SOGWE	Groundwater Level Trend	Remarks
<70%	Significant decline in trend in both pre-monsoon and post-monsoon	Not acceptable and needs reassessment
>100%	No significant decline in both pre-monsoon and post-monsoon long term trend	Not acceptable and needs reassessment

4.5. The categorisation of Assessment Units

As emphasized in the National Water Policy, 2012, a convergence of Quantity and Quality of groundwater resources is required while assessing the groundwater status in an assessment unit. Therefore, it is recommended to separate the estimation of resources where water quality is beyond permissible limits for the parameter salinity [9].

4.5.1. The categorisation of Assessment Units Based on Quantity. The categorization based on the status of groundwater quantity is defined by Stage of Ground Water Extraction as given below [9]:

Stage of Groundwater Extraction	Category
<70%	Safe
>70%and <90%	Semi-Critical
>90%and <100%	Critical
> 100%	Over Exploited

5. Results and Discussion

The groundwater resources of any assessment unit is the sum of the total groundwater availability in the principal aquifer (mostly unconfined aquifer) and the total groundwater availability of semi-confined and confined aquifers existing in that assessment unit. The total groundwater availability of any aquifer is the sum of dynamic groundwater resources and the aquifer's in-storage or static resources [9].

The recharge parameters form an important aspect of groundwater resources evaluation. It involves hydrometeorological and hydrological processes on the surface and sub-surfaces lithological characteristics [19].

The current study area is categorized under command area and Non-command area. The majority of the area is covered by the Non-command area, which falls under Tubewell irrigation. The groundwater fluctuation method is used for recharge assessment during the monsoon season. The monsoon season is considered from June to October. The Kharif crops (paddy, maize, fodder) are cultivated during this period. The non-monsoon season is taken from November to May. The Rabi and Zaid (wheat, oilseeds, pulses etc.) crops are cultivated during this season. The value of specific yield is taken from pumping test data. Quantities of irrigation return flow; canal seepage and surface water irrigation are estimated with the help of statistical data, field data and recommended values of seepage by GEC-2015.

The resource estimation was done for each block with a view to make it more relevant to managers, planners and administrators. The estimation for all the above mentioned three blocks has been carried out using GEC-2015 [9].

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5.1. Araziline block, Varanasi.

The groundwater resource estimation has been done using GEC-2015 for Araziline block, Varanasi and is summarized under as [9]:

ASSESSMENT OF GROUNDWATER RESOURCE
(BASED ON GROUNDWATER ESTIMATION COMMITTEE NORMS 2015)

Name of State	UTTAR PRADESH
Name of the District	VARANASI
Name of Groundwater Assessment Unit	**ARAZILINE BLOCK**
Type of Groundwater Assessment Unit	Block
Predominant type of Rock Formation	ALLUVIUM
Groundwater Assessment Unit Area in Hectares	22306
a) Hilly Area in Hectares:	0
b) Command Area in Hectares:	522
c) Non-command Area in Hectares:	21784
d) Poor Groundwater Quality Area in Hectares	0
Groundwater Assessment Year	**2016**

Summary Report in Respect of Each Groundwater Assessment Unit: Command and Non-command Area

Sl. No.	**Description of item**	**Command Area**		**Non-command Area**		**Block Total**	
		in HM	**in mm per Unit Area**	**in HM**	**in mm per Unit Area**	**in Hectare Metre (HM)**	**in mm per Unit Area (mm)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Recharge from 'Rainfall' during						
	a) Monsoon season	386	740	2064	95	2450	835
	b) Non-monsoon season	26	49	1072	49	1097	98
2	Recharge from 'Other Sources' during						
	a) Monsoon season	251	481	199	9	450	491
	b) Non-monsoon season	98	188	233	11	331	199
3	Annual groundwater recharge	761	1459	3567	164	4329	1623
4	Unaccounted annual natural discharge	38	73	178	8	216	81
5	Net annual groundwater availability	723	1386	3389	156	**4112**	**1541**
6	Current annual gross groundwater draft for 'All Uses'	163	312	3643	167	**3806**	**479**
7	Current annual gross groundwater draft for 'Irrigation'	58	110	1324	61	**1382**	**171**
8	Annual groundwater allocation for domestic and industrial water supply up to next 25 years	16	31	681	31	**698**	**63**
9	Net annual groundwater availability for ' Future Irrigation Use'	650	1244	1384	64	**2033**	**1308**
10	Was the rain fall recharge during monsoon season obtained by using the WTF method (Yes / No)	No		No		No	

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Sl. No.	Description of item	Command Area	Non-command Area	Block Total
1	**2**	**3**	**4**	**5**
11	If response to Sl. No. 10 is 'Yes' , how was specific yield value obtained (Norms / Pumping test / Dry season Water balance method)	0	Norms	0
12	Stage of Groundwater development as a percentage	22.51	107.49	**92.54**
13	Does the water table during pre-monsoon interval show a Falling or Rising trend	Falling	Falling	Falling
14	Does the water table during post-monsoon interval show a Falling or Rising trend	Falling	Falling	Falling
15	Categorisation for future Groundwater development (Safe / Semi -critical / Critical / Over exploited)	Safe	Over exploited	**Critical**
	Existing Groundwater Structures for Irrigation Use in Nos.			
	Dug Well with Tenda / DW	87	172	259
	Dug Well with Pump / DW	19	45	64
	Filter Point Tube Well / FPTW	0	0	0
	Bore Well / BW	0	0	0
	Low duty Tube Well / SHTW	0	0	0
	Medium duty Tube Well / MDTW	0	0	0
	Heavy duty Tube Well / DTW	0	0	0

The salient output of status of Groundwater in Araziline block, Varanasi:
- Net Annual Groundwater Recharge: 4329 HM
- Net Annual Groundwater Draft: 3806 HM
- Net Annual Groundwater Availability: 4112 HM
- Stage of Groundwater Development (%): 92.54 (Critical)

5.2. Sevapuri block, Varanasi
The groundwater resource estimation has been done using GEC-2015 for Sevapuri block, Varanasi and is summarized under as [9]:

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ASSESSMENT OF GROUNDWATER RESOURCE
(BASED ON GROUND WATER ESTIMATION COMMITTEE NORMS 2015)

Name of State	UTTAR PRADESH
Name of the District	VARANASI
Name of Groundwater Assessment Unit	**SEVAPURI BLOCK**
Type of Groundwater Assessment Unit	Block
Predominant type of Rock Formation	ALLUVIUM
Groundwater Assessment Unit Area in Hectares	16984
a) Hilly Area in Hectares:	0
b) Command Area in Hectares:	1003
c) Non-command Area in Hectares:	15981
d) Poor Groundwater Quality Area in Hectares	0
Groundwater Assessment Year	**2016**

Summary Report in Respect of Each Groundwater Assessment Unit: Command and Non-command Area

		Command Area		**Non-command Area**		**Block Total**	
Sl. No.	**Description of item**	**in HM**	**in mm per Unit Area**	**in HM**	**in mm per Unit Area**	**in Hectare Metre**	**in mm per Unit Area**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Recharge from 'Rainfall' during						
	a) Monsoon season	444	443	3985	249	4429	692
	b) Non-monsoon season	49	49	786	49	836	98
2	Recharge from 'Other Sources' during						
	a) Monsoon season	336	335	371	23	707	358
	b) Non-monsoon season	101	100	448	28	549	128
3	Annual groundwater recharge	930	927	5591	350	6521	1277
4	Unaccounted annual natural discharge	47	46	280	17	326	64
5	Net annual groundwater availability	884	881	5311	332	**6195**	**1213**
6	Current annual gross groundwater draft for 'All Uses'	250	250	4690	293	**4940**	**543**
7	Current annual gross groundwater draft for 'Irrigation'	96	96	2568	161	**2663**	**256**
8	Annual groundwater allocation for domestic and industrial water supply up to next 25 years	31	31	500	31	**531**	**63**
9	Net annual groundwater availability for ' Future Irrigation Use'	756	754	2244	140	**3000**	**895**
10	Was the rain fall recharge during monsoon season obtained by using the WTF method (Yes / No)	No		No		No	

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Sl. No.	Description of item	Command Area	Non-command Area	Block Total
1	2	3	4	5
11	If response to Sl. No. 10 is 'Yes' , how was specific yield value obtained (Norms / Pumping test / Dry season Water balance method)	0	Norms	0
12	Stage of Groundwater development as a percentage	28.33	88.30	**79.75**
13	Does the water table during pre-monsoon interval show a Falling or Rising trend	Falling	Falling	Falling
14	Does the water table during post-monsoon interval show a Falling or Rising trend	Falling	Falling	Falling
15	Categorisation for future Groundwater development (Safe / Semi -critical / Critical / Over exploited)	Safe	Semi-critical	**Semi-critical**
	Existing Groundwater Structures for Irrigation Use in Nos.			
	Dug Well with Tenda / DW	87	172	259
	Dug Well with Pump / DW	19	45	64
	Filter Point Tube Well / FPTW	0	0	0
	Bore Well / BW	0	0	0
	Low duty Tube Well / SHTW	0	0	0
	Medium duty Tube Well / MDTW	0	0	0
	Heavy duty Tube Well / DTW	0	0	0

The salient output of status of Groundwater in Sevapuri block, Varanasi:

- Net Annual Groundwater Recharge: 6521 HM
- Net Annual Groundwater Draft: 4940 HM
- Net Annual Groundwater Availability: 6195 HM
- Stage of Groundwater Development (%): 79.75 (Semi-critical)

5.3. Bhadohi block, Sant Ravidas Nagar.

The groundwater resource estimation has been done using GEC-2015 for Bhadohi block, Sant Ravidas Nagar and is summarized under as [9]:

ASSESSMENT OF GROUNDWATER RESOURCE
(BASED ON GROUND WATER ESTIMATION COMMITTEE NORMS 2015)

Name of State	UTTAR PRADESH
Name of the District	VARANASI
Name of Groundwater Assessment Unit	**BHADOHI BLOCK**
Type of Groundwater Assessment Unit	Block
Predominant type of Rock Formation	ALLUVIUM
Groundwater Assessment Unit Area in Hectares	24194
a) Hilly Area in Hectares:	0
b) Command Area in Hectares:	2212
c) Non-command Area in Hectares:	21982
d) Poor Groundwater Quality Area in Hectares	0
Groundwater Assessment Year	**2016**

Summary Report in Respect of Each Groundwater Assessment Unit: Command and Non-command Area

Sl. No.	**Description of item**	**Command Area**		**Non-command Area**		**Block Total**	
		in HM	**in mm per Unit Area**	**in HM**	**in mm per Unit Area**	**in Hectare Metre (HM)**	**in mm per Unit Area (mm)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Recharge from 'Rainfall' during						
	a) Monsoon season	590	267	2064	94	2653	360
	b) Non-monsoon season	109	49	1082	49	1190	98
2	Recharge from 'Other Sources' during						
	a) Monsoon season	3866	1748	448	20	4314	1768
	b) Non-monsoon season	183	83	530	24	713	107
3	Annual groundwater recharge	4747	2146	4124	188	8871	2334
4	Unaccounted annual natural discharge	237	107	206	9	444	117
5	Net annual groundwater availability	4510	2039	3917	178	**8427**	**2217**
6	Current annual gross groundwater draft for 'All Uses'	531	240	7586	348	**8117**	**588**
7	Current annual gross groundwater draft for 'Irrigation'	106	48	3066	141	**3172**	**189**
8	Annual groundwater allocation for domestic and industrial water supply up to next 25 years	69	31	688	31	**757**	**63**
9	Net annual groundwater availability for ' Future Irrigation Use'	4335	1960	164	7	**4498**	**1967**
10	Was the rain fall recharge during monsoon season obtained by using	No		No		No	

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	the WTF method (Yes / No)			
Sl. No.	**Description of item**	**Command Area**	**Non-command Area**	**Block Total**
1	**2**	**3**	**4**	**5**
11	If response to Sl. No. 10 is 'Yes' , how was specific yield value obtained (Norms / Pumping test / Dry season Water balance method)	0	Norms	0
12	Stage of Groundwater development as a percentage	11.77	193.65	**96.31**
13	Does the water table during pre-monsoon interval show a Falling or Rising trend	Falling	Falling	Falling
14	Does the water table during post-monsoon interval show a Falling or Rising trend	Falling	Falling	Falling
15	Categorisation for future Groundwater development (Safe / Semi -critical / Critical / Over exploited)	Safe	Over Exploited	**Critical**
	Existing Groundwater Structures for Irrigation Use in Nos.			
	Dug Well with Tenda / DW	87	172	259
	Dug Well with Pump / DW	19	45	64
	Filter Point Tube Well / FPTW	0	0	0
	Bore Well / BW	0	0	0
	Low duty Tube Well / SHTW	0	0	0
	Medium duty Tube Well / MDTW	0	0	0
	Heavy duty Tube Well / DTW	0	0	0

The salient output of status of Groundwater in Bhadohi block, Sant Ravidas Nagar:

- Net Annual Groundwater Recharge: 8871 HM
- Net Annual Groundwater Draft: 8117 HM
- Net Annual Groundwater Availability: 8427 HM
- Stage of Groundwater Development (%): 96.31 (Critical)

6. Conclusion

The groundwater resource of the study area has been estimated first time using GEC-2015 and validated with field data. The eastern block i.e. Araziline of Varanasi district and western block i.e. Bhadohi of Sant Ravidas Nagar district are under Critical category due to over exploitation of the groundwater and proper management or regulation for groundwater withdrawal has not been enforced in the area. The central portion mainly occupied by Sevapuri block, Varanasi district is under Semi-Critical condition. This area is under groundwater stress conditions due to intensive irrigation under agriculture depending upon the groundwater.

To overcome the problem of depleting groundwater resource, the runoff generated during monsoon period should be managed scientifically so that it adds up in groundwater resource or decrease the stress on this natural resource. The wastewater generated daily should also be treated with stringent scientific norms and can be reused for industrial and agricultural purposes in the study area.

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