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## **NORMS FOR GROUNDWATER RESOURCE ESTIMATION IN INDIA**

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### **Abstract:**

*The occurrence and movement of groundwater are controlled by various hydrogeological, hydrological and climatological factors. Reasonably accurate assessment of groundwater recharge and discharge components is not easy because no direct measurement techniques are presently available. Therefore, indirect methods are generally employed for assessment of groundwater resources. Groundwater is a dynamic and replenishable resource which is normally estimated based upon the annual groundwater recharge. It is subjected to withdrawal for various uses such as irrigation, domestic, industrial etc. This article presents the norms for various groundwater recharge components for estimation of groundwater resources in India.*

**Keywords:** Groundwater Balance; Recharge; Storage; Canal Seepage; GEC-1997; GEC-2015.

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### **1. Introduction**

Efficient use of water is crucial to the survival of the plants, animal life and ultimately human beings. Therefore, every effort must be made to make the best use of water so as to make possible a high level of production. For meeting the ever-increasing demands for water, more emphasis is now being given to improve the efficiency of water use through suitable water conservation measures. One of the long-term strategies could be inter-basin transfer of water from surplus basins to deficit basins.

Therefore, proper assessment of water resources potential has become necessary. For competing water demands such as irrigation, drought and flood management, domestic and industrial water supply, generation of electrical energy, fisheries and navigation etc., water resources projects are required to be properly planned, designed, constructed, operated and maintained. And to attain this, reliable estimates of the availability of the water resources are necessary.

The main source of water in India is precipitation (including snowfall) and the annual average has been estimated to be of the order of 4000 Billion Cubic Metres (BCM). Considering both surface water and groundwater into account, the total water resource potential of India, occurring as natural runoff in the rivers, has been estimated as 1913 BCM [2]. In view of various constraints such as topography and uneven distribution of water resource over space and time, it has been estimated that only about 1137 BCM of water can be utilized for beneficial purposes. It includes 690 BCM surface water resources and 447 BCM groundwater resources [1].

Groundwater is a dynamic system. Many areas in the country are facing scarcity of water in spite of the overall national scenario on the groundwater availability being favorable. The reason for such scarcity is mainly unplanned development of groundwater which has resulted in fall of groundwater levels, failure of wells, and seawater intrusion in coastal areas. There is an urgent need for judicious and scientific management and conservation of groundwater resources in view of unplanned development and over-exploitation of groundwater in certain parts of the country.

Hydrologic budget techniques are generally used for estimating groundwater resources. The hydrologic budget equation for groundwater is a specific form of water balance equation that includes components of inflow to and outflow from a groundwater system and change in groundwater storage in an area within a specified time period. Some of these inflow and outflow components can be directly measured and some components require indirect methods of estimation.

## 2. Groundwater in National Water Policy [7]

The '*National Water Policy*' was first adopted by Government of India in the year 1987. After that, it has been revised in the years 2002 and 2012 [7]. This policy regards water as one of the most important elements in the developmental planning of the country. Regarding groundwater, it recommends that

- A portion of river flows should be kept aside to meet ecological needs ensuring that the low and high flow releases are proportional to the natural flow regime, including base flow contribution in the low flow season through regulated groundwater use.
- The anticipated increase in variability in the availability of water because of climate change should be dealt with by increasing water storage in its various forms, namely, soil moisture, ponds, groundwater, small and large reservoirs and their combination. States should be incentivized to increase water storage capacity, which inter-alia should include the revival of traditional water harvesting structures and water bodies.
- There is a need to map the aquifers to know the quantum and quality of groundwater resources (replenishable as well as non-replenishable) in the country. This process should be fully participatory involving local communities. This may be periodically updated.
- Declining groundwater levels in over-exploited areas need to be arrested by introducing improved technologies of water use, incentivizing efficient water use and encouraging community-based management of aquifers. In addition, where necessary, artificial recharging projects should be undertaken so that extraction is less than the recharge. This would allow the aquifers to provide base flows to the surface system, and maintain ecology.
- Water saving in irrigation use is of paramount importance. Recycling of canal seepage water through conjunctive groundwater use may also be considered.
- There should be concurrent mechanism involving users for monitoring if the water use pattern is causing problems like unacceptable depletion or building up of ground waters, salinity, alkalinity or similar quality problems, etc., with a view to planning appropriate interventions.
- The over-drawal of groundwater should be minimized by regulating the use of electricity for its extraction. Separate electric feeders for pumping groundwater for agricultural use should be considered.

- Quality conservation and improvements are even more important for ground waters, since cleaning up is very difficult. It needs to be ensured that industrial effluents, local cesspools, residues of fertilizers and chemicals, etc., do not reach the groundwater.
- Industries in water-short regions may be allowed to either withdraw only the makeup water or should have an obligation to return treated effluent to a specified standard back to the hydrologic system. Tendencies to unnecessarily use more water within the plant to avoid treatment or to pollute groundwater need to be prevented.
- Appropriate institutional arrangements for each river basin should be developed to collect and collate all data on regular basis with regard to rainfall, river flows, area irrigated by crops and by source, utilization for various uses by both surface water and groundwater and to publish water accounts on ten daily basis every year for each river basin with appropriate water budgets and water accounts based on the hydrologic balances. In addition, water budgeting and water accounting should be carried out for each aquifer.
- Appropriate institutional arrangements for each river basin should also be developed for monitoring water quality in both surface and ground waters.

### 3. Groundwater Resource Estimation Methodology

The Government of India had constituted the Groundwater Estimation Committee (GEC) in the year 1982. The objective was to recommend methodologies for assessment of groundwater resource potential in India. The committee recommended that groundwater recharge should be assessed by using groundwater level fluctuation approach. It was also recommended that ad-hoc norms of rainfall infiltration may be used in the areas where sufficient data of groundwater level fluctuations are not available or groundwater level monitoring is not being carried out regularly. The committee was again reconstituted in the year 1995 in order to review the methodology recommended earlier. This reconstituted committee released its report in the year 1997 and suggested several modifications in the methodology based upon groundwater level fluctuation method.

The methodology recommended by Ground Water Estimation Committee - 1997 (GEC-1997) [3] was being used for groundwater assessment in the country for the last two decades. The National Water Policy suggests periodic assessment of groundwater potential in the country on a scientific basis. Therefore, in order to recommend revised and improved methodology, the Ministry of Water Resources (Government of India) again constituted a committee consisting of a number of groundwater experts. The revised methodology (GEC-2015) [4] has incorporated a number of changes in GEC-1997 [3] methodology. Few salient recommendations of GEC-2015 [4] are given below.

- 1) Groundwater resource assessment should be made aquifer-wise. Therefore, lateral and vertical extent and disposition of different aquifers should be demarcated.
- 2) However, the establishment of aquifer geometry at appropriate scale may take some time. Therefore, the current practice of using blocks/mandals/firkas in soft rock areas and watershed in hard rock areas as groundwater assessment unit may be continued.
- 3) Aquifer geometry is being established through aquifer mapping in the country. Till completion of the same, groundwater resources may be estimated to a depth of 300 metres in soft rock areas and 100 metres in hard rock areas.

- 4) Replenishable and in-storage groundwater resources should be estimated for both unconfined and confined aquifers.
- 5) If spring discharge data are available, then it can be used as a proxy for groundwater resource in hilly areas.
- 6) Norms for specific yield, rainfall infiltration factor, recharge due to canals, recharge from irrigation have been refined.
- 7) Instead of using as a criterion for categorization, groundwater level trends should be used as validation of the groundwater resource estimate.
- 8) A quality flag may be included in the groundwater assessment unit for salinity, fluoride and arsenic parameters.
- 9) Groundwater resources should be estimated once in every three years in view of rapid changes in groundwater extractions.

#### 4. Norms for Estimation of Groundwater Components

Kumar [5, 6] has described the methodologies to estimate various groundwater recharge and discharge components of the groundwater balance equation [5, 6], as indicated below.

$$R_r + R_c + R_i + R_t + S_i + I_g = E_t + T_p + S_e + O_g + \Delta S \quad \dots(1)$$

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 to rivers;
- $O_g$  = outflow to other basins; and
- $\Delta S$  = change in groundwater storage.

Various inflow and outflow components of the above groundwater balance equation may be measured or estimated through field experiments, suitable empirical relations developed for a region, Groundwater Estimation Committee norms [4], or any other relevant methods. Some of the norms recommended by GEC-2015 [4] are presented below.

##### 4.1. Recharge from Rainfall ( $R_r$ )

Groundwater level fluctuation and specific yield method takes into account the response of groundwater levels to groundwater inflow and outflow components. Therefore, GEC-1997 [3] and GEC-2015 [4] has recommended that groundwater recharge should be estimated by this approach. However, it requires representative water level measurements at adequately spaced locations for a sufficiently long period. It has been suggested that there should be at least one observation well per 100 sq. km. or a minimum of three spatially and uniformly distributed observation wells in the

groundwater assessment unit. Groundwater level data should preferably be available for around 10 years or at least a minimum period of 5 years. Rainfall data for the corresponding period must also be available. The minimum requirement of the frequency of groundwater level data is at least two times in a year (during pre-monsoon and post-monsoon season). However, it would be preferable to have monthly groundwater level data so that maximum rise and maximum fall in groundwater levels during the year can be recorded.

Groundwater recharge may be estimated using rainfall infiltration factor in case of assessment units or sub-areas where sufficient data on groundwater level fluctuations are not available. However, during the non-monsoon season, rainfall recharge may be estimated by using rainfall infiltration factor only.

It has been recommended that 10% of normal annual rainfall should be taken as minimum rainfall threshold and 3000 mm can be taken as maximum rainfall. To compute the recharge from rainfall, 10% of the normal annual rainfall should be deducted from the rainfall of monsoon season and the balance rainfall should be considered for estimation of recharge from rainfall. Same recharge factor may be taken for monsoon and non-monsoon seasons. If normal rainfall during the non-monsoon season is less than 10% of normal annual rainfall, then recharge due to non-monsoon rainfall may be taken as zero. For various aquifer units, Groundwater Resource Estimation Committee (2015) [4] has recommended the rainfall infiltration factors, as given in Table 1.

Table 1: Rainfall Infiltration Factors for Various Aquifer Units [4]

S.No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	22	20	24
2	Alluvium	AL02	Pebble / Gravel/ Bazada/ Kandi	Quaternary	22	20	24
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	Quaternary	22	20	24
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	22	20	24
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - East Coast	Quaternary	16	14	18
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay) - West Coast	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	22	20	24
7	Alluvium	AL07	Glacial Deposits	Quaternary	22	20	24
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	7	6	8
9	Basalt	BS01	Basic Rocks (Basalt) - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered	Mesozoic to Cenozoic	7	6	8

10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
11	Basalt	BS02	Ultra-Basic - Vesicular or Jointed	Mesozoic to Cenozoic	13	12	14
11	Basalt	BS02	Ultra-Basic - Weathered	Mesozoic to Cenozoic	7	6	8
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	2	1	3
13	Sandstone	ST01	Sandstone/ Conglomerate	Upper Palaeozoic to Cenozoic	12	10	14
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	12	10	14
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	12	10	14
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	12	10	14
17	Sandstone	ST05	Sandstone/ Conglomerate	Proterozoic to Cenozoic	6	5	7
18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	6	5	7
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	4	3	5
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	4	3	5
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	4	3	5
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	4	3	5
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	4	3	5
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	4	3	5
25	Limestone	LS01	Miliolitic Limestone	Quaternary	6	5	7
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	6	5	7
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	6	5	7

31	Limestone	LS04	Limestone with Shale	Proterozoic	6	5	7
33	Limestone	LS05	Marble	Azoic to Proterozoic	6	5	7
35	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Mesozoic to Cenozoic	7	5	9
36	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.) - Massive or Poorly Fractured	Mesozoic to Cenozoic	2	1	3
37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	11	10	12
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	7	5	9
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
41	Schist	SC02	Phyllite	Azoic to Proterozoic	4	3	5
42	Schist	SC03	Slate	Azoic to Proterozoic	4	3	5
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	6	5	7
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	6	5	7
46	Quartzite	QZ02	Quartzite - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	5	4	6
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	2	1	3
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	7	5	9
50	Khondalite	KH01	Khondalites, Granulites - Massive, Poorly Fractured	Azoic	2	1	3
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	7	5	9
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	2	1	3

Normally, recommended rainfall infiltration factors (as given in Table 1) should be used for assessment. However, minimum, maximum or other intermediate values can be adopted if sufficient data based on field studies are available to justify the same. In areas, where watershed development is being implemented with associated soil conservation measures, an additional 2% of rainfall recharge factor may be added to the recommended values. However, it may be noted that separate norms are defined for the recharge contribution due to water conservation structures such as check dams, nalla bunds, percolation tanks etc. This additional factor of 2% is separate from them.

#### 4.2. Recharge from Canal Seepage ( $R_c$ )

Canal seepage can be defined as the process of movement of water from a canal into and through the canal bed and wall materials. A significant portion of total recharge to groundwater system is normally contributed by seepage losses from irrigation canals. Therefore, it is necessary to properly estimate the canal seepage losses for assessment of recharge to the groundwater system. Canal seepage depends upon a number of factors such as size and cross-section of the canal, flow depth, soil characteristics of the canal bed and sides, location and level of drains on both sides of the canal. Norms for canal seepage, as recommended by the Groundwater Resource Estimation Committee (2015) [4] are given in Table 2.

Table 2: Canal Seepage Factors [4]

Formation	Canal Seepage Factor (ham/day/million square meters of wetted area)		
	Recommended	Minimum	Maximum
Unlined canals in normal soils with some clay content along with sand	17.5	15	20
Unlined canals in sandy soil with some silt content	27.5	25	30
Lined canals in normal soils with some clay content along with sand	3.5	3	4
Lined canals in sandy soil with some silt content	5.5	5	6
All canals in hard rock area	3.5	3	4

Above values of canal seepage factor are valid if the groundwater table is relatively deep. In water-logged and shallow water table areas, recharge from canal seepage may be appropriately reduced. Also, specific results of canal seepage from any case studies may be used, if available.

#### 4.3. Recharge from Field Irrigation ( $R_i$ )

Water requirements of crops are met by soil moisture, rainfall, and applied irrigation water. Some part of the water, applied to field crops, is utilized by consumptive use requirement of the crops and remaining water percolates down to recharge the groundwater system. Part of the water applied for irrigation, which joins the groundwater table, is called irrigation return flow. Groundwater recharge from applied irrigation water (both from surface water and groundwater sources) makes a significant contribution to the total recharge to the groundwater system. Recharge from field irrigation depends upon the type of soil, crop type, and irrigation practice. It is site specific and varies from one area to another.



For a proper estimation of groundwater recharge by applied irrigation, studies may be conducted on experimental plots with different crops in different seasons. By applying the water balance equation (involving inflow and outflow of water from the experimental fields), irrigation return flow can be estimated.

Groundwater Resource Estimation Committee (2015) [4] has provided the norms for recharge due to irrigation return flow (Table 3) depending upon the source of irrigation (groundwater or surface water), depth of groundwater table below ground surface and type of crop (paddy, non-paddy). Values given are in percentage of applied water.

Table 3: Norms for Recharge due to Irrigation Return Flow [4]

Depth to Water Table (m)	Ground Water		Surface Water	
	Paddy	Non-Paddy	Paddy	Non-Paddy
<=10	45	25	50	30
11	43.3	23.7	48.3	28.7
12	41.7	22.3	46.7	27.3
13	40	21	45	26
14	38.3	19.7	43.3	24.7
15	36.7	18.3	41.7	23.3
16	35	17	40	22
17	33.3	15.7	38.3	20.7
18	31.7	14.3	36.7	19.3
19	30	13	35	18
20	28.3	11.7	33.3	16.7
21	26.7	10.3	31.7	15.3
22	25	9	30	14
23	23.3	7.7	28.3	12.7
24	21.7	6.3	26.7	11.3
>=25	20	5	25	10

In case of application of surface water, recharge from field irrigation should be estimated based upon the surface water released at the outlet of canal/distribution system. In case of application of groundwater, recharge from field irrigation should be estimated based upon the gross draft from groundwater. If continuous supply of water is available for irrigation (instead of rotational supply of water), then an additional recharge of 5% of water application may be added in the above norms (percentages of applied water). If any specific results are available from case studies or field experiments, then those results may be used.

#### 4.4. Recharge from Tanks ( $R_t$ )

Various studies have shown that recharge from tanks generally varies in the range of 9 - 20 % of the live storage capacity of tanks. But live storage capacity may not be available for most of the tanks. Therefore, recharge from tanks may be assumed as 44 to 60 cm per year over the total water spread area of tanks, with due consideration of agro-climatic conditions in the study area. For

estimation of recharge from ponds and lakes, same norms may be applied. However, recharge from percolation tanks is relatively higher and may be assumed as 50 percent of gross storage.

Groundwater Resource Estimation Committee (2015) [4] has recommended that recharge from storage tanks and ponds may be adopted as 1.4 mm/day based upon average water spread area of tanks/ponds during the period of water storage. If required information about average water spread area is not available, then 60% of the maximum water spread area may be assumed as average water spread area.

Recharge from percolation tanks may be estimated as 50% of their gross storage. By taking into account the number of fillings in percolation tanks, recharge from percolation tanks may be equally divided between monsoon and non-monsoon seasons. Similarly, recharge from check dams and nala bunds may also be taken as 50% of their gross storage and equally divided between monsoon and non-monsoon seasons. However, it assumes that desilting maintenance is carried out every year, otherwise recharge from these structures are reduced.

#### 4.5. Change in Groundwater Storage ( $\Delta S$ )

In order to estimate the change in groundwater storage during a specified period (such as monsoon or non-monsoon season), the groundwater levels in the study are required to be observed through a well-distributed network of observation wells. The groundwater levels are lowest just before rainfall in the month of May/June and highest immediately after monsoon season in the month of October/November. During the monsoon season, recharge to groundwater is more than withdrawal from groundwater. Therefore, the change in groundwater storage during the monsoon season implies the amount of water added to the groundwater storage. On the other hand, change in groundwater storage during the non-monsoon season implies the amount of water withdrawn from the groundwater reservoir. The change in groundwater storage ( $\Delta S$ ) during a specified period is estimated as follows:

$$\Delta S = \sum \Delta h A S_y \quad (2)$$

where,  $\Delta h$  = change in groundwater level (rise or fall) during the given time period;  
 $A$  = area influenced by the well; and  
 $S_y$  = specific yield of the aquifer.

Groundwater Resource Estimation Committee (1997) [3] had recommended that there should be a minimum of three observation wells in the study area well-distributed spatially, or at least one observation well per 100 sq. km., whichever is more. Size of the watershed as an assessment unit can be around 100 - 300 sq. km. The specific yield of the aquifer can be estimated by conducting pump tests. Groundwater Resource Estimation Committee (2015) [4] has recommended the specific yield values for different aquifers units, as given in Table 4.

Table 4: Specific Yield for Different Aquifers Units [4]

S. No.	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
1	Alluvium	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	Quaternary	10	8	12
2	Alluvium	AL02	Pebble/ Gravel/ Bazada/ Kandi	Quaternary	16	12	20
3	Alluvium	AL03	Older Alluvium (Silt/Sand/Gravel/ Lithomargic clay)	Quaternary	6	4	8
4	Alluvium	AL04	Aeolian Alluvium (Silt/ Sand)	Quaternary	16	12	20
5	Alluvium	AL05	Coastal Alluvium (Sand/Silt/Clay)	Quaternary	10	8	12
6	Alluvium	AL06	Valley Fills	Quaternary	16	12	20
7	Alluvium	AL07	Glacial Deposits	Quaternary	16	12	20
8	Laterite	LT01	Laterite / Ferruginous concretions	Quaternary	2.5	2	3
9	Basalt	BS01	Basic Rocks (Basalt) - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
10	Basalt	BS01	Basic Rocks (Basalt) - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
11	Basalt	BS02	Ultra Basic - Weathered, Vesicular or Jointed	Mesozoic to Cenozoic	2	1	3
12	Basalt	BS02	Ultra Basic - Massive Poorly Jointed	Mesozoic to Cenozoic	0.35	0.2	0.5
13	Sandstone	ST01	Sandstone/Conglomerate	Upper Palaeozoic to Cenozoic	3	1	5
14	Sandstone	ST02	Sandstone with Shale	Upper Palaeozoic to Cenozoic	3	1	5
15	Sandstone	ST03	Sandstone with shale/ coal beds	Upper Palaeozoic to Cenozoic	3	1	5
16	Sandstone	ST04	Sandstone with Clay	Upper Palaeozoic to Cenozoic	3	1	5
17	Sandstone	ST05	Sandstone/Conglomerate	Proterozoic to Cenozoic	3	1	5

18	Sandstone	ST06	Sandstone with Shale	Proterozoic to Cenozoic	3	1	5
19	Shale	SH01	Shale with limestone	Upper Palaeozoic to Cenozoic	1.5	1	2
20	Shale	SH02	Shale with Sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
21	Shale	SH03	Shale, limestone and sandstone	Upper Palaeozoic to Cenozoic	1.5	1	2
22	Shale	SH04	Shale	Upper Palaeozoic to Cenozoic	1.5	1	2
23	Shale	SH05	Shale/Shale with Sandstone	Proterozoic to Cenozoic	1.5	1	2
24	Shale	SH06	Shale with Limestone	Proterozoic to Cenozoic	1.5	1	2
25	Limestone	LS01	Miliolitic Limestone	Quarternary	2	1	3
26	Limestone	LS01	Karstified Miliolitic Limestone	Quarternary	10	5	15
27	Limestone	LS02	Limestone / Dolomite	Upper Palaeozoic to Cenozoic	2	1	3
28	Limestone	LS02	Karstified Limestone / Dolomite	Upper Palaeozoic to Cenozoic	10	5	15
29	Limestone	LS03	Limestone/Dolomite	Proterozoic	2	1	3
30	Limestone	LS03	Karstified Limestone/Dolomite	Proterozoic	10	5	15
31	Limestone	LS04	Limestone with Shale	Proterozoic	2	1	3
32	Limestone	LS04	Karstified Limestone with Shale	Proterozoic	10	5	15
33	Limestone	LS05	Marble	Azoic to Proterozoic	2	1	3
34	Limestone	LS05	Karstified Marble	Azoic to Proterozoic	10	5	15
35	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Mesozoic to Cenozoic	1.5	1	2
36	Granite	GR01	Acidic Rocks (Granite, Syenite, Rhyolite etc.) - Massive or Poorly Fractured	Mesozoic to Cenozoic	0.35	0.2	0.5

37	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	3	2	4
38	Granite	GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
39	Schist	SC01	Schist - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
40	Schist	SC01	Schist - Massive, Poorly Fractured	Azoic to Proterozoic	0.35	0.2	0.5
41	Schist	SC02	Phyllite	Azoic to Proterozoic	1.5	1	2
42	Schist	SC03	Slate	Azoic to Proterozoic	1.5	1	2
43	Quartzite	QZ01	Quartzite - Weathered, Jointed	Proterozoic to Cenozoic	1.5	1	2
44	Quartzite	QZ01	Quartzite - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.3	0.2	0.4
45	Quartzite	QZ02	Quartzite - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2
46	Quartzite	QZ02	Quartzite- Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
47	Charnockite	CK01	Charnockite - Weathered, Jointed	Azoic	3	2	4
48	Charnockite	CK01	Charnockite - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	1.5	1	2
50	Khondalite	KH01	Khondalites, Granulites - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
51	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Weathered, Jointed	Azoic	1.5	1	2
52	Banded Gneissic Complex	BG01	Banded Gneissic Complex - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	1.5	1	2

54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
55	Gneiss	GN02	Gneiss - Weathered, Jointed	Azoic to Proterozoic	3	2	4
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	0.3	0.2	0.4
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	1.5	1	2
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	0.3	0.2	0.4
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5
61	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	2	1	3
62	Intrusive	IN02	Ultrabasics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	0.35	0.2	0.5

Normally, recommended specific yield values (as given in Table 4) should be used for assessment. However, minimum, maximum or other intermediate values can be adopted if sufficient data based on field studies (pumping tests) are available to justify the same.

## 5. Concluding Remarks

The recommended norms for recharge assessment are required to be applied in those cases where sufficient field data/results are not available to estimate recharge components. It is highly desirable that these ad-hoc norms should be periodically revised depending upon the recent studies undertaken by various central and state government departments, academic and research institutes, and non-government organizations for groundwater assessment in various parts of the country. Though it is appropriate that a specific standardized methodology is adopted for assessment of groundwater resources, it is essential that various ad-hoc norms are regularly updated based upon the results of various case studies being undertaken.

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