DETAILED GUIDELINES FOR IMPLEMENTING THE GROUND WATER RESOURCE ESTIMATION METHODOLOGY 2015

Central Ground Water Board
Ministry of Water Resources
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TYPE OF GROUND WATER ASSESSMENT UNIT AND CHARACTERISTICS OF GROUND WATER YEAR

1.1 GENERAL

GEC 2015 recommends to carry out aquifer wise assessment. Aquifers are normally of larger sizes and hence it is recommended to assess the resources in a smaller units called assessment units and present the results aquifer wise. A ground water assessment unit is a geographic land area for which ground water assessment is to be carried out with the objective of estimating the following components:

a) **Current gross ground water extraction.**
b) **Recharge due to 'Other Sources' (These are the sources other than rainfall)**
c) **Resultant Inflow into the system.**
d) **Recharge from rainfall.**
e) **Annual Extractable Ground Water Resource.**
f) **Current stage of ground water extraction.**
g) **Stage of ground water extraction**
h) **Ground Water Table trend.**
i) **Categorisation for future ground water development .**
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k) **Net annual ground water availability for future use.**
l) **Additional Potential Resources**
m) **In-storage resources**
n) **Dynamic and In-storage resources of Confined and semi-Confined Aquifers**

Each state/Union Territory should adopt a particular type of ground water assessment unit. Ground water assessment is also to be done on the basis of a ground water year. The type of ground water assessment unit and the characteristics of a ground water year which are common for all ground water assessment units in a particular State/Union Territory are discussed in this chapter.

1.2 TYPE OF GROUND WATER ASSESSMENT UNIT

Each State/Union Territory should adopt only one of the following five types of ground water assessment units for the entire State/Union Territory depending on the major lithology in the state. These are namely:

a) **Block**
b) **Taluka**
c) **Mandal**
d) **Firka**
e) **Watershed.**

The first four types mentioned above are administrative in character, and the last one namely, 'Watershed' is a hydrologic unit. All States/Union Territories are predominantly characterised by either 'Alluvial Aquifer' or 'Non Alluvial Aquifer'. The type of unit to be adopted will depend on the predominant Principal Aquifer a particular State/Union Territory contains.

Normally in any area, there will be one unconfined aquifer, one or more confined aquifers and one/more semi confined aquifers. Presently Aquifer Mapping is going on in the country on a war footing. In this, entire country is divided into 14 principal aquifers which in turn divided into 42 major aquifers. The major aquifers demarcated in the country are presented below:

TABLE 1. DESCRIPTION OF MAJOR AQUIFER SYSTEMS OF INDIA

S. No	Principal Aquifer Systems		Yield (m3/ day)	Major Aquifers		Area Covered (Sq km)	Age
	Code	Name		Code	Name		
1	AL	Alluvium (945753 sq km) (29.82 %)	10-6500	AL01	Younger Alluvium (Clay/Silt/Sand/ Calcareous concretions)	339298	Quaternary
2				AL02	Pebble / Gravel/ Bazada/ Kandi	5203	Quaternary
3				AL03	Older Alluvium (Silt/Sand/Gravel/Lithomargic clay)	407490	Quaternary
4				AL04	Aeolian Alluvium (Silt/ Sand)	149208	Quaternary
5				AL05	Coastal Alluvium (Sand/Silt/Clay)	40661	Quaternary
6				AL06	Valley Fills	3864	Quaternary
7				AL07	Glacial Deposits	31	Quaternary
8	LT	Laterite (40925 sq km) (1.29 %)	5 - 6000	LT01	Laterite / Ferruginous concretions	40926	Quaternary
9	BS	Basalt (512302 sq km) (16.15 %)	1-480	BS01	Basic Rocks (Basalt)	512290	Mesozoic to Cenozoic
10				BS02	Ultra-Basic	12	Mesozoic to Cenozoic
11	ST	Sandstone (260415 sqkm) (8.21 %)	5 - 3700	ST01	Sandstone/Conglomerate	50026	Upper Palaeozoic to Cenozoic
12				ST02	Sandstone with Shale	75355	Upper Palaeozoic to Cenozoic
13				ST03	Sandstone with Shale/ Coal beds	37720	Upper Palaeozoic to Cenozoic

S. No	Principal Aquifer Systems		Yield (m3/ day)	Major Aquifers		Area Covered (Sq km)	Age
	Code	Name		Code	Name		
14				ST04	Sandstone with Clay	21540	Upper Palaeozoic to Cenozoic
15				ST05	Sandstone/Conglomerate	56354	Proterozoic to Cenozoic
16				ST06	Sandstone with Shale	19420	Proterozoic to Cenozoic
17	SH	Shale (225397 sqkm) (7.11 %)	8 -2900	SH01	Shale with Limestone	3784	Upper Palaeozoic to Cenozoic
18				SH02	Shale with Sandstone	87771	Upper Palaeozoic to Cenozoic
19				SH03	Shale, Limestone and Sandstone	45539	Upper Palaeozoic to Cenozoic
20				SH04	Shale	5938	Upper Palaeozoic to Cenozoic
21				SH05	Shale/Shale with Sandstone	64265	Proterozoic to Cenozoic
22				SH06	Shale with Limestone	18100	Proterozoic to Cenozoic
23	LS	Limestone (62898 sqkm) (1.98 %)	4 - 2100	LS01	Miliolitic Limestone	2946	Quaternary
24				LS02	Limestone / Dolomite	19747	Upper Palaeozoic to Cenozoic
25				LS03	Limestone/Dolomite	34708	Proterozoic
26				LS04	Limestone with Shale	5499	Proterozoic
27				LS05	Marble	995	Azoic to Proterozoic
28	GR	Granite (100991 sqkm) (3.18 %)	10-1440	GR01	Acidic Rocks (Granite,Syenite, Rhyolite etc.)	133	Mesozoic to Cenozoic
29				GR02	Acidic Rocks (Pegmatite, Granite, Syenite, Rhyolite etc.)	100858	Proterozoic to Cenozoic
30	SC	Schist (140934.90 sqkm) (4.44%)	3-550	SC01	Schist	93026	Azoic to Proterozoic
31				SC02	Phyllite	31589	Azoic to Proterozoic
32				SC03	Slate	16321	Azoic to Proterozoic
33	QZ	Quartzite (46904 sqkm) (1.48%)	2 - 400	QZ01	Quartzite	20830	Proterozoic to Cenozoic
34				QZ02	Quartzite	26074	Azoic to Proterozoic
35	CK	Charnockite (76359 sq km) (2.41%)	1 - 3000	CK01	Charnockite	76360	Azoic

S. No	Principal Aquifer Systems		Yield (m3/ day)	Major Aquifers		Area Covered (Sq km)	Age
	Code	Name		Code	Name		
36	KH	Khondalite (32913 sq km) (1.04 %)	20-1500	KH01	Khondalite, Granulite	32914	Azoic
37	BG	Banded Gneissic Complex (478382 sq km) (15.09 %)	2 - 3600	BG01	Banded Gneissic Complex	478383	Azoic
38	GN	Gneiss (158753 sq km) (5.01 %)	10 - 2500	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic	59260	Azoic to Proterozoic
39				GN02	Gneiss	43266	Azoic to Proterozoic
40				GN03	Migmatitic Gneiss	56228	Azoic
41	IN	Intrusive (19895 sqkm) (0.63 %)	Low Yield	IN01	Basic Rocks (Dolerite, Anorthosite etc.)	11167	Proterozoic to Cenozoic
42				IN02	Ultra-Basics (Epidiorite, Granophyre etc.)	8729	Proterozoic to Cenozoic

Wherever Aquifer Mapping is completed, the aquifer disposition is fully known and the resources can be assessed at unit wise for each of the aquifer and finally total resources of different aquifers can be presented. Wherever aquifer mapping is not completed, assessment should be done upto a depth of 100m in hard rock areas and 300m in soft rock areas. If disposition of deeper aquifers is not known, resources should be computed as if there exists only a single aquifer and that is in unconfined condition.

All States/Union Territories which are predominantly characterised by ‘Non Alluvial Aquifers’ should adopt ‘Watershed’ as the type of ground water assessment unit. Such States/Union Territories which have been adopting either ‘Block’ or ‘Taluka’ or ‘Mandal’ or Firka as the type of ground water assessment unit should switch over to ‘Watershed’ as the type of ground water assessment unit for the second national assessment using GEC 2015 methodology. The reasons for recommending ‘Watershed’ as the type of ground water assessment unit in the area with Non Alluvial Aquifers are as follows:

a) The undulating topography in the area of Non-Alluvial Aquifers allows easy demarcation of a hydrologic unit like ‘Watershed’.
b) The boundary of a ‘Watershed’ in Non-Alluvial Aquifer terrain mostly coincides with the ground water divide as a result of which ground water balance within it can be made very conveniently.

All States/Union Territories which are predominantly characterised by ‘Alluvial’ aquifers should adopt either ‘Block’ or ‘Taluka’ or ‘Mandal’ or ‘Firka’ as the type of ground water assessment unit. A hydrologic unit like a ‘Watershed’ as the type of ground water assessment unit is not recommended in the ‘Alluvial’ aquifers for the following reasons.

a) Demarcation of the boundaries of the 'Watershed' in 'Alluvial' aquifers is difficult because of the relative flatness of the alluvial areas.
b) The boundary of a 'Watershed' in 'Alluvial' aquifers will not usually coincide with the ground water divide, as a result of which there is no particular advantage of adopting 'Watershed' as the type of ground water assessment unit.

1.3 CHARACTERISTICS OF GROUND WATER YEAR

1.3.1 GROUND WATER YEAR

India receives rainfall from both South-West and North-East monsoons. The former is more or less consistently active during June to August, and the latter is more or less consistently active during October and November. Any given State/Union Territory is however, characterised by the fact that the quantum of rainfall received from one of these two monsoons is significantly much higher than that from the other. Some states may receive rainfall from both the monsoons equally. With these considerations in mind, a ground water year for purposes of ground water assessment can be very conveniently considered to comprise of 12 calendar months beginning from the commencement of the predominant monsoon.

1.3.2 SEASONS WITHIN A GROUND WATER YEAR

The ground water table is at the lowest level (or, farthest from the ground level) just prior to the onset of the predominant monsoon and reaches a peak (highest level or closest to the ground level) a little before the cessation of the predominant monsoon. Thereafter, the ground water table shows a declining trend with the recession limb having two significant segments. The first segment has a relatively steeper slope and extends to about a month after the cessation of the predominant monsoon. The second segment has a much flatter slope and extends up to the time when the predominant monsoon commences again is the next year. Ground water is usually not significantly developed for irrigation use during the one month period corresponding to the first segment of the recession limb of the water table hydrograph as mentioned above, because of availability of adequate moisture in the root zone during this one month period. Keeping the above considerations in mind, a ground water year can be conveniently sub-divided into the following two seasons :

a) 'Monsoon Season' between the commencement of the predominant monsoon and a month after its cessation.
b) 'Non-monsoon Season' covering the rest of the ground water year.

It needs to be emphasised here that, the 'Monsoon Season' as defined above does not coincide with the duration of the predominant monsoon as commonly understood on the basis of occurrence of rainfall, but in fact extends to a month after its cessation. Ground water assessment computations will have to be made separately for these two seasons within a ground water year.

1.3.3 PRE- MONSOON AND POST- MONSOON MONITORINGS

Water table data as recorded from a number of observation wells will be used in the assessment of ground water. These water table data will have to be recorded during two times within a ground water year. These two specified times are referred to as 'Pre-monsoon' and 'Post- monsoon' monitorings. The former corresponds to the calendar month just prior to the 'Monsoon Season', and the latter corresponds to the calendar month just after one month of the cessation of monsoon.

1.3.4 GROUND WATER ASSESSMENT YEAR

The ground water year for which ground water assessment is made and reported is referred to is as the 'Ground Water Assessment Year'.

The components of gross ground water extraction, recharge due to 'Other Sources' and resultant inflow into the system mentioned earlier in Section 1.1. are computed with reference to the 'Ground Water Assessment Year'. The component of recharge from 'Rainfall' is however a little different in the sense that, the rainfall for which the rainfall recharge is computed is not the rainfall during the ground water assessment year but a 'Normal Rainfall' value obtained as the average rainfall over a sufficiently long number of ground water years. The reasons for these are obvious. The components of gross ground water extraction and recharge from 'Other Sources' and resultant inflows are to be assessed for an average situation. Ground water assessment reports are to be prepared once in three years.

1.3.5 SUMMARY

Based on what has been described earlier, the combinations of ground water year, monsoon & non-monsoon seasons and pre-monsoon & post-monsoon monitorings which can be adopted by a particular State/Union Territory are summarised below :

a) Applicable when the predominant monsoon is the south-west monsoon and the same commences by late May or early June

Ground water year :	12 calendar months between June of one calendar year and May of next calendar year.
Monsoon season	4 calendar months between June and September.
Non-monsoon season	the remaining 8 calendar months between October of one calendar year and May of the next calendar year.
Pre- monsoon monitoring	calendar month of May.
Post- monsoon monitoring	calendar month of October.

b) Applicable when the predominant monsoon is the south-west monsoon and the same commences by end of June or early July.

Ground water year :	12 calendar months between July of one calendar year and June of next calendar year.
Monsoon season	4 calendar months between July and October.
Non-monsoon season	the remaining 8 calendar months between November of one calendar year and June of the next calendar year.
Pre- monsoon monitoring	calendar month of June .
Post- monsoon monitoring	calendar month of November.

c) Applicable when the predominant monsoon is the north-east monsoon

Ground water year :	12 calendar months between October of one calendar year and September of next calendar year
Monsoon season	3 calendar months between October and December.
Non-monsoon season	The remaining 9 calendar months between January and September.
Pre- monsoon monitoring	calendar month of September of the previous Calendar year
Post- monsoon monitoring	calendar month of January of next calendar year.

d) Applicable when both the monsoons are predominant

Ground water year :	12 calendar months between June of one calendar year and May of next calendar year.
Monsoon season	7 calendar months between June and December.
Non-monsoon season	The remaining 5 calendar months between January and May.
Pre- monsoon monitoring	calendar month of June of the previous Calendar year.
Post- monsoon monitoring	calendar month of January of the next calendar year.

1.4 PRESENTATION OF INFORMATION

Information on the type of ground water assessment unit and the characteristics of ground water year as discussed in the previous sections and which are common for all ground water assessment units in a particular State/Union Territory are to be presented in Table 1.1.

1.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the type of ground water assessment unit, its characteristics and the ground water year.

S.No	Parameter	Type	Size	Decimals
1	State or Union Territory	Text	30	
2	Predominant Principal Aquifer	Text	30	
3	Predominant Monsoon	Text	30	
4	Type of Assessment Unit	Text	10	
5	Ground Water Year	Text	20	
6	Monsoon Season	Text	20	
7	Non-Monsoon Season	Text	20	
8	Pre-Monsoon Monitoring Month	Text	10	
9	Post-Monsoon Monitoring Month	Text	10	

Table 1.1 Type of Ground Water Assessment Unit and Characteristics of Ground Water Year

Name of State / Union Territory :
Ground Water Assessment Year :

S. No.	Description of item	Quantity
1	Predominant type of Principal Aquifer System (Alluvial / Non Alluvial)	
2	Predominant monsoon (South –west / North – east/ Both)	
3	If predominant monsoon is, 'South – west', The time when it usually commences (late May or early June / late June or early July)	
4	Type of Ground Water Assessment Unit (Block / Taluka / Mandal / Firka/ Watershed)	
5	Ground Water Year (June to May / July to June / October to September)	
6	Monsoon Season (June to September / July to October / October to December / June to December)	
7	Non – monsoon Season (October to May / November to June / January to September / January to May)	
8	Month of Pre – monsoon Monitoring (May / June / September)	
9	Month of Post – monsoon Monitoring (October / November / January)	

2

GROUND WATER ASSESSMENT UNIT AND IT's SUB-UNITS

2.1 GENERAL

The type of ground water assessment unit to be adopted by each State/Union Territory has been presented in Chapter 1. Wherever a 'Watershed' is adopted as the type of ground water assessment unit, each such watershed for which ground water assessment is made can typically have a geographic area ranging between ten thousand and thirty thousand hectares (100 and 300 sq.km.). To that extent, a watershed adopted as the assessment unit may have a few sub-watersheds within it. Delineation of individual watersheds should be carried out properly using Survey of India toposheets as the basis, and ensuring that no areas within the State/Union Territory are left out, and that, the boundary of the assessment unit is a real water divide, except for those units which may have an inter-state boundary.

2.2 SUB-UNITS WITHIN AN ASSESSMENT UNIT

Each ground water assessment unit should be further sub-divided in to the following four sub-units.

a) **Hilly Area**
b) **Poor ground water quality area**
c) **Command Area**
d) **Non-command Area**

2.2.1 Hilly Area

This sub-unit comprises of all portions of the ground water assessment unit which have ground slopes greater than 20 percent. However, localised pockets like valley fills, terraces, plateau etc., occurring within the region of greater than 20 percent slopes, but having good ground water potential should be included within one of the other three sub-units mentioned above whichever is most appropriate. This sub-unit is characterised by more run off and less ground water recharge, and hence no ground water assessment is made for it. While demarcating hilly area, it is adviced to use DEM and use computer generated slope map.

2.2.2 Area Suitable for Ground Water Recharge

The portion of the ground water assessment unit other than the hilly area as described in Section 2.2.1, is referred to as the area of the ground water assessment unit in which ground water recharge is considerable. This area is further sub-divided into three sub-units namely, poor ground water quality area, command area and non-command area.

2.2.3 Poor Ground Water Quality Area

This sub-unit comprises of all portions of the ground water assessment unit in which ground water recharge is possible, but in which ground water quality is beyond the permissible limits as adopted by the particular State/Union Territory for purpose of suitability for irrigation use. This sub-unit includes portions of the assessment unit characterised by brackish/saline ground water and saline soil tracts. Ground water assessment should be separately made for this sub-unit.

2.2.4 Good Ground Water Quality Area

This area comprises of all portions of the ground water assessment unit in which ground water recharge is possible, and in which ground water quality is well within the permissible limits as adopted by the particular State/Union Territory for the purpose of suitability for irrigation use. This area is further sub-divided into command area and non-command area.

2.2.5 Command Area

This sub-unit comprises of all portions of the good ground water quality area within the ground water assessment unit as described in Section 2.2.4, and which are under the command of Major or Medium Irrigation Projects. Portions of this sub-unit can also be under irrigation by ground water source. Ground water assessment is to be made separately for this sub-unit.

2.2.6 Non-Command Area

This sub-unit comprises of all portions of the good ground water quality area within the ground water assessment unit as described in Section 2.2.4 and which is not in the command of Major or Medium Irrigation projects.. Irrigation in this sub-unit is predominantly by ground water sources. But there is a possibility of Surface water irrigation by Lift Irrigation Schemes, Minor Irrigation Sources etc. Ground water assessment is to be separately made for this sub-unit.

2.3 PRESENTATION OF INFORMATION

Each ground water assessment unit is assigned a unique name, and a unique index number (1/ 2/ 3 etc.). All relevant information on the location and area of each ground water assessment unit and the sub-units within it are presented in Table 2.1.

2.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the sub units of ground water assessment unit.

S.No	Parameter	Type	Size	Decimals
1	Toposheet Numbers	Text	50	
2	Starting Latitude	Text	10	
3	Ending Latitude	Text	10	
4	Starting Longitude	Text	10	
5	Ending Longitude	Text	10	
6	Total Area	Number	7	0
7	Hilly Area	Number	7	0
8	Recharge Worthy Area	Number	7	0
9	Poor Ground Water Quality Area	Number	7	0
10	Command Area	Number	7	0
11	Non Command Area	Number	7	0

Table 2.1 Location Details and Area of Each Ground Water Assessment Unit and its Sub – Units.

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Quantity
1	Reference number(s) of Survey of India Toposheet(s) of 1: 50,000 scale in which the Ground Water Assessment Unit is located	
2	Latitudes within which the Ground Water Assessment Unit is located i) Starting ii) Ending	
3	Longitudes within which the Ground Water Assessment Unit is located i) Starting ii) Ending	
4	Total Geographical area of the **'Ground Water Assessment Unit'** in hectares	
5	**'Hilly Area'** in hectares	
6	Area in hectares of the portion of the Ground Water Assessment Unit in where ground water recharge is more [(4) - (5)]	
7	**'Poor Ground Water Quality Area'** in hectares	
8	**'Command Area'** in hectares	
9	**'Non - command Area'** in hectares	
10	Quality Hazard (Salinity/ Arsenic/Fluoride/Others)	

3

GROUND WATER EXTRACTION

3.1 GENERAL

Ground water is primarily made use of to meet domestic water supply and irrigation water requirements. In some States/Union Territories ground water may also be important to meet industrial water supply requirements. The gross ground water extraction components for the estimation of most probable ground water extraction in an year which are required to be known in respect of command area, non-command area and poor ground water quality area of each ground water assessment unit are listed below:

a) Gross ground water extraction for 'Irrigation' during monsoon and non-monsoon seasons**.** They are used for computing recharge from irrigation water applied by ground water irrigation (Chapter 6)
b) Annual gross ground water extraction for 'Irrigation' and 'Industrial' use. It is used for computing net annual ground water availability for 'Future Use' (Chapter 26).
c) Annual gross ground water extraction for 'All Uses'. It is used for computing the current stage of ground water extraction (Chapter 21).
d) Gross ground water extraction for 'All Uses' during monsoon season. It is used for computing rainfall recharge during monsoon season by the water table fluctuation method (Chapter 19).

The norms to be adopted and the assumptions to be made for estimating the ground water extraction components are likely to vary considerably from State to State. In other words, the task of estimating the current gross ground water extraction components as listed above is a highly location specific problem. Consequently it is difficult to specify a common uniform procedure to be followed by all States/Union Territories for computing the ground water extraction components. Hence, all States/Union Territories are given the freedom to adopt a procedure most suitable to them. The only requirement is that all the current gross ground water extraction components as listed above should be estimated with as much accuracy as possible. No single method is accurate because of lack of valid data available. Hence it is recommended to apply more than one method for estimating the ground water extraction and take the average of those figures as the accepted ground water extraction. If the ground water extraction computed by any one of the methods is very much deviating from the other estimates, this may be ignored in the computation of accepted ground water extraction.

The GEC 2015 methodology suggests the following methods for estimating the ground water extraction.

For estimating Ground Water Extraction for Irrigation (GE_{IRR})

- Unit Draft Method
- Crop Water Requirement Method
- Power Consumption Method

For estimating Ground Water Extraction for Domestic Use (GE_{DOM})

- Unit Draft Method
- Consumptive Use Method

For estimating Ground water Extraction for Industrial use (GE_{IND})

- Unit Draft Method
- Consumptive Use Pattern Method

Hence there are only five methods for estimating any type of ground water extraction. These are as follows:

- Unit Draft Method
- Crop Water Requirement Method
- Power Consumption Method
- Consumptive Use Method
- Consumptive Use Pattern Method

3.2 ASSUMPTIONS

3.2.1 Unit Draft Method

In unit draft method for estimating the ground water extraction for any use can be estimated by following the suggested procedure which has the following assumptions.

a) Different types of wells which are commonly used in the ground water assessment sub unit are identified and unit ground water extraction per well during monsoon and non-monsoon seasons for each type are to be estimated through field study, which is called unit draft.

b) The number of wells belonging to different types as identified in 'a' above, and which are currently in actual use are then estimated.

c) The gross ground water extraction is finally estimated using the results from 'a' and 'b' above.

3.2.2 Crop Water Requirement Method

Estimation of the ground water extraction using crop water requirement method following the suggested procedure has the following assumptions.

a) Different types of crops which are grown in the ground water assessment sub unit are identified and crop water requirement for each crop are to be collected from Agricultural Research Institutes.

b) Cropping pattern in the ground water assessment sub unit during monsoon season and non-monsoon seasons are to be collected from the agricultural department or block development office. Remote sensing techniques may also be applied for acquiring this data.

c) The gross ground water extraction for Irrigation is finally estimated using the results from ‘a’ and ‘b’ above.

3.2.3 Power Consumption Method

Estimation of the ground water extraction using power consumption method following the suggested procedure has the following assumptions.

a) Ground water extracted for a unit of electricity consumed for different hydrogeological conditions is to be estimated during monsoon and non-monsoon seasons through field studies.
b) Total power consumed in each of the hydrogeological units mentioned in a are to be collected from the electricity department.
c) The gross ground water extraction for irrigation is finally estimated using the results from ‘a’ and ‘b’ above.

3.2.4 Consumptive Use Method

Estimation of the ground water extraction using consumptive use method following the suggested procedure has the following assumptions.

a) Consumptive water requirement per person in various population zones depending on the urbanization can be estimated through field surveys or taking the standard norms.
b) Total population of the various population zones as mentioned in ‘a’ are to be collected from the recent population census and applying suitable growth rate for estimating the population as on the year of assessment.
c) The fractional load on ground water as a fraction between 0 and 1 can be collected from the agencies supplying domestic water in the ground water assessment sub units.
d) The gross ground water extraction for domestic need is finally estimated using the results from ‘a’ ‘b’ and ‘c’ above.

3.2.5 Consumptive Use Pattern Method

Estimation of the ground water extraction using consumptive use pattern method following the suggested procedure has the following assumptions.

a) Consumptive water requirement per industrial unit for various types of industries can be estimated through field surveys or taking the standard norms.
b) Total number of similar industrial units as mentioned in ‘a’ in each of the assessment sub units are to be collected from the District Industrial Centres.
c) The fractional load on ground water as a fraction between 0 and 1 can be collected from the agencies supplying industrial water in the ground water assessment sub units.
d) The gross ground water extraction for Industrial need is finally estimated using the results from ‘a’ ‘b’ and ‘c’ above.

3.3 SUGGESTED COMPUTATIONAL PROCEDURE

3.3.1 Unit Draft Method

Different types of wells which are commonly used in the ground water assessment unit are first identified. The ground water extraction per well per day and the number of days during which the wells are used in the monsoon and non-monsoon seasons are then estimated for each type of well. These estimates are finally used to obtain the unit ground water extraction per well in the monsoon and non-monsoon seasons for each type of well. All wells of the same type are such that, each of them,

a) have more or less the same ground water withdrawal per day,
b) are more or less used for the same number of days during monsoon and non-monsoon seasons respectively and
c) have a single use (either irrigation, domestic water supply or industrial water supply) to which they are put to.

The last requirement mentioned above arises as a result of the need to estimate separately the gross ground water extraction for different uses. However, there may be some types of wells which are employed for more than one use. In such cases, a separate type is considered for each use, and unit ground water extraction per well should be separately estimated for each usage. Also, the ground water withdrawal from the same type of well will be usually more in the non-command area than in the command area, because of more extensive use of the wells in the non-command area. In such cases also, the same type of well should be actually considered as two different types, and unit ground water extraction per well should be separately estimated for each of the sub unit.

The unit draft or the ground water extraction per well per season is computed as below:

$$\text{Unit Draft or Ground Water Extraction per well per season in ham} = \frac{\text{Extraction in cubic meters/day} * \text{No. of Days}}{10000}$$

This Unit draft whatever is estimated is for the year of field study for the rainfall of that year. If the rainfall in that year is more, normally unit draft will be less and similarly if rainfall for the year is less, the unit draft will be more. GEC 2015 methodology recommends a normalization procedure using the following formula.

$$Normalised\ Unit\ Draft = Unit\ Draft \times \frac{Current\ Year\ Rainfall}{Normal\ Rainfall}$$

The Ground water extraction for any use for any season can be computed using the following formula.

$$GGWE = \sum_{i=1}^{types} No_i \times Normalised\ \ Unit\ Draft_i$$

3.3.2 Crop Water Requirement Method

Water requirement is different for different crops and if the crop water requirement of each crop is known, the irrigation water applied can be estimated. If the area is dependent on ground water, this irrigation water is applied by ground water sources. This can be computed using the following formula. If the crop water requirement is in meters and area in hectares then the extraction will be in hectare meters.

$$GGWE_{IRR} = \sum_{i=1}^{crops} Crop\ water\ requirement_i \times cropped\ area_i$$

3.3.3 Power Consumption Method

Depending on the depth to water level and the efficiency of pump, the power requirement to lift 1 cubic meter of water varies. Hence it is recommended to do field studies in various hydrogeological conditions and estimate the power requirement for lifting one cubic meter of water.

Once this data is available, the total power consumed through the agriculture feeders in the sub unit may be collected from electricity department and compute the total ground water extraction for irrigation in hectare meters using the following formula.

$$GGWE = \sum_{i=1}^{sections} \frac{Total\ Power\ Consumed_i}{Power\ required\ for\ unit\ water\ lift_i \times 10000}$$

3.3.4 Consumptive Use Method

Consumptive use method requires population as on today. But normally population census is done every ten years and current population may not be available. Hence it is to be estimated using nearest census data and growth rate using the following formula.

$$P_A = P_C + \frac{P_C * (Assessment\ year - Census\ year) * Growth\ rate}{100}$$

Where,

P_A = Population as on Assessment year

P_C= Population as on Census year

The consumptive requirement can be collected from field surveys or by taking from the norms suggested by various organizations. In case percapita requirement data is not available percapita requirement of 60lpcd may be taken as norm. Load on Ground water can be collected from the water supplying department. The fractional load (Lg) is 0 means the area is fully dependent on surface water, whereas 1 indicates that the area is fully dependent on ground water. In normal situations it will be in between 0 and 1. The Ground water extraction in hectare meters can be estimated using the following formula.

$$\mathrm{GE} = \frac{\mathrm{Population\ X\ Consumptive\ Requirement\ X\ Lg \times No.\ of\ days}}{10000000}$$

3.3.5 Consumptive Use Pattern Method

The consumptive use pattern method is used for estimating the ground water extraction from the Industrial units. The water consumption from an industrial unit is estimated either by field studies or collected from the literature and the number of such units existing in the area are to be collected from the Industries department. The total ground water extraction in hectare meters form these industrial units can be estimated using the following formula.

$$GE_{IND} = \sum_{i=1}^{types} \frac{\text{Number of industrial units X Unit Water Consumption in } \textit{cubic meters} \text{ XLg}}{10000}$$

Where,

Types= No of Different types of Industrial units

Lg = Fractional load on ground water for industrial water supply

3.4 FORMATS SUGGESTED FOR THE COMPUTATION

3.4.1 Command Area

The estimation of ground water extraction for various uses in command area is done in the Tables from 3.1 to 3.13. The unit draft estimation for irrigation use is prepared in table 3.1 and the computation of the ground water extraction for irrigation using unit draft method in command area is done in table 3.2. The ground water extraction for irrigation using crop water requirement method is estimated in Table 3.3. In power requirement method the estimation of power requirement for unit water lift is done in the Table 3.4 whereas the current gross ground water extraction for irrigation use using power consumption method is estimated in table 3.5. Estimation of unit draft for the wells used for domestic use is done in Table 3.6 and the current gross ground water extraction for domestic water supply is estimated in Table 3.7. The estimation of current gross ground water extraction for domestic use using consumptive muse method is done in Table 3.8. Estimation of unit draft for the wells used for industrial use is done in Table 3.9 and the current gross ground water extraction for industrial water supply using unit draft method is estimated in table 3.10. The estimation of current gross ground water extraction for industrial use using consumptive use pattern method is done in Table 3.11. Current gross ground water extraction for all uses is reported in Table 3.12. In this table the accepted average extraction for individual uses are computed if more than one method is used for the estimation. In some of the cases if the figure estimated by one method is very much different from the others, it may be ignored in calculating the averages. The summary details are prepared in Table 3.13.

3.4.2 Non-Command Area

The computational scheme to be adopted for the non-command area is identical to what has been described earlier in Section 3.4.1 for the command area. The computations for the ground water extraction components in the non-command area are presented in the Tables 3.14 to 3.26.

3.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for the poor ground water quality area is identical to what has been described earlier in Section 3.4.1 for the command area. The computations for the ground water extraction components in the poor ground water quality area are presented in the Tables 3.27 to 3.39.

3.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the ground water extraction.

3.4.1 Data Elements Pertaining to the Estimation of Unit Draft

S.No	Parameter	Type	Size	Decimals
1	Type of Structure	Text	50	
2	Assessment Sub Unit	Text	20	
3	Extraction Type	Text	10	0
4	Draft Per day	Number	3	0
5	Monsoon Days	Number	3	0
6	Non-Monsoon Days	Number	3	0
7	Monsoon Unit Draft	Number	5	2
8	Non-Monsoon Unit Draft	Number	5	2
9	Annual Unit Draft	Number	5	2
10	Normal Monsoon Rainfall	Number	7	2
11	Normal Non Monsoon Rainfall	Number	7	2
12	Monsoon Rainfall for Current Year	Number	7	2
13	Non Monsoon Rainfall for Current Year	Number	7	2
14	Normalized Monsoon Unit Draft	Number	5	2
15	Normalized Non-Monsoon Unit Draft	Number	5	2
16	Normalized Annual Unit Draft	Number	5	2

3.4.2 Data Elements Pertaining to the Estimation of Ground Water Extraction of Each Type of Structure Using Unit Draft Method

S.No	Parameter	Type	Size	Decimals
1	Type of Structure	Text	50	
2	Assessment Sub Unit	Text	20	
3	Extraction Type	Text	10	0
4	Normalized Monsoon Unit Draft	Number	5	2
5	Normalized Non-Monsoon Unit Draft	Number	5	2
6	Total No. of Structures	Number	5	0
7	Total No. of Structures in Use	Number	5	0
8	Total Structure Monsoon Extraction	Number	7	0
9	Total Structure Non-Monsoon Extraction	Number	7	0
10	Total Structure Annual Extraction	Number	7	0

3.4.3 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Unit Draft Method

S.No	Parameter	Type	Size	Decimals
1	Type of Structure	Text	50	
2	Assessment Sub Unit	Text	20	
3	Total Sub Unit Domestic Monsoon Extraction	Number	7	0
4	Total Sub Unit Domestic Non-Monsoon Extraction	Number	7	0
5	Total Sub Unit Domestic Annual Extraction	Number	7	0
6	Total Sub Unit Irrigation Monsoon Extraction	Number	7	0
7	Total Sub Unit Irrigation Non-Monsoon Extraction	Number	7	0
8	Total Sub Unit Irrigation Annual Extraction	Number	7	0
9	Total Sub Unit Industrial Monsoon Extraction	Number	7	0
10	Total Sub Unit Industrial Non-Monsoon Extraction	Number	7	0
11	Total Sub Unit Industrial Annual Extraction	Number	7	0
12	Total Sub Unit All Uses Monsoon Extraction	Number	8	0
13	Total Sub Unit All Uses Non-Monsoon Extraction	Number	8	0
14	Total Sub Unit All Uses Annual Extraction	Number	8	0
15	Total Sub Unit All Uses Monsoon Extraction m	Number	5	3
16	Total Sub Unit All Uses Non-Monsoon Extraction m	Number	5	3
17	Total Sub Unit All Uses Annual Extraction m	Number	5	3

3.4.4 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Crop Water Requirement Method

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Crop Type	Text	10	
3	Crop Name	Text	20	
4	Crop Season	Text	10	
5	Crop Acreage	Number	8	2
6	Crop Water Requirement	Number	6	2
7	Extraction for the Crop During Monsoon	Number	7	2
8	Extraction for the Crop During Non-Monsoon Season	Number	7	2
9	Annual Extraction for the Crop	Number	7	2
10	Extraction Type	Text	10	0
11	Total Sub Unit Irrigation Extraction During Monsoon	Number	8	0
12	Total Sub Unit Irrigation Extraction During Non Monsoon	Number	8	0
13	Total Sub Unit Annual Irrigation Extraction	Number	8	0

3.4.5 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Power Consumption Method

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Domestic Power consumption in Monsoon Season	Number	8	0
3	Domestic Power Consumption in Non-Monsoon Season	Number	8	0
4	Annual Domestic Power Consumption	Number	8	0
5	Irrigation Power consumption in Monsoon Season	Number	8	0

S.No	Parameter	Type	Size	Decimals
6	Irrigation Power Consumption in Non-Monsoon Season	Number	8	0
7	Irrigation Domestic Power Consumption	Number	8	0
8	Irrigation Extraction For Unit Power Consumption During Monsoon Season	Number	7	2
9	Irrigation Extraction For Unit Power Consumption During Non-Monsoon Season	Number	7	2
10	Irrigation Extraction using Power Consumption During Monsoon	Number	8	0
11	Irrigation Extraction using Power Consumption During Non-Monsoon	Number	8	0
12	Annual Irrigation Extraction using Power Consumption	Number	8	0

3.4.6 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Consumptive Use Method

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Population as on base year	Number	6	0
3	Growth Rate of Population per year	Number	5	0
4	Population as the Assessment Year	Number	6	0
5	Per capita daily requirement for Domestic Needs	Number	3	0
6	Fractional Load on Ground Water	Number	4	2
7	Domestic extraction During Monsoon Season	Number	8	0
8	Domestic extraction During Non-Monsoon Season	Number	8	0
9	Annual Domestic extraction	Number	8	0

3.4.7 Data Elements Pertaining to the Estimation of Ground Water Extraction Using Consumptive Use Pattern Method

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Type of Industry	Text	20	
3	No of Such Units	Number	4	0
4	Ground Water Requirement of the Industry During Monsoon	Number	6	0
5	Ground Water Requirement of the Industry During Non-Monsoon	Number	6	0
6	Annual Ground Water Requirement of the Industry	Number	6	0
7	Fractional Load on Ground Water	Number	4	2
8	Industrial Extraction For the Type of Industry During Monsoon Season	Number	8	0
9	Industrial Extraction For the Type of Industry During Monsoon Season	Number	8	0
10	Annual Industrial Extraction For the Type of Industry	Number	8	0
11	Industrial Extraction For the Sub Unit During Monsoon Season	Number	8	0
12	Industrial Extraction For the Sub Unit During Monsoon Season	Number	8	0
13	Annual Industrial Extraction For the Sub Unit	Number	8	0

3.4.8 Data Elements Pertaining to the Accepted Average Extraction For Various Purposes

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Accepted Average Extraction for Domestic Use in Monsoon Season	Number	8	0
3	Accepted Average Extraction for Domestic Use in Non-Monsoon Season	Number	8	0
4	Accepted Average Annual Extraction for Domestic Use	Number	8	0
5	Accepted Average Extraction for Irrigation Use in Monsoon Season	Number	8	0
6	Accepted Average Extraction for Irrigation Use in Non-Monsoon Season	Number	8	0
7	Accepted Average Annual Extraction for Irrigation Use	Number	8	0
8	Accepted Average Extraction for Industrial Use in Monsoon Season	Number	8	0
9	Accepted Average Extraction for Industrial Use in Non-Monsoon Season	Number	8	0
10	Accepted Average Annual Extraction for Industrial Use	Number	8	0

Table 3.1 Estimation of Unit Draft for Irrigation Use in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		
Normal Monsoon Season Rainfall (NMR)	:	Normal Non-Monsoon Season Rainfall(NNMR)	:
Monsoon Season Rainfall of Current Year(CMR)	:	Non-Monsoon Season Rainfall of Current Year(CNMR)	:

S. No.	Type of well	Estimated ground water extraction per well per day in cubic meters per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare meters during		
			Monsoon Season	Non-monsoon Season	Monsoon Season $\frac{CMR \times (3) \times (4)}{NMR \times 10000}$	Non-monsoon Season $\frac{CNMR \times (3) \times (5)}{NNMR \times 10000}$	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 3.2 Current Gross Ground Water Extraction for Irrigation Use using Unit Draft Method in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for irrigation use in hectare meters during		Estimated gross ground water extraction for irrigation from all wells of a given type in hectare meters during		
			Monsoon Season [From Table 3.1]	Non-monsoon Season [From Table 3.1]	Monsoon Season [(3)*(4)]	Non-monsoon Season [(3)*(5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for Irrigation use using unit draft method in command area in hectare meters (Total of all the types of wells considered)							

Table 3.3 Current Gross Ground Water Extraction for Irrigation using Crop Water Requirement Method in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Crop	Estimated Crop Water Requirement in meters	Area under the crop in acres		Estimated gross ground water extraction for irrigation using Crop Water Requirement method in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)* 0.404686]	Non-monsoon Season [(3)*(5)*0.404686]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for irrigation using crop water requirement method in command area in hectare meters (Total of all Crops considered)							

Table 3.4 Estimation of Power Requirement for Unit Water Lift in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Section	Monsoon Season					Non Monsoon Season				
		Volume of Water Pumped in Cubic meters	Power Meter Readings		Total Units Consumed [(5)-(4)]	Estimated Power Requirement for Cubic meter of water lift [(6)/(3)]	Volume of Water Pumped in Cubic meters	Power Meter Readings		Total Units Consumed [(10)-(9)]	Estimated Power Requirement for Cubic meter of water lift [(11)/8)]
			Starting Reading	Ending Reading				Starting Reading	Ending Reading		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											

Table 3.5 Current Gross Ground Water Extraction for Irrigation using Power Consumption Method in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Section	Estimated power Requirement for cubic meter water lift in kilo watt hours [From Table 3.4]		Total Power Consumed in kilo watt hours		Estimated gross ground water extraction for irrigation using Power Requirement method in hectare metres during		
		Monsoon	Non-Monsoon	Monsoon Season	Non-monsoon Season	Monsoon Season $[(3)/((5)*10^4)]$	Non-monsoon Season $[(4)/((6)*10^4)]$	Annual $[(7) + (8)]$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Current gross ground water extraction for irrigation using power consumption method in command area in hectare meters (Total of all sections considered)								

Table 3.6 Estimation of Unit Draft for Domestic Use in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of well	Estimated ground water extraction per well per day in cubic metres per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)/ 10^4]	Non-monsoon Season [(3)*(5)/ 10^4]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 3.7 Current Gross Ground Water Extraction for Domestic Use using Unit Draft Method in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for domestic use in hectare meters during [From Table 3.6]		Estimated gross ground water extraction for domestic use from all wells of a given type in hectare meters during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)]	Non-monsoon Season [(3)*(5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for domestic use using unit draft method in command area in hectare meters (Total of all the types of wells considered)							

Table 3.8 Current Gross Ground Water Extraction for Domestic Use using Consumptive use Method in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year (AYEAR)	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:	Census Year (CYEAR)	:

S. No.	Ward/ Village	Population Details			Percapita Requirement in lpcd	Fractional Load on Ground Water		No of days in		Estimated gross ground water extraction for domestic use using consumptive use method in hectare metres during		
		as on _______	Growth Rate	As on Assessment year $(3) + \frac{(3)*((AYEAR)-(PYEAR))*(4)}{100}$		Monsoon Season	Non-monsoon Season	Monsoon Season	Non-monsoon Season	Monsoon Season [(5)*(6)*(7)*(9)/10^7]	Non-monsoon Season [(5)*(6)*(8)*(10)/10^7]	Annual [(11) + (12)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1												
2												
3												
Current gross ground water extraction for domestic use using consumptive use method in command area in hectare meters (Total of all wards/villages considered)												

Table 3.9 Estimation of Unit Draft for Industrial Use in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of well	Estimated ground water extraction per well per day in cubic metres per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)/ 10^4]	Non-monsoon Season [(3)*(5)/ 10^4]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 3.10 Current Gross Ground Water Extraction for Industrial Use using Unit Draft Method in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for industrial use in hectare metres during [From Table 3.9]		Fractional Load on Ground Water		Estimated gross ground water extraction for industrial use from all wells of a given type in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)*(6)]	Non-monsoon Season [(3)*(5)*(7)]	Annual [(8) + (9)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Current gross ground water extraction for industrial use using unit draft method in command area in hectare meters (Total of all the types of wells considered)									

Table 3.11 Current Gross Ground Water Extraction for Industrial Use using Consumptive Use Pattern Method in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Type of Industry	Estimated Consumptive Requirement in cubic meters/day	Fractional Load on Ground Water		No. of days water is being extracted		Estimated gross ground water extraction for industrial use using Consumptive use pattern method in hectare meters during		
			Monsoon Season	Non-Monsoon Season	Monsoon Season	Non-Monsoon Season	Monsoon Season [(3)*(4)*(6)/10^4]	Non-Monsoon Season [(3)*(5)*(7)/10^4]	Annual [(8) + (9)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Current gross ground water extraction for industrial use using consumptive use pattern method in command area in hectare meters (Total of All types of Industries)									

Table 3.12 Current Gross Ground Water Extraction for 'All Uses' in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (in command area)	Monsoon season	Non-Monsoon Season	Annual [(3)+(4)]
(1)	(2)	(3)	(4)	(5)
1	Gross ground water draft in command area during current ground water assessment year in hectare metres for			
a)	Irrigation			
	i. Unit Draft Method [From Table 3.2]			
	ii. Cropping Pattern Method [From Table 3.3]			
	iii. Power Consumption Method [From Table 3.5]			
	iv. Accepted Average Extraction			
b)	Domestic Water Supply			
	i. Unit Draft Method [From Table 3.7]			
	ii. Consumptive Use Method [From Table 3.8]			
	iii Accepted Average Extraction			
c)	Industrial Water Supply			
	i. Unit Draft Method [From Table 3.10]			
	ii. Consumptive Use Pattern Method [From Table 3.11]			
	iii. Accepted Average Extraction			
d)	'All Uses' [(1a iv) + (1b iii) + (1c iii)]			

Table 3.13 Summary of Current Gross Ground Water Extraction for 'All Uses' in Command Area

Name of Ground Water Assessment Unit	:
Principal Aquifer	:
Major Aquifer	:
Index Number of Ground Water Assessment Unit	:
Ground Water Assessment Year	:

A. Gross ground water extraction for 'Irrigation' during monsoon season in command area in hectare meters [Table 3.12]	
B. Gross ground water extraction for 'Irrigation' during Non-Monsoon season in command area in hectare meters [Table 3.12]	
C. Annual gross ground water Extraction for 'Irrigation needs' in command area in hectare meters [Table 3.12]	
D. Gross ground water extraction for 'All Uses' during monsoon season in command area in hectare meters [Table 3.12]	
E. Annual gross ground water Extraction for 'All Uses' in command area in hectare meters [Table 3.12]	
F. Annual gross ground water Extraction for 'Domestic needs' in command area in hectare meters [Table 3.12]	
G. Annual gross ground water Extraction for 'Industrial needs' in command area in hectare meters [Table 3.12]	
H. Command area in hectares [From Table 2.1]	
I. Gross ground water extraction for 'Irrigation' during monsoon season in command area in mm [(A)*1000/(H)]	
J. Gross ground water extraction for 'Irrigation' during Non-Monsoon season in command area in mm [(B)*1000/(H)]	
K. Annual gross ground water Extraction for 'Irrigation needs' in command area in hectare meters [(C)*1000/(H)]	
L. Gross ground water extraction for 'All Uses' during monsoon season in command area in mm [(D)*1000 / (H)]	
M. Annual gross ground water extraction for 'All Uses' in command area per unit area in millimeters [(D)*1000 / (H)]	
N. Annual gross ground water Extraction for 'Domestic needs' in command area in hectare meters [(F)*1000 /(H)]	
O. Annual gross ground water Extraction for 'Industrial needs' in command area in hectare meters [(G)*1000 / (H)]	

Table 3.14 Estimation of Unit Draft for Irrigation Extraction in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		
Normal Monsoon Season Rainfall (NMR)	:	Normal Non-Monsoon Season Rainfall(NNMR)	:
Monsoon Season Rainfall of Current Year(CMR)	:	Non-Monsoon Season Rainfall of Current Year(CNMR)	:

S. No.	Type of well	Estimated ground water extraction per well per day in cubic meters per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare meters during		
			Monsoon Season	Non-monsoon Season	Monsoon Season $\frac{CMR \times (3) \times (4)}{NMR \times 10000}$	Non-monsoon Season $\frac{CNMR \times (3) \times (5)}{NNMR \times 10000}$	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 3.15 Current Gross Ground Water Extraction for Irrigation Use using Unit Draft Method in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for irrigation use in hectare meters during		Estimated gross ground water extraction for irrigation from all wells of a given type in hectare meters during		
			Monsoon Season [From Table 3.14]	Non-monsoon Season [From Table 3.14]	Monsoon Season [(3)*(4)]	Non-monsoon Season [(3)*(5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for Irrigation use using unit draft method in command area in hectare meters (Total of all the types of wells considered)							

Table 3.16 Current Gross Ground Water Extraction for Irrigation using Crop Water Requirement Method in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Crop	Estimated Crop Water Requirement in meters	Area under the crop in acres		Estimated gross ground water extraction for irrigation using Crop Water Requirement method in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)* 0.404686]	Non-monsoon Season [(3)*(5)*0.404686]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for irrigation using crop water requirement method in non-command area in hectare meters (Total of All Crops Considered)							

Table 3.17 Estimation of Power Requirement for Unit Water Lift in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Section	Monsoon Season					Non Monsoon Season				
		Volume of Water Pumped in Cubic meters	Power Meter Readings		Total Units Consumed [(5)-(4)]	Estimated Power Requirement for Cubic meter of water lift [(6)/(3)]	Volume of Water Pumped in Cubic meters	Power Meter Readings		Total Units Consumed [(10)-(9)]	Estimated Power Requirement for Cubic meter of water lift [(11)(/8)]
			Starting Reading	Ending Reading				Starting Reading	Ending Reading		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											

Table 3.18 Current Gross Ground Water Extraction for Irrigation using Power Consumption Method in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Section	Estimated power Requirement for cubic meter water lift in kilo watt hours [From Table 3.17]		Total Power Consumed in kilo watt hours		Estimated gross ground water extraction for irrigation using Power Requirement method in hectare metres during		
		Monsoon	Non-Monsoon	Monsoon Season	Non-monsoon Season	Monsoon Season [(3)/((5)*10^4)]	Non-monsoon Season [(4)/((6)*10^4)]	Annual [(7) + (8)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Current gross ground water extraction for irrigation using power consumption method in non-command area in hectare meters (total of All Sections Considered)								

Table 3.19 Estimation of Unit Draft for Domestic Use in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of well	Estimated ground water extraction per well per day in cubic metres per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)/ 10^{4}]	Non-monsoon Season [(3)*(5)/ 10^{4}]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 3.20 Current Gross Ground Water Extraction for Domestic Use using Unit Draft Method in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for domestic use in hectare metres during [From Table 3.19]		Estimated gross ground water extraction for domestic use from all wells of a given type in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)]	Non-monsoon Season [(3)*(5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for domestic use using unit draft method in non-command area in hectare meters (Total of all the types of wells considered)							

Table 3.21 Current Gross Ground Water Extraction for Domestic Use using Consumptive use Method in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Ward/ Village	Population Details			Percapita Requirement in lpcd	Fractional Load on Ground Water		No of days in		Estimated gross ground water extraction for domestic use using consumptive use method in hectare metres during		
		as on _______	Growth Rate	As on Assessment year $(3) + \frac{(3)*((AYEAR)-(PYEAR))*(4)}{100}$		Monsoon Season	Non-monsoon Season	Monsoon Season	Non-monsoon Season	Monsoon Season $[(5)*(6)*(7)*(9)/10^7]$	Non-monsoon Season $[(5)*(6)*(8)*(10)/10^7]$	Annual [(11) + (12)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1												
2												
3												
Current gross ground water extraction for domestic use using consumptive use method in non-command area in hectare meters (Total of all wards/villages considered)												

Table 3.22 Estimation of Unit Draft for Industrial Use in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of well	Estimated ground water extraction per well per day in cubic metres per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)/ 10^{4}]	Non-monsoon Season [(3)*(5)/ 10^{4}]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 3.23 Current Gross Ground Water Extraction for Industrial Use using Unit Draft Method in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for industrial use in hectare metres during [From Table 3.9]		Fractional Load on Ground Water		Estimated gross ground water extraction for industrial use from all wells of a given type in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)*(6)]	Non-monsoon Season [(3)*(5)*(7)]	Annual [(8) + (9)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Current gross ground water extraction for industrial use using unit draft method in non-command area in hectare meters (Total of all the types of wells considered)									

Table 3.24 Current Gross Ground Water Extraction for Industrial Use using Consumptive Use Pattern Method in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Industry	Estimated Consumptive Requirement in cubic meters/day	Fractional Load on Ground Water		No. of days water is being extracted		Estimated gross ground water extraction for industrial use using Consumptive use pattern method in hectare meters during		
			Monsoon Season	Non-Monsoon Season	Monsoon Season	Non-Monsoon Season	Monsoon Season [(3)*(4)*(6)/10^4]	Non-Monsoon Season [(3)*(5)*(7)/10^4]	Annual [(8) + (9)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Current gross ground water extraction for industrial use using consumptive use pattern method in non-command area in hectare meters (Total of All types of Industries)									

Table 3.25 Current Gross Ground Water Extraction for 'All Uses' in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (in command area)	Monsoon season	Non-Monsoon Season	Annual [(3)+(4)]
(1)	(2)	(3)	(4)	(5)
1	Gross ground water draft in non-command area during current ground water assessment year in hectare metres for			
a)	Irrigation			
	i. Unit Draft Method [From Table 3.2]			
	ii. Cropping Pattern Method [From Table 3.3]			
	iii. Power Consumption Method [From Table 3.5]			
	iv. Accepted Average Extraction			
b)	Domestic Water Supply			
	i. Unit Draft Method [From Table 3.7]			
	ii. Consumptive Use Method [From Table 3.8]			
	iii. Accepted Average Extraction			
c)	Industrial Water Supply			
	i. Unit Draft Method [From Table 3.10]			
	ii. Consumptive Use Pattern Method [From Table 3.11]			
	iii. Accepted Average Extraction			
d)	'All Uses' [(1a iv) + (1b iii) + (1c iii)]			

Table 3.26 Summary of Current Gross Ground Water Extraction for 'All Uses' in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

A. Gross ground water extraction for 'Irrigation' during monsoon season in non-command area in hectare meters [Table 3.25]	
B. Gross ground water extraction for 'Irrigation' during Non-Monsoon season in non-command area in hectare meters [Table 3.25]	
C. Annual gross ground water Extraction for 'Irrigation needs' in non-command area in hectare meters [Table 3.25]	
D. Gross ground water extraction for 'All Uses' during monsoon season in non-command area in hectare meters [Table 3.25]	
E. Annual gross ground water Extraction for 'All Uses' in non-command area in hectare meters [Table 3.25]	
F. Annual gross ground water Extraction for 'Domestic needs' in non-command area in hectare meters [Table 3.25]	
G. Annual gross ground water Extraction for 'Industrial needs' in non-command area in hectare meters [Table 3.25]	
H. Non-Command area in hectares [From Table 2.1]	
I. Gross ground water extraction for 'Irrigation' during monsoon season in non-command area in mm [(A)*1000/(H)]	
J. Gross ground water extraction for 'Irrigation' during Non-Monsoon season in non-command area in mm [(B)*1000/(H)]	
K. Annual gross ground water Extraction for 'Irrigation needs' in non-command area in mm [(C)*1000/ (H)]	
L. Gross ground water extraction for 'All Uses' during monsoon season in non-command area in mm [(D)*1000 / (H)]	
M. Annual gross ground water extraction for 'All Uses' in non-command area per unit area in mm [(D)*1000 / (H)]	
N. Annual gross ground water Extraction for 'Domestic needs' in non-command area in mm [(F)*1000 / (H)]	
O. Annual gross ground water Extraction for 'Industrial needs' in non-command area in mm [(G)*1000 / (H)]	

Table 3.27 Estimation of Unit Draft for Irrigation Extraction in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :
Normal Monsoon Season Rainfall (NMR) : Normal Non-Monsoon Season Rainfall(NNMR) :
Monsoon Season Rainfall of Current Year(CMR) : Non-Monsoon Season Rainfall of Current Year(CNMR) :

S. No.	Type of well	Estimated ground water extraction per well per day in cubic meters per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare meters during		
			Monsoon Season	Non-monsoon Season	Monsoon Season $\frac{CMR \times (3) \times (4)}{NMR \times 10000}$	Non-monsoon Season $\frac{CNMR \times (3) \times (5)}{NNMR \times 10000}$	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)

Table 3.28 Current Gross Ground Water Extraction for Irrigation Use using Unit Draft Method in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Major Aquifer :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for irrigation use in hectare meters during [From Table 3.27]		Estimated gross ground water extraction for irrigation from all wells of a given type in hectare meters during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)]	Non-monsoon Season [(3)*(5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for irrigation use using unit draft method in Poor Ground Water Quality Area in hectare meters (Total of all the types of wells considered)							

Table 3.29 Current Gross Ground Water Extraction for Irrigation using Crop Water Requirement Method in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Crop	Estimated Crop Water Requirement in meters	Area under the crop in acres		Estimated gross ground water extraction for irrigation using Crop Water Requirement method in hectare meters during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)* 0.404686]	Non-monsoon Season [(3)*(5)*0.404686]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for irrigation using crop water requirement method in poor ground water quality area in hectare meters (Total of all types of crops)							

Table 3.30 Estimation of Power Requirement for Unit Water Lift in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : 	Ground Water Assessment Year :
Principal Aquifer : 	Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Section	Monsoon Season					Non Monsoon Season				
		Volume of Water Pumped in Cubic meters	Power Meter Readings		Total Units Consumed [(5)-(4)]	Estimated Power Requirement for Cubic meter of water lift [(6)/(3)]	Volume of Water Pumped in Cubic meters	Power Meter Readings		Total Units Consumed [(10)-(9)]	Estimated Power Requirement for Cubic meter of water lift [(11)(/8)]
			Starting Reading	Ending Reading				Starting Reading	Ending Reading		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											

Table 3.31 Current Gross Ground Water Extraction for Irrigation using Power Consumption Method in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Section	Estimated power Requirement for cubic meter water lift in kilo watt hours [From Table 3.30]		Total Power Consumed in kilo watt hours		Estimated gross ground water extraction for irrigation using Power Requirement method in hectare meters during		
		Monsoon	Non-Monsoon	Monsoon Season	Non-monsoon Season	Monsoon Season [(3)/((5)*10^4)]	Non-monsoon Season [(4)/((6)*10^4)]	Annual [(7) + (8)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Current gross ground water extraction for irrigation using power consumption method in poor ground water quality area in hectare meters (Total of all sections considered)								

Table 3.32 Estimation of Unit Draft for Domestic Use in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		
Normal Monsoon Season Rainfall (NMR)	:	Normal Non-Monsoon Season Rainfall(NNMR)	:
Monsoon Season Rainfall of Current Year(CMR)	:	Non-Monsoon Season Rainfall of Current Year(CNMR)	:

S. No.	Type of well	Estimated ground water extraction per well per day in cubic metres per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)/ 10^4]	Non-monsoon Season [(3)*(5)/ 10^4]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 3.33 Current Gross Ground Water Extraction for Domestic Use using Unit Draft Method in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for domestic use in hectare meters during [From Table 3.32]		Estimated gross ground water extraction for domestic use from all wells of a given type in hectare meters during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)]	Non-monsoon Season [(3)*(5)]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Current gross ground water extraction for domestic use using unit draft method in Poor Ground Water Quality area in hectare meters (Total of all the types of wells considered)							

Table 3.34 Current Gross Ground Water Extraction for Domestic Use using Consumptive use Method in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Principal Aquifer : Major Aquifer :

Index Number of Ground Water Assessment Unit :

S. No.	Ward/ Village	Population Details			Percapita Requirement in lpcd	Fractional Load on Ground Water		No of days in		Estimated gross ground water extraction for domestic use using consumptive use method in hectare metres during		
		as on _______	Growth Rate	As on Assessment year $(3)+\frac{(3)*((AYEAR)-(PYEAR))*(4)}{100}$		Monsoon Season	Non-monsoon Season	Monsoon Season	Non-monsoon Season	Monsoon Season [(5)*(6)*(7)*(9)/10^7]	Non-monsoon Season [(5)*(6)*(8)*(10)/10^7]	Annual [(11) + (12)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
1												
2												
3												
Current gross ground water extraction for domestic use using consumptive use method in poor ground water quality area in hectare meters (Total of all wards/villages considered)												

Table 3.35 Estimation of Unit Draft for Industrial Use in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :
Normal Monsoon Season Rainfall (NMR) : Normal Non-Monsoon Season Rainfall(NNMR) :
Monsoon Season Rainfall of Current Year(CMR) : Non-Monsoon Season Rainfall of Current Year(CNMR) :

S. No.	Type of well	Estimated ground water extraction per well per day in cubic metres per day	Estimated number of days the wells are operated during		Estimated gross ground water extraction per well in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)/ 10^{4}]	Non-monsoon Season [(3)*(5)/ 10^{4}]	Annual [(6) + (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 3.36 Current Gross Ground Water Extraction for Industrial Use using Unit Draft Method in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Well	Estimated number of wells currently in actual use	Estimated unit ground water extraction per well for industrial use in hectare metres during [From Table 3.9]		Fractional Load on Ground Water		Estimated gross ground water extraction for industrial use from all wells of a given type in hectare metres during		
			Monsoon Season	Non-monsoon Season	Monsoon Season	Non-monsoon Season	Monsoon Season [(3)*(4)*(6)]	Non-monsoon Season [(3)*(5)*(7)]	Annual [(8) + (9)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Current gross ground water extraction for industrial use using unit draft method in poor ground water quality area in hectare meters (Total of all the types of wells considered)									

Table 3.37 Current Gross Ground Water Extraction for Industrial Use using Consumptive Use Pattern Method in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Type of Industry	Estimated Consumptive Requirement in cubic meters/day	Fractional Load on Ground Water		No. of days water is being extracted		Estimated gross ground water extraction for industrial use using Consumptive use pattern method in hectare meters during		
			Monsoon Season	Non-Monsoon Season	Monsoon Season	Non-Monsoon Season	Monsoon Season [(3)*(4)*(6)/10^4]	Non-Monsoon Season [(3)*(5)*(7)/10^4]	Annual [(8) + (9)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Current gross ground water extraction for industrial use using consumptive use pattern method in poor ground water quality area in hectare meters (Total of All types of Industries)									

Table 3.38 Current Gross Ground Water Extraction for 'All Uses' in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (in command area)	Monsoon season	Non-Monsoon Season	Annual [(3)+(4)]
(1)	(2)	(3)	(4)	(5)
1	Gross ground water draft in poor ground water quality area during current ground water assessment year in hectare metres for			
a)	Irrigation			
	i) Unit Draft Method [From Table 3.2]			
	ii) Cropping Pattern Method [From Table 3.3]			
	iii) Power Consumption Method [From Table 3.5]			
	iv) Accepted Average Extraction			
b)	Domestic Water Supply			
	i. Unit Draft Method [From Table 3.7]			
	ii. Consumptive Use Method [From Table 3.8]			
	iii Accepted Average Extraction			
c)	Industrial Water Supply			
	i. Unit Draft Method [From Table 3.10]			
	ii. Consumptive Use Pattern Method [From Table 3.11]			
	iii. Accepted Average Extraction			
d)	'All Uses' [(1a iv) + (1b iii) + (1c iii)]			

Table 3.39 Summary of Current Gross Ground Water Extraction for 'All Uses' in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

A.	Gross ground water extraction for 'Irrigation' during monsoon season in poor ground water quality area in hectare meters [Table 3.25]	
B.	Gross ground water extraction for 'Irrigation' during Non-Monsoon season in poor ground water quality area in hectare meters [Table 3.25]	
C.	Annual gross ground water Extraction for 'Irrigation needs' in poor ground water quality area in hectare meters [Table 3.25]	
D.	Gross ground water extraction for 'All Uses' during monsoon season poor ground water quality area in hectare meters [Table 3.25]	
E.	Annual gross ground water Extraction for 'All Uses' in poor ground water quality area in hectare meters [Table 3.25]	
F.	Annual gross ground water Extraction for 'Domestic needs' in poor ground water quality area in hectare meters [Table 3.25]	
G.	Annual gross ground water Extraction for 'Industrial needs' in poor ground water quality area in hectare meters [Table 3.25]	
H.	Poor ground water quality area in hectares [From Table 2.1]	
I.	Gross ground water extraction for 'Irrigation' during monsoon season in poor ground water quality area in mm [(A)*1000/(H)]	
J.	Gross ground water extraction for 'Irrigation' during Non-Monsoon season in poor ground water quality area in mm [(B)*1000/(H)]	
K.	Annual gross ground water Extraction for 'Irrigation needs' in poor ground water quality area in mm [(C)*1000/ (H)]	
L.	Gross ground water extraction for 'All Uses' during monsoon season in poor ground water quality area in mm [(D)*1000 / (H)]	
M.	Annual gross ground water extraction for 'All Uses' in poor ground water quality area per unit area in mm [(D)*1000 / (H)]	
N.	Annual gross ground water Extraction for 'Domestic needs' in poor ground water quality area in mm [(F)*1000 / (H)]	
O.	Annual gross ground water Extraction for 'Industrial needs' in poor ground water quality area in mm [(G)*1000 /(H)]	

4

RECHARGE FROM CANALS

4.1 GENERAL

Recharge from canals which is to be computed separately for the monsoon and non-monsoon seasons of the ground water assessment year is applicable only for the following two sub-units:

a) Command area
b) Poor ground water quality area

The estimation of recharge from canals involves the following steps to be carried out.

a) The main canals, major canals, minor canals and distributaries of the canal system are divided in to a number of canal segments called canal reaches with each canal segment fulfilling certain requirements as described later in this chapter.
b) The wetted perimeter and wetted area for each canal segment is computed
c) A canal seepage factor value is assigned to each canal segment on the basis of certain norms as described later in this chapter.
d) Recharge from each canal reach during the monsoon and non-monsoon seasons are computed
e) Recharge from the canal system as a whole during the monsoon and non-monsoon seasons are finally obtained as the sum of the recharge from each canal reach.

4.2 ASSUMPTIONS

The estimation of recharge from canals is based on the following assumptions

a) Recharge in hectare metres can be computed as the product of the following three parameters:
    i) seepage factor expressed in hectare metres per day per million square metres of wetted area
    ii) wetted area in million square metres
    iii) number of days the canal reach is in operation
b) The seepage factor mentioned in 'a' above, depends only on the following factors-
    i) whether the canal segment is lined or unlined

ii) whether the soil type over which the canal segment traverses is normal soil or sandy soil or the canal reach is on a hard rock terrain.

c) The seepage factor mentioned in 'a' above , can be assigned a value either from the specified norms as given in the Annexure I, or on the basis of results from documented field studies.

d) The average depth of flow in a canal segment during the duration in which it is in operation can be considered to be 0.6 times the design depth of flow of that canal segment if average supply depth is not available.

4.3 COMPUTATIONAL PROCEDURE

The computational procedure which is to be adopted for estimating recharge from canals in any sub unit during monsoon and non-monsoon seasons is as given below.
Main canals, major canals, minor canals and distributaries in the canal system alone are considered for computing recharge from canals. They are divided in to a number of canal reaches, each having a specified length. Each such canal reach in its entire stretch,

a. is either lined or unlined,
b. traverses the same soil/rock type,
c. has same value of design depth of flow, same value of base width and same value of side slope, and
d. is in operation for the same number of days in a given season.

The wetted area in million square metres for each canal segment is computed making use of data on length, base width, side slope and design depth of flow using the following formulae.

Wetted Area= Wetted perimeter * Length

$$Wetted\ \ Perimeter = \frac{2 * Average\ Supply\ Depth}{Sin(SideAngle)} + Bed\ Width$$

The canal seepage factor in hectare metres per day per million square metres of wetted area is assigned to each canal segment based on either the norms as given in Annexure I or on the basis of results obtained from documented field studies.
The data on wetted area and canal seepage factor as discussed in the previous two sections are then used along with data on the number of days the canal segment is in operation during monsoon and non-monsoon seasons to estimate the recharge due to canals from each canal segment.

Recharge due to canal reach = Wetted Area*Days*Seepage Factor

Recharge from canals in the command area during monsoon and non-monsoon season are finally obtained as the sum of the recharge values computed for each canal segment.

4.4 FORMATS SUGGESTED FOR COMPUTATION

4.4.1 Command Area

The recharge due to canals in command area are to be presented in Tables 4.1 to 4.4. The location details of all the canal segments in the command area are presented in the Table 4.1. The wetted area computation are presented in the Table 4.2. Assigning the Seepage factor is presented in the Table 4.3 and the recharge due to canals during monsoon and non-monsoon seasons are computed in the Table 4.4. The recharge from canals in the command area during monsoon and non-monsoon season are finally obtained as the sum of the recharge values computed for each canal segment.

4.4.2 Poor Ground water Quality Area

The computational scheme to be adopted for estimating recharge from canals in the poor ground water quality area is identical to what has been described earlier in Section 4.4.1 for command area. The results are presented in Tables 4.5 to 4.8

4.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Recharge from canals.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Canal Segment	Text	50	
3	Type of Canal	Text	10	
4	Canal Length	Number	6	0
5	Starting Latitude	Text	10	
6	Ending Latitude	Text	10	
7	Starting Longitude	Text	10	
8	Ending Longitude	Text	10	
9	Full Supply Depth	Number	5	2
10	Base Width	Number	5	2
11	Side Slope	Number	4	1
12	Wetted Perimeter	Number	6	2
13	Wetted Area million sq m	Number	8	5
14	Lining	Text	10	
15	Soil Type	Text	10	
16	Canal Seepage factor	Number	4	1
17	Monsoon Days	Number	3	0
18	Non-Monsoon Days	Number	3	0
19	Monsoon Canal Recharge	Number	7	2
20	Non-Monsoon Canal Recharge	Number	7	2
21	Total Sub Unit Monsoon Canal Recharge	Number	7	0
22	Total Sub Unit Non-Monsoon Canal Recharge	Number	7	0
23	Total Sub Unit Annual Canal Recharge	Number	7	0

Table 4.1 Location Details of Different Canal Segments of the Canal System in the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal reach	Type (main / minor / distributary)	Length in metres	Starting Point of Canal segment		Ending Point of Canal segment	
				Latitude	Longitude	Latitude	Longitude
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 4.2 Wetted Area in Different Canal Reaches of the Canal System in the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal reach	Length in metres [From Table 4.1]	Design depth of flow in metres	Average depth of flow in metres	Base width in metres	Side slope in degrees	Wetted perimeter in metres $\frac{2\times(5)}{\sin((7))}+(6)$	Wetted area in million square metres [(8) * (3)] / 10^6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								

Table 4.3 Canal Seepage Factor for Different Canal Reaches of the Canal System in the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal reach	Type (lined / unlined)	If Principal Aquifer is alluvial soil type (normal / sandy) Else Rock type	Are canal seepage factor values available from documented field studies (Yes/No)	Assigned canal seepage factor in hectare metres per day per million square metres of wetted Area
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 4.4 Recharge from Canals in the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal segment	Canal seepage factor in hectare metres per day per million square metres of wetted area (From Table 4.3)	Wetted area in million square metres (From Table 4.2)	Number of days the canal segment is in operation during		Recharge from canal segment in hectare metres during	
				Monsoon Season	Non Monsoon season	Monsoon Season [(3) * (4) * (5)]	Non Monsoon season [(3) * (4) * (6)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Recharge from canals in the command area (Sum of recharge from all canal segments)							

Table 4.5 Location Details of Different Canal Reaches of the Canal System in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal reach	Type (main / minor / distributary)	Length in metres	Starting Point of Canal segment		Ending Point of Canal segment	
				Latitude	Longitude	Latitude	Longitude
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 4.6 Wetted Area in Different Canal Reaches of the Canal System in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal reach	Length in metres [From Table 4.5]	Design depth of flow in metres	Average depth of flow in metres	Base width in metres	Side slope in degrees	Wetted perimeter in metres $\frac{2\times(5)}{\sin((7))}+(6)$	Wetted area in million square metres [(8) * (3)] / 10^6
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								

Table 4.7 Canal Seepage Factor for Different Canal Reaches of the Canal System in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal reach	Type (lined / unlined)	If Principal Aquifer is alluvial soil type (normal / sandy) Else Rock type	Are canal seepage factor values available from documented field studies (Yes/No)	Assigned canal seepage factor in hectare metres per day per million square metres of wetted Area
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 4.8 Recharge from Canals in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of canal segment	Canal seepage factor in hectare metres per day per million square metres of wetted area (From Table 4.7)	Wetted area in million square metres (From Table 4.6)	Number of days the canal segment is in operation during		Recharge from canal segment in hectare metres during	
				Monsoon Season	Non Monsoon season	Monsoon Season [(3) * (4) * (5)]	Non Monsoon season [(3) * (4) * (6)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Recharge from canals in the poor ground water quality area (Sum of recharge from all canal segments)							

5

RECHARGE FROM APPLIED SURFACE WATER IRRIGATION

5.1 GENERAL

Recharge from irrigation water applied by surface water sources which has to be computed for the monsoon and non-monsoon seasons of the ground water assessment year is applicable for all the three sub-units of each ground water assessment unit,
The computations of recharge from irrigation water applied by surface water sources in a given sub-unit and during a given season involves the following steps to be carried out.

a) estimation of irrigation water applied by surface water sources
b) estimation of average depth to water table below ground level
c) estimation of irrigated area under paddy and non-paddy
d) assigning a return flow factor on the basis of results from 'b' and 'c' above
e) computation of the recharge on the basis of the results from 'a' and 'd' above

5.2 ASSUMPTIONS

The computation of recharge from applied surface water irrigation is based on the following assumptions.

a) recharge in hectare metres can be obtained as the product of the following parameters:
    i) irrigation water applied in hectare metres
    ii) return flow factor as a fraction
a) the irrigation water applied as mentioned in 'a' above is considered as the sum of water released from all outlets in the canal system. Each such outlet is located in the distributaries of the canal system.
b) the water released in hectare metres from each outlet as mentioned in 'b' above can be computed as the product of the following parameters
    i) average discharge of the outlet in hectare metres per day
    ii) number of days water is actually released from the outlet
c) if average discharge is not available, it is assumed that 0.6 times of the design discharge is the average discharge.
d) the return flow factor mentioned in 'a' above depends only on the following factors

i) whether the crop irrigated is paddy or non-paddy

ii) The range of depth to water table below ground level

iii) whether the release from outlets is continuous or rotational.

e) the return flow factor mentioned in ‘a’ and ‘e’ above can be assigned a value either on the basis of norms as given in Annexure II or on the basis of results from documented field studies.

5.3 COMPUTATIONAL PROCEDURE

The computational scheme to be adopted for computing the recharge from irrigation water applied by surface water irrigation in any sub unit is described in this section.

5.3.1 Irrigation Water Applied

The average water released from each outlet during the monsoon and non-monsoon season are computed. The irrigation water applied during these two seasons are obtained as the sum of the releases from each outlet. This can be calculated using the following formula.

Irrigation Water Applied = Average Discharge *No. of days water is released by the outlet

If average discharge from the canal outlets are available, this data is to be used in computing irrigation water applied. If the average data is not available, then 60% of the design discharge may be considered as average discharge.

5.3.2 Depth to Water Table Below Ground Level

The average depth to water table below ground level in the subunit as a whole during the monsoon and non-monsoon seasons are to be categorised based on the depth to water level to assign the return flow factor for paddy and non paddy in the area.

a) Less than 10 metres

b) Between 10 and 25 metres with 1m zonation

c) Greater than 25 metres

The computational scheme to be adopted for this purpose is given below :

a) The following data on depth to water table below ground level as recorded from each of the observation wells in the command area are considered.

   i) during pre-monsoon monitoring month of the current ground water assessment year

   ii) during post-monsoon monitoring month of current ground water assessment year

   iii) during pre-monsoon monitoring month of the ground water year immediately following the current ground water assessment year.

b) The above three water table data items applicable for the sub-unit as a whole are obtained as the arithmetic average of the corresponding data from all the observation wells considered.

   c) Average depth of water table below ground level in the sub-unit as a whole during the monsoon season is computed as the arithmetic mean of the water table data during pre-monsoon and post-monsoon monitoring months of the current ground water assessment year as obtained in ‘b’ above.

d) Average depth of water table below ground level in the sub-unit as a whole during the non-monsoon season is computed as the arithmetic mean of the water table data during post-monsoon monitoring month of the current ground water assessment year and pre-monsoon monitoring month of the ground water year immediately following the current ground water assessment year as obtained in ‘b’ above.

e) The results obtained from ‘c’ and ‘d’ above or made use of to categorise the depth to water table below ground level in the subunit during monsoon and non-monsoon seasons to assign a return flow factor as per the norms suggested by GEC 2015.

5.3.3 Irrigated Area Under Paddy and Non-paddy

The irrigated area in acres under paddy and non-paddy in the subunit during monsoon and non-monsoon seasons of the current ground water assessment year are estimated by adopting any convenient method. The most obvious method, though it will be time consuming, is through actual field survey. They can also be estimated indirectly, using information on irrigation water applied and irrigation water requirement of the crops. This data can be collected from agricultural department also.

5.3.4 Return Flow Factor

The return flow factor for the sub unit during monsoon and non-monsoon seasons are obtained either on the basis of the norms as given in Annexure II or on the basis of results from documented field studies. The use of the norms require information on depth to water table and irrigated area mentioned in the previous two sections. The weighted average return flow factor can be calculated using the following formula.

$$Weighted\ \ Average\ RFF = \frac{Paddy\ Area \times Paddy\ RFF + Non - Paddy\ Area \times Non - Paddy\ RFF}{Paddy\ Area + Non - Paddy\ Area}$$

5.3.5 Recharge Due to Irrigation Water Applied

The estimates of irrigation water applied and the return flow factor are then made use of to compute the recharge from irrigation water applied by surface water irrigation in the sub-unit during the monsoon and non-monsoon seasons of the current ground water assessment year. The Recharge from applied surface water irrigation can be computed using the following formula.

Recharge due to surface water irrigation = Irrigation Water Applied * Return Flow Factor

5.4 FORMATS SUGGESTED FOR THE COMPUTATION

The formats suggested in the computation of the recharge from irrigation water applied by surface water sources in the sub-units are described in the following sections.

5.4.1 Command Area

The location details of all the outlets in the canal system are presented in the Table 5.1. The actual water released from each outlet during the monsoon and non-monsoon seasons are presented in Table 5.2. The depth to water table during monsoon and non-monsoon seasons are presented in Table 5.3. The irrigated area under paddy and non-paddy in the subunit are presented in Table 5.4 . The weighted average return flow factor for the sub-unit during monsoon and non-monsoon seasons are presented in Table 5.5. Finally the recharge due to applied surface water irrigation is presented in Table 5.6.

5.4.2 Non-Command Area

The computational scheme to be adopted for estimating recharge due to applied surface water irrigation in the non-command area is identical to what has been described earlier in Section 5.4.1 for command area. The results are presented in Tables 5.7 to 5.12

5.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating recharge due to applied surface water irrigation in the poor ground water quality area is identical to what has been described earlier in Section 5.4.1 for command area. The results are presented in Tables 5.13 to 5.18 .

5.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Recharge from surface water irrigation..

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Outlet	Text	50	
3	Name of the Canal	Text	50	
4	Latitude	Text	10	
5	Longitude	Text	10	
6	Design Discharge	Number	6	3
7	Monsoon Days	Number	3	0
8	Non-Monsoon Days	Number	3	0
9	Monsoon Water Released	Number	7	2
10	Non-Monsoon Water released	Number	7	2
11	Total Sub Unit Monsoon Water Released	Number	7	0
12	Total Sub Unit Non-Monsoon Water Released	Number	7	0
13	Total Sub Unit Annual Water Released	Number	7	0
14	Name of the Observation Well	Text	50	
15	Current Pre Monsoon Water level	Number	6	2
16	Current Post Monsoon Water level	Number	6	2
17	Subsequent Pre Monsoon Water level	Number	6	2
18	Average Current Pre Monsoon Water level	Number	6	2
19	Average Current Post Monsoon Water level	Number	6	2
20	Average Subsequent Pre Monsoon Water level	Number	6	2
21	Water level During Monsoon	Number	6	2
22	Water level During Non-Monsoon	Number	6	2
23	Name of the Crop	Text	20	
24	Area of Crop Monsoon	Number	7	2
25	Area of Crop Non Monsoon	Number	7	2

S.No	Parameter	Type	Size	Decimals
26	Total Area of Paddy Monsoon	Number	8	2
27	Total Area of Paddy Non Monsoon	Number	8	2
28	Total Area of Non Paddy Monsoon	Number	8	2
29	Total Area of Non Paddy Non Monsoon	Number	8	2
30	Type of Irrigation Water Monsoon	Text	10	
31	Average Discharge	Number	6	**3**
32	Return Flow Factor Paddy Monsoon	Number	5	2
33	Return Flow Factor Non Paddy Monsoon	Number	5	2
34	Weighted Average Return Flow Factor Monsoon	Number	5	2
35	Type of Irrigation Water Non Monsoon	Text	10	
36	Return Flow Factor Paddy Non Monsoon	Number	5	2
37	Return Flow Factor Non Paddy Non Monsoon	Number	5	2
38	Weighted Average Return Flow Factor Non Monsoon	Number	5	2
39	Total Sub Unit Monsoon Recharge due to SWI	Number	7	0
40	Total Sub Unit Non-Monsoon Recharge due to SWI	Number	7	0
41	Total Sub Unit Annual Recharge due to SWI	Number	7	0

Table 5.1 Location Details of All Outlets of the Canal System in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of outlet	Distributary on which the outlet is located	Latitude	Longitude	Design discharge in hectare meters per day	Average discharge in hectare meters per day
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 5.2 Irrigation Water Applied by Surface Water Sources in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the outlet	Average discharge in hectare meters per day [From Table 5.1]	Number of days water is released from the outlet during		Water released from outlet in hectare meters during	
			Monsoon Season	Non-Monsoon Season	Monsoon Season (3) * (4)	Non-Monsoon Season (3) * (5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Irrigation water applied by surface water sources in command area in hectare meters (Sum of water released from each outlet)						

Table 5.3 Water Table Data during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (All wells in command area)	Depth to water table below ground level in meters		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
For the command area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

Depth to water table below ground level in command area in meters
(rounded off to the nearest integer)

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Table 5.4 Irrigated Area under Paddy and Non - paddy Under Surface Water Sources in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the crop (in command area)	Area under surface water irrigation in acres during			
		Monsoon season		Non – monsoon season	
		Paddy	Non-Paddy	Paddy	Non-Paddy
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	Total				

Table 5.5 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Surface Water Sources in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for command area)	Monsoon season	Non - monsoon season
1	Irrigated area under Paddy [From Table 5.4]		
2	Irrigated area under Non - paddy [From Table 5.4]		
3	Depth to water table below ground level (Rounded off to nearest Integer in m) [From Table 5.3]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy available based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy available based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Weighted Average Return flow factor for the command area as a whole $\left[\frac{(7)*(1)+(8)*(2)}{(1)+(2)}\right]$		

Table 5.6 Recharge from Irrigation Water Applied by Surface Water Sources in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for command area)	Monsoon season	Non - monsoon season
1	Irrigation water applied by surface water sources in command area in hectare metres [From Table 5.2]		
2	Return flow factor for computing recharge from irrigation water applied by surface water sources in command area as a fraction [From Table 5.5]		
3	Recharge from irrigation water applied by surface water sources in command area in hectare metres [(1) * (2)]		

Table 5.7 Location Details of All Outlets of the Lift Canal System in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :
Major Aquifer :

S. No.	Name of outlet	Distributary on which the outlet is located	Latitude	Longitude	Design discharge in hectare meters per day	Average discharge in hectare meters per day
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 5.8 Irrigation Water Applied by Surface Water Sources in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the outlet	Average discharge in hectare meters per day [From Table 5.7]	Number of days water is released from the outlet during		Water released from outlet in hectare metres during	
			Monsoon Season	Non-Monsoon Season	Monsoon Season (3) * (4)	Non-Monsoon Season (3) * (5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Irrigation water applied by surface water sources in non-command area in hectare meters (Sum of water released from each outlet)						

Table 5.9 Water Table Data during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

<table>
<tr><td rowspan="3">S. No.</td><td rowspan="3">Name of observation well
(All wells in non-command area)</td><td colspan="3">Depth to water table below ground level in meters</td></tr>
<tr><td colspan="2">in ground water assessment year during</td><td>in ground water year immediately following the ground water assessment year during</td></tr>
<tr><td>Pre - monsoon monitoring month</td><td>Post - monsoon monitoring month</td><td>Pre - monsoon monitoring month</td></tr>
<tr><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td></tr>
<tr><td>1
2
3</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">For the non-command area as a whole
(Average of all wells considered)</td><td>Y1 =</td><td>Y2 =</td><td>Y3 =</td></tr>
</table>

Depth to water table below ground level in non-command area in meters
(Rounded off to the nearest Integer)

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Table 5.10 Irrigated Area under Paddy and Non - paddy Under Surface Water Sources in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the crop (in non-command area)	Area under surface water irrigation in acres during			
		Monsoon season		Non – monsoon season	
		Paddy	Non-Paddy	Paddy	Non-Paddy
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	Total				

Table 5.11 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Surface Water Sources in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for non-command area)	Monsoon season	Non - monsoon season
1	Irrigated area under Paddy [From Table 5.10]		
2	Irrigated area under Non - paddy [From Table 5.10]		
3	Depth to water table below ground level (Rounded off to nearest Integer in m) [From Table 5.9]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy available based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy available based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Weighted Average Return flow factor for the non-command area as a whole $\left[\frac{(7)*(1)+(8)*(2)}{(1)+(2)}\right]$		

Table 5.12 Recharge from Irrigation Water Applied by Surface Water Sources in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for non-command area)	Monsoon season	Non - monsoon season
1	Irrigation water applied by surface water sources in non-command area in hectare meters [From Table 5.8]		
2	Return flow factor for computing recharge from irrigation water applied by surface water sources in non-command area as a fraction [From Table 5.11]		
3	Recharge from irrigation water applied by surface water sources in non-command area in hectare meters [(1) * (2)]		

Table 5.13 Location Details of All Outlets of the Canal System in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :
Major Aquifer :

S. No.	Name of outlet	Distributary on which the outlet is located	Latitude	Longitude	Design discharge in hectare meters per day	Average discharge in hectare meters per day
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 5.14 Irrigation Water Applied by Surface Water Sources in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the outlet	Average discharge in hectare meters per day [From Table 5.13]	Number of days water is released from the outlet during		Water released from outlet in hectare meters during	
			Monsoon Season	Non-Monsoon Season	Monsoon Season (3) * (4)	Non-Monsoon Season (3) * (5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Irrigation water applied by surface water sources in poor ground water quality area in hectare meters (Sum of water released from each outlet)						

Table 5.15 Water Table Data during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (All wells in poor ground water quality area)	Depth to water table below ground level in meters		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
For the poor ground water quality area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a)Depth to water table below ground level in poor ground water quality area in meters
(rounded off to nearest Integer)

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

b) If water table data are not available, the depth to water table below ground level during both monsoon and non-monsoon seasons may be considered to be less than 10 metres below ground level .

Table 5.16 Area Under Paddy and Non - paddy Under Surface Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the crop (in poor ground water quality area)	Area under surface water irrigation in acres during			
		Monsoon season		Non – monsoon season	
		Paddy	Non-Paddy	Paddy	Non-Paddy
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	Total				

Table 5.17 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Surface Water Sources in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for poor ground water quality area)	Monsoon season	Non - monsoon season
1	Irrigated area under Paddy [From Table 5.16]		
2	Irrigated area under Non - paddy [From Table 5.16]		
3	Depth to water table below ground level (Rounded off to nearest Integer in m) [From Table 5.15]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy available based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy available based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Weighted Average Return flow factor for the poor ground water quality area as a whole $\left[\frac{(7)*(1)+(8)*(2)}{(1)+(2)}\right]$		

Table 5.18 Recharge from Irrigation Water Applied by Surface Water Sources in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for poor ground water quality area)	Monsoon season	Non - monsoon season
1	Irrigation water applied by surface water sources in poor ground water quality area in hectare meters [From Table 5.14]		
2	Return flow factor for computing recharge from irrigation water applied by surface water sources in poor ground water quality area as a fraction [From Table 5.17]		
3	Recharge from irrigation water applied by surface water sources in poor ground water quality area in hectare meters [(1) * (2)]		

6

RECHARGE FROM APPLIED GROUND WATER IRRIGATION

6.1 GENERAL

Recharge from irrigation water applied by ground water sources which has to be computed for the monsoon and non-monsoon seasons of the current ground water assessment year is applicable for the following three sub-units of each ground water assessment unit:

a. Command area
b. Non-command area
c. Poor groundwater quality area

The computation of recharge from irrigation water applied by ground water sources in a given sub-unit during a given season involves the following steps to be carried out:

a. Estimation of irrigation water applied by ground water irrigation .
b. Estimation of average depth to water table below ground level.
c. Estimation of irrigated area under paddy and non-paddy.
d. Assigning a return flow factor on the basis of results from ‘b’ and ‘c’ above.
e. Computation of the required recharge on the basis of results from ‘a’ and ‘d’ above.

6.2 ASSUMPTIONS

The computation of recharge from irrigation water applied by ground water sources is based on the following assumptions :

a) Recharge in hectare metres can be obtained as the product of the following parameters :
    i. Irrigation water applied in hectare metres
    ii. Return flow factor as a fraction
b) The irrigation water applied as mentioned in ‘a’ above is considered as the gross groundwater extraction for irrigation as obtained in Chapter 3. In other words, the transmission losses are considered as nil.
c) The return flow factor mentioned in ‘a’ above depends only on the following parameters:
    i. Whether the crop irrigated is paddy or non-paddy.

    ii. The range of depth to water table below ground level

d) The return flow factor mentioned in ‘a’ and ‘c’ above can be assigned a value either on the basis of norms as given in Annexure II or on the basis of results from documented field studies.

6.3 COMPUTATIONAL PROCEDURE

The computational scheme to be adopted for computing the recharge from irrigation water applied by ground water sources in any sub unit is described in this section.

6.3.1 Irrigation Water Applied

The gross ground water extraction for irrigation , during the monsoon and non-monsoon seasons in any of the sub unit as computed in Chapter 3 are considered as the irrigation water applied by ground water sources.

6.3.2 Depth to Water Table Below Ground Level

The average depth to water table below ground level in the subunit as a whole during the monsoon and non-monsoon seasons are to be categorised based on the depth to water level to assign the return flow factor for paddy and non-paddy in the area.

a) Less than 10 metres
b) Between 10 and 25 metres with 1m zonation
c) Greater than 25 metres

The computational scheme to adopted for this purpose is given below :

a) The following data on depth to water table below ground level as recorded from each of the observation wells in the sub unit are considered.
    i. during pre-monsoon monitoring month of the current ground water assessment year
    ii. during post-monsoon monitoring month of current ground water assessment year
    iii. during pre-monsoon monitoring month of the ground water year immediately following the current ground water assessment year.
b) The above three water table data items applicable for the subunit as a whole are obtained as the arithmetic mean of the corresponding data from all the observation wells considered.
c) Average depth of water table below ground level in the subunit as a whole during the monsoon season is computed as the arithmetic mean of the water table data during pre-monsoon and post-monsoon monitoring months of the current ground water assessment year as obtained in ‘b’ above.
d) Average depth of water table below ground level in the subnuit as a whole during the non-monsoon season is computed as the arithmetic mean of the water table data during post-monsoon monitoring month of the current ground water assessment year and pre-monsoon monitoring month of the ground water year immediately following the current ground water assessment year as obtained in ‘b’ above.

e) The results obtained from ‘c’ and ‘d’ above or made use of to categorise the depth to water table below ground level in the subunit during monsoon and non-monsoon seasons to assign a return flow factor as per the norms suggested by GEC 2015.

6.3.3 Irrigated Area Under Paddy and Non-paddy

The irrigated area in acres under paddy and non-paddy in the subunit during monsoon and non-monsoon seasons of the current ground water assessment year are estimated by adopting any convenient method. The most obvious method, though it will be time consuming, is through actual field survey. They can also be estimated indirectly, using information on irrigation water applied and irrigation water requirement of the crops. This data can be collected from agricultural department also.

6.3.4 Return Flow Factor

The return flow factor for the sub unit during monsoon and non-monsoon seasons are obtained either on the basis of the norms as given in Annexure II or on the basis of results from documented field studies. The use of the norms require information on depth to water table and irrigated area mentioned in the previous two sections. The weighted average return flow factor can be calculated using the following formula.

$$Weighted\ Average\ RFF = \frac{Paddy\ Area \times Paddy\ RFF + Non - Paddy\ Area \times Non - Paddy\ RFF}{Paddy\ Area + Non - Paddy\ Area}$$

6.3.5 Recharge

The estimates of irrigation water applied and the return flow factor are then made use of to compute the recharge from irrigation water applied by ground water sources in the subunit during the monsoon and non-monsoon seasons of the current ground water assessment year. The Recharge from applied ground water irrigation can be computed using the following formula.

Recharge due to ground water irrigation = Irrigation Water Applied * Return Flow Factor

6.4 FORMATS SUGGESTED FOR THE COMPUTATION

The formats suggested in the computation of the recharge from applied ground water irrigation in the subunits are described in the following sections.

6.4.1 Command Area

The gross ground water extraction for irrigation during monsoon and non-monsoon seasons as computed in Chapter 3 are considered as irrigation water applied by ground water sources. The results are presented in Table 6.1 The depth to water during monsoon and non-monsoon seasons are computed in Table 6.2. The irrigated area under paddy and non-paddy in the subunit are estimated in Table 6.3 . The weighted average return flow factor for the subunit during monsoon and non-monsoon seasons are computed in Table 6.4. Finally the recharge due to applied ground water irrigation is computed in Table 6.5.

6.4.2 Non-Command Area

The computational scheme to be adopted for estimating recharge due to applied ground water irrigation in the non-command area is identical to what has been described earlier in Section 6.4.1 for command area. The results are presented in Tables 6.6 to 6.10

6.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating recharge due to applied ground water irrigation in the poor ground water quality area is identical to what has been described earlier in Section 6.4.1 for command area. The results are presented in Tables 6.11 to 6.15.

6.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Recharge from ground water irrigation.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Ground Water Applied Monsoon	Number	7	2
3	Ground Water Applied Non-Monsoon	Number	7	2
4	Name of the Observation Well	Text	50	
5	Pre Monsoon Water level in the Assessment Year	Number	6	2
6	Post Monsoon Water level in the Assessment Year	Number	6	2
7	Pre Monsoon Water level in the succeeding Year	Number	6	2
8	Average Previous Post Monsoon Water level	Number	6	2
9	Average Current Pre Monsoon Water level	Number	6	2
10	Average Current Post Monsoon Water level	Number	6	2
11	Water level During Monsoon	Number	6	2
12	Water level During Non-Monsoon	Number	6	2
13	Name of the Crop	Text	20	
14	Area of Crop Monsoon	Number	7	2
15	Area of Crop Non Monsoon	Number	7	2
16	Total Area of Paddy Monsoon	Number	8	2
17	Total Area of Paddy Non Monsoon	Number	8	2
18	Return Flow Factor Paddy Monsoon	Number	5	2
19	Return Flow Factor Non Paddy Monsoon	Number	5	2
20	Weighted Average Return Flow Factor Monsoon	Number	5	2
21	Return Flow Factor Paddy Non Monsoon	Number	5	2
22	Return Flow Factor Non Paddy Non Monsoon	Number	5	2
23	Weighted Average Return Flow Factor Non Monsoon	Number	5	2
24	Total Sub Unit Monsoon Recharge due to GWI	Number	7	0
25	Total Sub Unit Non-Monsoon Recharge due to GWI	Number	7	0
26	Total Sub Unit Annual Recharge due to GWI	Number	7	0

Table 6.1 Irrigation Water Applied by Ground Water Sources in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for command area)	Quantity
(1)	(2)	(3)
1	Irrigation water applied by ground water sources in command area during monsoon season in hectare meters [From Table 3.13]	
2	Irrigation water applied by ground water irrigation in command area during non - monsoon season in hectare meters [From Table 3.13]	

Note : Irrigation water applied by ground water irrigation during a given season is considered to be the same as the gross ground water extraction for irrigation during that season

Table 6.2 Water Table Data during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (All wells are in command area)	Depth to water table below ground level in meters		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month
(1)	(2)	(3)	(4)	(5)
1 2 3				
For the command area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in command area in metres

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Table 6.3 Irrigated Area Under Paddy and Non - Paddy Under Ground Water Irrigation in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the crop (in command area)	Area under ground water irrigation in acres during			
		Monsoon season		Non – monsoon season	
		Paddy	Non-Paddy	Paddy	Non-Paddy
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	Total				

Table 6.4 Return Flow Factor for Computing Recharge from Applied Ground Water Irrigation in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for command area)	Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1	Irrigated area under Paddy [From Table 6.3]		
2	Irrigated area under Non - paddy [From Table 6.3]		
3	Depth to water table below ground level (Rounded off to nearest Integer in m) [From Table 6.2]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy available based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy available based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Weighted Average Return flow factor for the command area as a whole $\left[\frac{(7)*(1)+(8)*(2)}{(1)+(2)}\right]$		

Table 6.5 Recharge from Applied Ground Water Irrigation in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for command area)	Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1	Irrigation water applied by ground water sources in command area in hectare meters [From Table 6.1]		
2	Return flow factor for computing recharge from applied ground water irrigation in command area as a fraction [From Table 6.4]		
3	Recharge from applied ground water irrigation in command area in hectare meters [(1) * (2)]		

Table 6.6 Irrigation Water Applied by Ground Water Sources in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for non-command area)	Quantity
(1)	(2)	(3)
1	Irrigation water applied by ground water sources in non-command area during monsoon season in hectare meters [From Table 3.26]	
2	Irrigation water applied by ground water sources in non-command area during non - monsoon season in hectare meters [From Table 3.26]	

Note : Irrigation water applied by ground water sources during a given season is considered to be the same as the gross ground water extraction for irrigation during that season

Table 6.7 Water Table Data during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (All wells are in non-command area)	Depth to water table below ground level in meters		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
For the non-command area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in non-command area in meters

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Table 6.8 Irrigated Area Under Paddy and Non - paddy Under Ground Water Irrigation in Non -command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the crop (in non-command area)	Area under ground water irrigation in acres during			
		Monsoon season		Non – monsoon season	
		Paddy	Non-Paddy	Paddy	Non-Paddy
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	Total				

Table 6.9 Return Flow Factor for Computing Recharge from Applied Ground Water Irrigation in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for non-command area)	Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1	Irrigated area under Paddy [From Table 6.8]		
2	Irrigated area under Non - paddy [From Table 6.8]		
3	Depth to water table below ground level (Rounded off to nearest Integer in m) [From Table 6.7]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy available based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy available based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Weighted Average Return flow factor for the command area as a whole $\left[\frac{(7)*(1)+(8)*(2)}{(1)+(2)}\right]$		

Table 6.10 Recharge from Applied Ground Water Irrigation in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for non-command area)	Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1	Irrigation water applied by ground water sources in non-command area in hectare meters [From Table 6.6]		
2	Return flow factor for computing recharge from applied ground water irrigation in non-command area as a fraction [From Table 6.9]		
3	Recharge from applied ground water irrigation in non-command area in hectare meters [(1) * (2)]		

Table 6.11 Irrigation Water Applied by Ground Water Sources in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for poor ground water quality area)	Quantity
(1)	(2)	(3)
1	Irrigation water applied by ground water sources in poor ground water quality area during monsoon season in hectare meters [From Table 3.39]	
2	Irrigation water applied by ground water sources in poor ground water quality area during non - monsoon season in hectare meters [From Table 3.39]	

Note : Irrigation water applied by ground water sources during a given season is considered to be the same as the gross ground water extraction for irrigation during that season

Table 6.12 Water Table Data during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (All wells are in poor ground water quality area)	Depth to water table below ground level in meters		
		in ground water assessment year during		in ground water year immediately following the ground water assessment year during
		Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
For the poor ground water quality area as a whole (Average of all wells considered)		Y1 =	Y2 =	Y3 =

a) Depth to water table below ground level in poor ground water quality area in meters

i) During monsoon season =
[(Y1 + Y2) / 2]

ii) During non - monsoon season =
[(Y2 + Y3) / 2]

Table 6.13 Irrigated Area Under Paddy and Non - paddy Under Ground Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the crop (in poor ground water quality area)	Area under ground water irrigation in acres during			
		Monsoon season		Non – monsoon season	
		Paddy	Non-Paddy	Paddy	Non-Paddy
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	Total				

Table 6.14 Return Flow Factor for Computing Recharge from Irrigation Water Applied by Ground Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for poor ground water quality area)	Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1	Irrigated area under Paddy [From Table 6.13]		
2	Irrigated area under Non - paddy [From Table 6.13]		
3	Depth to water table below ground level (Rounded off to nearest Integer in m) [From Table 6.12]		
4	Type of irrigation water supply (Continuous / Rotational)		
5	Is return flow factor for Paddy available based on results from documented field studies (Yes / No)		
6	Is return flow factor for Non - paddy available based on results from documented field studies (Yes / No)		
7	Return flow factor for Paddy as a fraction		
8	Return flow factor for Non - paddy as a fraction		
9	Weighted Average Return flow factor for the command area as a whole $\left[\frac{(7)*(1)+(8)*(2)}{(1)+(2)}\right]$		

Table 6.15 Recharge from Applied Ground Water Irrigation in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for poor ground water quality area)	Monsoon season	Non - monsoon season
(1)	(2)	(3)	(4)
1	Irrigation water applied by ground water sources in poor ground water quality area in hectare meters [From Table 6.11]		
2	Return flow factor for computing recharge from applied ground water irrigation in poor ground water quality area as a fraction [From Table 6.14]		
3	Recharge from applied ground water irrigation in poor ground water quality area in hectare meters [(1) * (2)]		

7

RECHARGE FROM TANKS & PONDS

7.1 GENERAL

Recharge from tanks and ponds which is to be computed for the monsoon and non-monsoon seasons of the current ground water assessment year and is applicable for the following sub-units.

a) Command area
b) Non-command area
c) Poor Ground Water Quality Area

The computation of recharge from tanks and ponds in a given sub-unit and during a given season involves the following steps to be carried out.

a) Estimation of the number of days when water is actually available and the average water spread area during that period
b) Computation of recharge using results from 'a' above

7.2 ASSUMPTIONS

The computation of recharge from tanks and ponds is based in the following assumptions :

a) Recharge in hectare metres from each tank and pond can be obtained as the product of the following parameters
   i) Average water spread area
   ii) Number of days water is actually available
   iii) A recharge factor of 0.0014 metres per day if not available from field studies.
b) The average area of water spread mentioned in 'a' above is obtained as the arithmetic average of water spread areas recorded during different time intervals. However, if such periodic data are not available, the average area of water spread can be taken as 0.6 times the designed water spread area.
c) The total recharge from tanks and ponds is obtained as the sum of recharge computed for each tank/ pond existing in the sub unit.

7.3 COMPUTATIONAL PROCEDURE

7.3.1 Average Water Spread Area

The average water spread area in hectares of each tank/ pond in each of them during the monsoon and non-monsoon seasons of the current ground water assessment year are to be obtained. This is to be arrived at either as,

i) the arithmetic average of water spread areas recorded periodically during the season under consideration, or as,
ii) 0.6 times the maximum designed water spread area during the season under consideration, if periodic water spread area data are not available

7.3.2 No. of Days

The number of days when water was available in the tank during monsoon and non-monsoon seasons of the current ground water assessment year is to be obtained.

7.3.3 Recharge From Tank/Pond

The recharge from each tank/ pond in hectare metres during the monsoon and non-monsoon seasons of the current ground water assessment year are computed as the product of the average water spread area, the number of days water was available and the recharge factor in metres per day.

7.4 FORMATS SUGGESTED FOR THE COMPUTATION

7.4.1 Command Area

All tanks and ponds in the command area are identified, and their location details are presented in the Table 7.1. The computation of recharge due to tanks/ponds in command area as described above are presented in the Table 7.2.

7.4.2 Non-Command Area

The computational scheme for estimating recharge from tanks and ponds in the non-command area is identical to what has been described earlier in Section 7.4.1 for the command area . The computations are presented in the Tables 7.3 and 7.4.

7.4.3 Poor Ground Water Quality Area

The computational scheme for estimating recharge from tanks and ponds in the poor ground water quality area is identical to what has been described earlier in Section 7.4.1, for the command area . The computations are presented in the Tables 7.5 and 7.6.

7.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Recharge from Tanks and Ponds.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Tank	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	Year of Construction	Text	9	
6	Monsoon Water Spread Area	Number	5	0
7	Non-Monsoon Water Spread Area	Number	5	0
8	Monsoon Days	Number	3	0
9	Non-Monsoon Days	Number	3	0
9	Monsoon Recharge TP	Number	7	2
10	Non-Monsoon Recharge TP	Number	7	2
11	Total Sub Unit Monsoon Recharge TP	Number	7	0
12	Total Sub Unit Non-Monsoon Recharge TP	Number	7	0
13	Total Sub Unit Annual Recharge TP	Number	7	0

Table 7.1 Location Details of Tanks and Ponds in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of tank / pond in command area	Latitude	Longitude	Year of construction	Design Water Spread Area in hectares
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 7.2 Recharge from Tanks and Ponds in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of tank / pond in command area	Average water spread area in hectares during		Number of days water is available during		Recharge Factor in meters		Recharge in hectare meters during	
		Monsoon Season	Non - monsoon season	Monsoon Season	Non - monsoon season	Monsoon Season	Non - monsoon season	Monsoon Season (3)*(5)*(7)	Non - monsoon (4) * (6)* (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Total recharge from all tanks and ponds in the command area (Sum of Recharge from all the Individual Tanks/Ponds)									

Table 7.3 Location Details of Tanks and Ponds in Non - Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of tank / pond in non-command area	Latitude	Longitude	Year of construction	Design Water Spread Area in hectares
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 7.4 Recharge from Tanks and Ponds in Non - Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of tank / pond in Non-command area	Average water spread area in hectares during		Number of days water is available during		Recharge Factor in meters		Recharge in hectare meters during	
		Monsoon Season	Non - monsoon season	Monsoon Season	Non - monsoon season	Monsoon Season	Non - monsoon season	Monsoon Season (3)*(5)*(7)	Non - monsoon (4) * (6)* (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Total recharge from all tanks and ponds in the non-command area (Sum of Recharge from all the Individual Tanks/Ponds)									

Table 7.5 Location Details of Tanks and Ponds in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of tank / pond in poor ground water quality area	Latitude	Longitude	Year of construction	Design Water Spread Area in hectares
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 7.6 Recharge from Tanks and Ponds in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of tank / pond in Poor Ground Water Quality area	Average water spread area in hectares during		Number of days water is available during		Recharge Factor in meters		Recharge in hectare meters during	
		Monsoon Season	Non - monsoon season	Monsoon Season	Non - monsoon season	Monsoon Season	Non - monsoon season	Monsoon Season (3)*(5)*(7)	Non - monsoon (4) * (6)* (8)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Total recharge from all tanks and ponds in Poor Ground Water Quality area (Sum of Recharge from all the Individual Tanks/Ponds)									

8

RECHARGE FROM WATER CONSERVATION STRUCTURES

8.1 GENERAL

With increasing focus on sustainable development of ground water resources, all States and Union Territories have been implementing several water conservation schemes with the aim of increasing ground water recharge. The water conservation structures include percolation tanks, check dams, nulla bunds etc. Recharge from water conservation structures are to be computed during monsoon and non-monsoon seasons of the current ground water assessment year for the following sub-units within each ground water assessment unit :

a) Command area
b) Non-command area
c) Poor ground water quality area

The computations of recharge from water conservation structures in a given sub-unit and during a given season involves the following steps to be carried out :

a) Computing recharge from each water conservation structure based on gross storage of that structure
b) Obtaining the total recharge as the sum of the recharge from each water conservation structure

8.2 ASSUMPTIONS

The computations of recharge from water conservation structures are based on the following assumptions :

a) Annual recharge in hectare metres from each water conservation structure can be obtained as the product of the following three parameters :
    i) Storage capacity of the structure in hectare metres
    ii) Number of fillings which take place in a ground water year (This can be a fraction greater than zero and sometimes it can be more than one also)
    iii) A Recharge factor, which is recommended as of 0.4
b) The annual recharge from all water conservation structures is obtained as the sum of the recharge from each structure
c) The annual recharge from all water conservation structures is distributed equally during the monsoon and non-monsoon seasons of a ground water year

8.3 COMPUTATIONAL PROCEDURE

The scheme for computing recharge from water conservation structures in any of the sub units during the monsoon and non-monsoon seasons of the current ground water assessment year comprises of the following steps

a) The storage capacity in hectare metres of each water conservation structure and the number of fillings in each of them during the current ground water assessment year are obtained. The gross annual storage in hectare metres of each structure is then obtained as the product of these two values.
b) The annual recharge in hectare metres from each water conservation structure is obtained by multiplying the gross annual storage of that structure with the recharge factor. The recharge factor as recommended by GEC 2015 is 0.4.
c) The annual recharge in hectare metres from all water conservation structures in the command area is obtained as the sum of the recharge from each structure
d) Recharge from water conservation structures in any sub unit during both monsoon and non-monsoon seasons are taken as 0.5 times the annual recharge

8.4 FORMATS SUGGESTED FOR THE COMPUTATION

8.4.1 Command Area

All water conservation structures in the command area are identified, and their location details are presented in Table 8.1. The scheme for computing recharge from water conservation structures in the command area during the monsoon and non-monsoon seasons of the current ground water assessment year is presented in Table 8.2.

8.4.2 Non-Command Area

The computational scheme to be adopted for estimating the recharge from water conservation structures in the non-command area during monsoon and non-monsoon seasons of the current ground water assessment year is identical to what has been described earlier in Section 8.4.1 for the command area. The computations are presented in Tables 8.3 and 8.4.

8.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating recharge from water conservation structures in poor ground water quality area during the monsoon and non-monsoon seasons of the current ground water assessment year is identical to what has been described earlier in Section 8.4.1 for the command area. The computations are presented in Tables 8.5 and 8.6.

8.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Recharge from Water Conservation Structures.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Water Conservation Structure	Text	50	
3	Type of Water Conservation Structure	Text	20	
4	Latitude	Text	10	
5	Longitude	Text	10	
6	Year of Construction	Text	9	
7	Storage Capacity	Number	5	0
8	No Fillings	Number	3	1
9	Gross Storage	Number	6	0
10	Monsoon Recharge WCS	Number	7	2
11	Non-Monsoon Recharge WCS	Number	7	2
12	Total Sub Unit Monsoon Recharge WCS	Number	7	0
13	Total Sub Unit Non-Monsoon Recharge WCS	Number	7	0
14	Total Sub Unit Annual Recharge WCS	Number	7	0

Table 8.1 Location Details of Water Conservation Structures in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of water conservation structure (in command area)	Type (percolation tank / check dam / nulla bund)	Latitude	Longitude	Year of construction
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 8.2 Recharge from Water Conservation Structures in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of water conservation structure (in command area)	Storage capacity in hectare meters	Number of fillings during the ground water assessment year	Gross storage in hectare meters [(3) * (4)]	Recharge Factor		Recharge in hectare meters	
					Monsoon Season	Non-Monsoon Season	Monsoon Season [(5) * (6)]	Non – monsoon Season [(5) * (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Recharge from water conservation structures in command area (Total of recharge from each structure)								

Table 8.3 Location Details of Water Conservation Structures in Non - command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :
Major Aquifer :

S. No.	Name of water conservation structure (in non-command area)	Type (percolation tank / check dam / nulla bund)	Latitude	Longitude	Year of construction
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 8.4 Recharge from Water Conservation Structures in Non - command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :
Major Aquifer :

S. No.	Name of water conservation structure (in non-command area)	Storage capacity in hectare meters	Number of fillings during the ground water assessment year	Gross storage in hectare meters [(3) * (4)]	Recharge Factor		Recharge in hectare meters	
					Monsoon Season	Non-Monsoon Season	Monsoon Season [(5) * (6)]	Non – monsoon Season [(5) * (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Recharge from water conservation structures in non-command area (Total of recharge from each structure)								

Table 8.5 Location Details of Water Conservation Structures in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of water conservation structure (in poor ground water quality area)	Type (percolation tank / check dam / nulla bund)	Latitude	Longitude	Year of construction
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 8.6 Recharge from Water Conservation Structures in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of water conservation structure (in poor ground water quality area)	Storage capacity in hectare meters	Number of fillings during the ground water assessment year	Gross storage in hectare meters [(3) * (4)]	Recharge Factor		Recharge in hectare meters	
					Monsoon Season	Non-Monsoon Season	Monsoon Season [(5) * (6)]	Non – monsoon Season [(5) * (7)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Recharge from water conservation structures in poor ground water quality area (Total of recharge from each structure)								

9

RECHARGE FROM OTHER SOURCES

9.1 GENERAL

The sources of ground water recharge other than rainfall are five in number as listed below:

a) **Canals**
b) **Irrigation Water Applied by Surface Water Sources**
c) **Irrigation Water Applied by Ground Water Sources**
d) **Tanks and Ponds**
e) **Water Conservation Structures**

The above five sources are together referred to as **'**Other Sources'. The estimation of recharge from these five sources have been presented in Chapters 4 to 8. Recharge from **'**Other sources' in a given sub-unit is obtained as the sum of the recharge from those sources which are applicable for that sub-unit .

Recharge from 'Other Sources' during the monsoon and non-monsoon seasons of the current ground water assessment year are to be obtained for the following sub-units within each ground water assessment unit.

a) Command area : All Five sources described above are applicable.
b) Non-Command Area : All the sources except the recharge due to canals are applicable.
c) Poor Ground Water Area: All Five sources described above are applicable.

Recharge from 'Other Sources' in all the sub-units during the monsoon season of the current ground water assessment year will be made use of for computing rainfall recharge by the water table fluctuation method (Chapter 19). This is also used for computing the Annual Extractable Ground Water Resources in those three sub-units (Chapter 20).

9.2 FORMATS SUGGESTED FOR THE COMPUTATION

The recharge from 'Other Sources' are presented in Tables 9.1 to 9.3, one table for each sub-unit.

9.3 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Recharge from Other Sources.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	

S.No	Parameter	Type	Size	Decimals
2	Total Sub Unit Monsoon Canal Recharge	Number	7	0
3	Total Sub Unit Non-Monsoon Canal Recharge	Number	7	0
4	Total Sub Unit Annual Canal Recharge	Number	7	0
5	Total Sub Unit Monsoon Recharge due to SWI	Number	7	0
6	Total Sub Unit Non-Monsoon Recharge due to SWI	Number	7	0
7	Total Sub Unit Annual Recharge due to SWI	Number	7	0
8	Total Sub Unit Monsoon Recharge due to GWI	Number	7	0
9	Total Sub Unit Non-Monsoon Recharge due to GWI	Number	7	0
10	Total Sub Unit Annual Recharge due to GWI	Number	7	0
11	Total Sub Unit Monsoon Recharge TP	Number	7	0
12	Total Sub Unit Non-Monsoon Recharge TP	Number	7	0
13	Total Sub Unit Annual Recharge TP	Number	7	0
14	Total Sub Unit Monsoon Recharge WCS	Number	7	0
15	Total Sub Unit Non-Monsoon Recharge WCS	Number	7	0
16	Total Sub Unit Annual Recharge WCS	Number	7	0
17	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
18	Total Sub Unit Non-Monsoon Recharge Other Sources	Number	8	0
19	Total Sub Unit Annual Recharge Other Sources	Number	8	0

Table 9.1 Recharge from 'Other Sources' in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Type of source	Recharge in hectare meters during	
		Monsoon Season	Non-monsoon Season
1	Recharge from canals [From Table 4.4]		
2	Recharge from irrigation water applied by surface water sources [From Table 5.6]		
3	Recharge from irrigation water applied by ground water sources [From Table 6.5]		
4	Recharge from tanks and ponds [From Table 7.2]		
5	Recharge from water conservation structures [From Table 8.2]		
Recharge from 'Other Sources' in command area [(1)+(2)+(3)+(4)+(5)]			

a) Annual recharge from 'Other Sources' in command area =
in hectare metres
[Sum of monsoon and non-monsoon seasons]

Table 9.2 Recharge from ‘Other Sources ` in Non - Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Type of source	Recharge in hectare meters during	
		Monsoon Season	Non-monsoon Season
1	Recharge from irrigation water applied by surface water sources [From Table 5.12]		
2	Recharge from irrigation water applied by ground water sources [From Table 6.10]		
3	Recharge from tanks and ponds [From Table 7.4]		
4	Recharge from water conservation structures [From Table 8.4]		
Recharge from ‘Other Sources’ in non-command area (1)+(2)+(3)+(4)			

a) Annual recharge from ‘Other Sources’ in non-command area =
in hectare metres
[Sum of monsoon and non-monsoon seasons]

Table 9.3 Recharge from 'Other Sources' in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Type of source	Recharge in hectare meters during	
		Monsoon Season	Non-monsoon Season
1	Recharge from canals [From Table 4.8]		
2	Recharge from irrigation water applied by surface water sources [From Table 5.18]		
3	Recharge from irrigation water applied by ground water sources [From Table 6.15]		
4	Recharge from tanks and ponds [From Table 7.6]		
5	Recharge from water conservation structures [From Table 8.6]		
Recharge from 'Other Sources' in poor ground water quality area [(1)+(2)+(3)+(4)+(5)]			

a) Annual recharge from 'Other Sources' in poor ground water quality area =
in hectare metres
[Sum of monsoon and non-monsoon seasons]

10

LATERAL FLOW ALONG THE AQUIFER SYSTEM (THROUGH FLOW)

10.1 GENERAL

Unless and until the assessment unit is a hydrological unit with sealed boundaries, there is always a possibility of ground water movement across the boundaries. Wherever the assessment units are blocks, there will be a ground water flow across the boundaries. Even in hydrological boundaries like watersheds, if the water divide is of low relief, then also there is a possibility of ground water flow depending on the condition of ground water heads in the area. In GEC 1997 methodology it is assumed that lateral inflows into the assessment unit are equivalent to ground water outflows. But this is always not true. Hence GEC 2015 suggested to compute the Lateral Flows along the Aquifer System or Through Flows and utilise in the estimation of ground water balancing components.

For assessing the through flow, there should be well distributed network of ground water level observation wells. As other components are normalized in one or other methods, this component also to be estimated for an average situation. Hence there is a requirement of minimum 5 sets of data during pre-monsoon and post-monsoon seasons for all the observation wells. Generally there will not be more than three wells in an assessment sub unit, hence this exercise should be done to a bigger area to calculate the hydraulic gradient. This hydraulic gradient can be used for the boundaries of the assessment sub unit in calculating the flow.

The computations of through flow from/into the assessment sub unit during a given season involves the following steps to be carried out :

a) Computing average ground water head for both the seasons by taking the ground water head data of at least five years.
b) Computing the Average Groundwater heads during monsoon season and non-monsoon season separately.
c) Preparation of Ground water Table contour with suitable contour interval for both the seasons.
d) Computation of Hydraulic gradient at required number of places for both the seasons.

e) Depending on the variation in hydraulic gradients, demarcation of sections on the boundary for both the seasons.
f) Computation of Flow across the boundary for each of the section for both the seasons.
g) Summation of the flow across boundary for each of the section and resultant through flow for both the seasons.

10.2 ASSUMPTIONS

The computations of lateral flow across the boundary are based on the following assumptions :

a) The average ground water head of pre monsoon season and the post monsoon season of the assessment year is considered as the ground water head during monsoon season. Similarly, the average ground water head of the post monsoon season of the current assessment year and ground water head of the pre monsoon season of the next assessment year is considered as the ground water head during non-monsoon season.
b) The ground water flow across the boundary can be obtained as the product of following:
    i) Transmissivity of the aquifer
    ii) Length of section
    iii) Hydraulic gradient across the section.
    iv) No. of days flow exists across the boundary in the given season
c) The ground water flow across the boundary from the assessment sub unit is obtained as the algebraic sum of the ground water flow across the boundary from all the sections.

10.3 COMPUTATIONAL PROCEDURE

As per the existing density of network stations, it may be difficult to compute the hydraulic gradient for each assessment sub unit separately. Depending on the availability of network stations, the estimation of hydraulic gradient may be done for each assessment sub unit, assessment unit or to a group of assessment units. The computations of through flow from/into the assessment sub unit during a given season involves the following steps to be carried out :

10.3.1 Average Ground Water Head

For knowing the most probable through flow from/into assessment sub unit the average ground water heads for both the monsoon and non-monsoon seasons are needed. The average ground water head in any season may be computed as the average of ground water head observed by taking the ground water head data of at least five years data. The average groundwater heads during monsoon season and non-monsoon season are to be estimated separately. For each of the year under consideration, the average of Pre-monsoon water level and post monsoon water level may be considered as monsoon season water level and the average of post monsoon water level of current year and pre monsoon water level of succeeding year may be considered as non-monsoon water level.

10.3.2 Average Hydraulic Gradient

Hydraulic gradient is the ratio between change in head and the distance between the observations. For computing average hydraulic gradient, water table contour map with suitable contour interval is to be prepared. The hydraulic gradient at required number of places can be computed by calculating the head difference between contours along the flow direction and computing the distance between both the contours. The average hydraulic gradient for monsoon season and non-monsoon season are to be estimated separately.

10.3.3 Ground Water Flow Across Boundary

The Hydraulic gradient may not be uniform throughout the boundary. Hence it is essential to divide the entire boundary into various sections where the hydraulic gradient is constant. For each section, the ground water flows can be estimated by multiplying Transmissivity of the aquifer, hydraulic gradient, length of the section and number of days inflow/ outflow occurs through the section during the season. Depending on the direction of flow, the flow should be given sign, positive sign for inflows and negative sign for outflows. The flow across the boundary for monsoon season and non-monsoon season are to be estimated separately.

10.4 FORMATS SUGGESTED FOR THE COMPUTATION

10.4.1 Command Area

Water Level during monsoon and non-monsoon seasons is computed for all the years and the average monsoon season water level and non-monsoon water level is calculated as the average of at least last five years data and is presented in Table 10.1. The computed average water levels during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 10.2. Using the water table data, water table contour maps are prepared in Map 10.1 and Map 10.2 for monsoon season and non-monsoon seasons respectively. From these maps hydraulic gradient is to be computed for entire area. But the spacing between the contours vary with space. Hence the entire boundary is divided into number of sections, such that each section will have equal spacing between contours and in turn same hydraulic gradient. Hydraulic gradients are calculated in Table 10.3 and Table 10.4 for monsoon season and non-monsoon season respectively. Once the hydraulic gradient is computed and length of the section is noted using darcy's law ground water flow across the boundary is computed in Table 10.5 and Table 10.6 for monsoon season and non-monsoon season respectively. Care must be taken to include the positive sign for inflows and negative sign for outflows. The resultant flow into or out of the sub unit is calculated as the algebraic sum of the flows of all sections on the boundary.

10.4.2 Non-Command Area

The computational scheme to be adopted for estimating the lateral flow across the boundary in the non-command area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 10.4.1 for the command area. The computations are presented in Tables 10.7 to 10.12 and the maps are presented in Maps 10.3 and 10.4.

10.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating the lateral flow across the boundary in the poor ground water quality area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 10.4.1 for the command area. The computations are presented in Tables 10.13 to 10.18 and the maps are presented in Maps 10.5 and 10.6.

10.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of lateral flows along the aquifer system.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Through Flow section ID	Text	20	
3	Average Hydraulic gradient Through seepage face During monsoon Season	Number	7	2
4	Average Hydraulic gradient Through seepage face During Non-Monsoon Season	Number	7	2
5	Transmissivity of the Aquifer	Number	8	2
6	Length of Seepage Section	Number	8	2
7	Through flow During Monsoon Season	Number	8	0
8	Through flow During Non-Monsoon Season	Number	8	0
9	Sub Unit Resultant Through flow During Monsoon Season	Number	8	0
10	Sub Unit Resultant Through flow During Non-Monsoon Season	Number	8	0

Table 10.1 Average Water Table Data of Each Well during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (For each of the wells in command area)	Year	water table head above mean sea level in meters			water table head above mean sea level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Head For each well							

Table 10.2 Water Table Data during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of observation well (for all wells in command area)	Longitude	Latitude	Ground Water head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 10.1: Water Table Contour During Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:
Principal Aquifer	:		Major Aquifer	:
Index Number of Ground Water Assessment Unit	:			

MAP 10.2: Water Table Contour During Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:	
Principal Aquifer	:		Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:				

Table 10.3 Hydraulic Gradient during Monsoon Season in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Ground Water Head Contour in meters above mean sea level During Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient	Nature of Boundary (Inflow/ Outflow)
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)		(5)/(6)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 10.4 Hydraulic Gradient during Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Ground Water Head Contour in meters above mean sea level During Non-Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient	Nature of the Boundary (Inflow/ Outflow)
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)		(5)/(6)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
1							
2							
3							

Table 10.5 Ground Water Flow Across the Boundary during Monsoon Season in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Inflow/ Outflow	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Water flows Across the boundary	Ground Water Flow Across the boundary through the section in Hectare meters. $\frac{(3)*(4)*(5)*(6)}{10000}$	
							Inflow (+)	Outflow (-)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
1								
2								
3								
4								
5								
Total Inflows and Outflows in hectare meters								
Ground Water Flow Across the boundary through all the sections during Monsoon season in hectare meters.								

Table 10.6 Ground Water Flow Across the Boundary during Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Inflow/ Outflow	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Water flows Across the boundary	Ground Water Flow Across the boundary through the section in Hectare meters. $\frac{(3)*(4)*(5)*(6)}{10000}$	
							Inflow (+)	Outflow (-)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
1								
2								
3								
4								
5								
Total Inflows and Outflows in hectare meters								
Ground Water Flow Across the boundary through all the sections during Non-Monsoon season in hectare meters.								

Table 10.7 Average Water Table Data of Each Well during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

<table>
<tr><td rowspan="3">S. No.</td><td rowspan="3">Name of observation well (For each of the wells in non-command area)</td><td rowspan="3">Year</td><td colspan="3">water table head above mean sea level in meters</td><td colspan="2">water table head above mean sea level in meters</td></tr>
<tr><td colspan="2">in ground water assessment year during</td><td>in ground water year immediately following the ground water assessment year during</td><td>During Monsoon Season</td><td>During Non-Monsoon Season</td></tr>
<tr><td>Pre - monsoon monitoring month</td><td>Post - monsoon monitoring month</td><td>Pre - monsoon monitoring month</td><td>$\frac{(4)+(5)}{2}$</td><td>$\frac{(5)+(6)}{2}$</td></tr>
<tr><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td><td>(6)</td><td>(7)</td><td>(8)</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Average Ground Water Head For each well</td><td></td><td></td></tr>
</table>

Table 10.8 Water Table Data during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of observation well (for all wells in non-command area)	Longitude	Latitude	Ground Water head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 10.3: Water Table Contour During Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:	
Principal Aquifer	:		Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:				

MAP 10.4: Water Table Contour During Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 10.9 Hydraulic Gradient during Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Ground Water Head Contour in meters above mean sea level During Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient	Nature of Boundary (Inflow/ Outflow)
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)		(5)/(6)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 10.10 Hydraulic Gradient during Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Ground Water Head Contour in meters above mean sea level During Non-Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient (5)/(6)	Nature of the Boundary (Inflow/ Outflow)
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 10.11 Ground Water Flow Across the Boundary during Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Inflow/ Outflow	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Water flows Across the boundary	Ground Water Flow Across the boundary through the section in Hectare meters. $\frac{(3)*(4)*(5)*(6)}{10000}$	
							Inflow (+)	Outflow (-)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
1								
2								
3								
4								
5								
Total Inflows and Outflows in hectare meters								
Ground Water Flow Across the boundary through all the sections during Monsoon season in hectare meters.								

Table 10.12 Ground Water Flow Across the Boundary during Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Inflow/ Outflow	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Water flows Across the boundary	Ground Water Flow Across the boundary through the section in Hectare meters. $\frac{(3)*(4)*(5)*(6)}{10000}$	
							Inflow (+)	Outflow (-)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
1								
2								
3								
4								
5								
Total Inflows and Outflows in hectare meters								
Ground Water Flow across the boundary through all the sections during Non-Monsoon season in hectare meters.								

Table 10.13 Average Water Table Data of Each Well during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (For each of the wells in poor ground water quality area)	Year	water table head above mean sea level in meters			water table head above mean sea level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Head For each well							

Table 10.14 Water Table Data during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of observation well (for all wells are in poor ground water quality area)	Longitude	Latitude	Ground Water head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 10.5: Water Table Contour During Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 10.6: Water Table Contour During Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 10.15 Hydraulic Gradient during Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Ground Water Head Contour in meters above mean sea level During Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient	Nature of Boundary (Inflow/ Outflow)
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)		(5)/(6)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

Table 10.16 Hydraulic Gradient during Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Ground Water Head Contour in meters above mean sea level During Non-Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient	Nature of the Boundary (Inflow/ Outflow)
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)		(5)/(6)	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	
1							
2							
3							

Table 10.17 Ground Water Flow Across the Boundary during Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Inflow/ Outflow	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Water flows Across the boundary	Ground Water Flow Across the boundary through the section in Hectare meters. $\frac{(3)*(4)*(5)*(6)}{10000}$	
							Inflow (+)	Outflow (-)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
1								
2								
3								
4								
5								
Total Inflows and Outflows in hectare meters								
Ground Water Flow Across the boundary through all the sections during Monsoon season in hectare meters.								

Table 10.18 Ground Water Flow Across the Boundary during Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Inflow/ Outflow	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Water flows Across the boundary	Ground Water Flow Across the boundary through the section in Hectare meters. $\frac{(3)*(4)*(5)*(6)}{10000}$	
							Inflow (+)	Outflow (-)
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)
1								
2								
3								
4								
5								
Total Inflows and Outflows in hectare meters								
Ground Water Flow Across the boundary through all the sections during Non-Monsoon season in hectare meters.								

11

BASE FLOW

11.1 GENERAL

Even when the aquifers are under developed, the water levels will not rise to ground level. The reason for this is base flow. If the ground water head is above the stage in the local stream, the ground water flows from the aquifer to the stream, this is known as base flow. The preferred method for this estimation is base flow separation using the stream hydrograph. There are many methods and softwares for estimating the base flow. In the absence of any software and the required competency, the following procedure of hydrograph separation with straight line method can be used. If continuous stream gauge data is not available, then one can use the method described in the Chapter 12 i.e stream recharge for estimating the base flow also.

For assessing the base flow, there should be stream discharge data for at least five years. If the stream gauge is not at the mouth of the assessment unit, there should be two stream gauges one in the upstream direction and the other one is at the downstream side. The base flow generated in the assessment sub unit will be the difference of base flow computed at upstream and downstream stream gauges. If required, it should be apportioned as per the catchment area. As in the case of other components which are normalized, this component is also to be estimated for an average situation. Hence there is a requirement of minimum 5 sets of daily discharge data of either one stream gauge, if the gauging is done at the mouth of the hydrological assessment unit. In case of other areas there is a need of at least two stream gauge stations. The base flow is estimated for the entire assessment unit and apportioned for the sub units depending on the areas if the assessment is hydrological unit. If assessment unit is administrative unit, then the base flow estimation is to be estimated for a hydrological unit and apportion the base flow for the respective sub units depending on the area of the sub units.

The computations of base flow in the assessment sub units during a given season involves the following steps to be carried out :

a) Selection of area for the estimation of base flow. If the assessment unit is a hydrological unit, the same can be selected for the estimation of base flow for all the sub units. If the assessment unit is as administrative unit the hydrological unit covering entire assessment unit should be selected.
b) If the stream gauge is at the mouth of the hydrological unit, the entire base flow generated by the stream can be estimated with only one stream gauge. If the stream gauge is not at the mouth, then there is a need of at least two stream gauge stations to estimate the base flow generated by the area.

c) Computing average daily stream discharge by taking the average of stream discharge of at least five years.
d) Estimation of base flow during monsoon and non-monsoon seasons separately.
e) Apportioning the base flow for each of the sub units.

11.2 ASSUMPTIONS

The estimation of base flow is based on the following assumptions :

a) The average stream discharge of the stream gauge is computed for estimating the average situation.
b) During monsoon season, number of direct runoff spells are to be identified.
c) For each of the direct runoff spells starting point discharge and the ending point stream discharge are noted to estimate the lower bound of the direct run off .
d) The lower bound of the direct runoff is estimated as a linear function between starting point discharge and end point discharge.
e) The stream discharge up to the lower bound of the direct runoff is the base flow.
f) This can be converted to hectare meters per day.
g) If the gauge is at the mouth of the hydrological unit, then the sum of the daily base flow will be the total base flow generated from this unit.
h) If it is not at the mouth, the difference between the discharges at the upstream gauge and the downstream gauge is the base flow generated in the area covered by these stream gauges. This should be apportioned for the area under consideration.
i) The base flow generated in the non-monsoon will be the total discharge in the stream as there will not be any direct runoff.

11.3 COMPUTATIONAL PROCEDURE

It is advisable to have a closed hydrological boundaries as assessment units. But this is not always possible. Hence the following procedure is suggested to carry out the computations. It is necessary to have this estimation for entire assessment unit and apportion between various sub units. Wherever the assessment unit is a closed watershed and all the rainfall occurring in the area forms a stream and we have a gauging station at the mouth of the watershed, the base flow separation algorithm should be applied to the gauge on the mouth and whatever base flow generated is apportioned between various sub units. .

Sometimes, the assessment unit may not be a closed watershed and may contribute to the stream which may be computed as the difference in the base flow generated at the stream gauge at the upstream side and the stream gauge at the downstream. But this also may not be strictly from the assessment unit and may be somewhat from a larger area of catchment. Hence, it is recommended to demarcate a larger catchment area of the stream from which it is getting the base flow and the base flow is then apportioned between various sub units.

Sometimes the stream gauges may be less in number and may not be possible to estimate the base flow for any single assessment unit. In such a case it may be attempted to estimate the base flow for a group of assessment units and apportion the same. The disposition of the assessment units and stream gauges is presented in Map 11.1.

For deciding on the availability of stream gauge stations and deciding on the feasibility of accurate estimation, field ground water scientist is the better person. Hence if felt it is not feasible, it should be planned to establish more number of stream gauges before estimating the base flow..

11.3.1 Average Stream Discharge

For knowing the most probable base flow from the assessment unit the average daily stream discharges of the stream during the monsoon and non-monsoon seasons are needed. The average stream discharge of a day may be computed as the average of stream discharge observed on the same day of at least last five years. The average daily stream discharges may be estimated for the entire year.

11.3.2 Direct Runoff Spells

The stream discharge against time is plotted on arithmetic graph to know various direct run off spells. Even though there are many more methods to compute base flow, it is recommended to use the straight line method as it is the simplest method. For this purpose to implement, the starting discharge and end time discharge of each of the direct runoff spells is required to be known. These two points are joined by a straight line and the bottom of this line nothing but base flow. The upstream hydrograph is presented as Map 11.2 where as down stream hydrograph is presented as Map 11.3.

11.3.3 Base Flow Generated by the Area Under Study

If there are two stream gauge stations one at the upstream side of the area and the other at the downstream side of the area, the base flow should be computed for both the stations and the difference between these two would be the base flow generated by the area of the catchment of the stream between these two points. To know the base flow generated by a sub unit is calculated by apportioning this base flow for the area of the sub unit.

11.4 FORMATS SUGGESTED FOR THE COMPUTATION

11.4.1 Monsoon Season

There are three possibilities already discussed that there may be a suitable stream gauge at the mouth of a closed watershed. In this case only one stream gauge data is analysed using the formats suggested for downstream stream gauge. .But in cases where the stream is not completely covering the watershed. In such cases two stream gauges one at the upstream and the other at downstream side has to be analysed and the difference between the baseflow will be the baseflow generated by the watershed. The third situation is similar to the earlier case but the assessment unit may not be covering entire catchment between the stream gauges. Hence the baseflow generated is to be apportioned for the sub units.

The base flow estimation from the stream gauges also to be estimated for the average situation of at least five years. The average stream discharge is computed by taking average of previous five years data of the same day. This computation is done in Table 11.1. The direct runoff spells and their starting stream discharge and end discharge and no of days of the spell and the slope of the discharge of the spell in the area during monsoon season is Tabulated in Table 11.2. The base flow is computed using the straight line method is in Table 11.3. Similarly the base flow is computed in the downstream stream gauge and is presented in Tables 11.4 to11.6. The apportioning of the computed base flow to various sub units viz. command are, non-command area and poor ground water quality area is presented in Table 11.11.

11.4.2 Non-Monsoon Season

The computational scheme to be adopted for estimating the base flow in the non-monsoon season is identical to what has been described earlier in Section 11.4.1 for the monsoon season . The only difference is that most of the time the entire stream run off is nothing but base flow, but where ever the rainfall spells occur in the area the procedure will be same. Where ever there is direct run off spell, the procedure is same as that of monsoon season. As already average discharges are computed even for non monsoon season, baseflows can be estimated in Tables 11.7 to 11.10.The apportioning of the computed base flow to various sub units viz. command area, non-command area and poor ground water quality area is presented in Table 11.11.

11.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of base flow.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	River Segment ID	Text	20	
3	Stream Flow	Number	8	2
4	Base Flow	Number	8	2
5	Total Base flow During Monsoon Season	Number	9	2
6	Total Base flow During Monsoon Season	Number	9	2
7	Sub Unit Base flow During Monsoon Season	Number	9	2
8	Sub Unit Base flow During Non-Monsoon Season	Number	9	2
9	Direct Runoff Spell No.	Number	2	
10	Start Day	Number	3	
11	End Day	Number	3	
12	No of Days	Number	2	
13	Discharge at Beginning	Number	8	2
14	Discharge at End	Number	8	2
15	Discharge Difference	Number	8	2
16	Slope of baseflow line	Number	8	2

MAP 11.1: Disposition of Stream Gauges in the Assessment Units

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 11.1 Average Stream Discharge at the Stream Gauge Located at the Upstream Side Location in the Area of Interest During Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Day	Daily Stream Discharge in cumecs					
		Assessment year -4	Assessment year -3	Assessment year -2	Assessment year -1	Assessment year	Average $\frac{(3)+(4)+(5)+(6)+(7)}{5}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

MAP 11.2: Stream Hydrograph of the Upstream side Stream Gauge

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 11.2 Direct Runoff Spells Recorded at the Stream Gauge Located at the Upstream Side Location in the Area of Interest During Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Spell No.	Start Day	End Day	No of Days (4)-(3)	Discharge at Start day in cumecs	Discharge at End day in cumecs	Discharge Difference in cumecs (7)-(6)	Slope of the Discharge Straight Line in cumecs/day (8)/(5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								

Table 11.3 Base Flow Estimation at the Stream Gauge Located at the Upstream Side Location in the Area of Interest During Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Day	Stream Discharge in cumecs	Direct Runoff Spell No.	Discharge at Start day in the spell in cumecs	Day No in the Spell	Slope of Discharge Straight line of the Spell in cumecs/day	Base Flow in cumecs	Base Flow in ham (8)*60*60*24/10^4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Total Base Flow Contributed at the stream gauge located at Upstream side Location During Monsoon Season in ham								

Column(4) is zero if it is not part of any Direct Runoff Spell.
Column (6): Day in the spell starts with 0
Column (8) same as Column(3) if Spell Number 0
Else (5)+((6)*(7))

Table 11.4 Average Stream Discharge at the Stream Gauge Located at the Downstream Side Location in the Area of Interest During Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Day	Daily Stream Discharge in cumecs					
		Assessment year -4	Assessment year -3	Assessment year -2	Assessment year -1	Assessment year	Average $\frac{(3)+(4)+(5)+(6)+(7)}{5}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							

MAP 11.3: Stream Hydrograph of the Downstream side Stream Gauge

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 11.5 Direct Runoff Spells Recorded at the Stream Gauge Located at the Downstream Side Location in the Area of Interest During Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Spell No.	Start Day	End Day	No of Days (4)-(3)	Discharge at Start day in cumecs	Discharge at End day in cumecs	Discharge Difference in cumecs (7)-(6)	Slope of the Discharge Straight Line in cumecs/day (8)/(5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								

Table 11.6 Base Flow Estimation at the Stream Gauge Located at the Downstream Side Location in the Area of Interest During Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Day	Stream Discharge in cumecs	Direct Runoff Spell No.	Discharge at Start day in the spell in cumecs	Day No in the Spell	Slope of Discharge Straight line of the Spell in cumecs/day	Base Flow in cumecs	Base Flow in ham (8)*60*60*24/10^4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Total Base Flow Contributed at the stream gauge located at Downstream side Location During Monsoon Season in ham								

Column(4) is zero if it is not part of any Direct Runoff Spell.
Column (6): Day in the spell starts with 0
Column (8) same as Column(3) if Spell Number 0
Else (5)+((6)*(7))

Table 11.7 Direct Runoff Spells Recorded at the Stream Gauge Located at the Upstream Side Location in the Area of Interest During Non-Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Spell No.	Start Day	End Day	No of Days (4)-(3)	Discharge at Start day in cumecs	Discharge at End day in cumecs	Discharge Difference in cumecs (7)-(6)	Slope of the Discharge Straight Line in cumecs/day (8)/(5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								

Table 11.8 Base Flow Estimation at the Stream Gauge Located at the Upstream Side Location in the Area of Interest During Non-Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Day	Stream Discharge in cumecs	Direct Runoff Spell No.	Discharge at Start day in the spell in cumecs	Day No in the Spell	Slope of Discharge Straight line of the Spell in cumecs/day	Base Flow in cumecs	Base Flow in ham (8)*60*60*24/10^4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Total Base Flow Contributed at the stream gauge located at Upstream side Location During Non-Monsoon Season in ham								

Column(4) is zero if it is not part of any Direct Runoff Spell.
Column (6): Day in the spell starts with 0
Column (8) same as Column(3) if Spell Number 0
Else (5)+((6)*(7))

Table 11.9 Direct Runoff Spells Recorded at the Stream Gauge Located at the Downstream Side Location in the Area of Interest During Non-Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Spell No.	Start Day	End Day	No of Days (4)-(3)	Discharge at Start day in cumecs	Discharge at End day in cumecs	Discharge Difference in cumecs (7)-(6)	Slope of the Discharge Straight Line in cumecs/day (8)/(5)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								

Table 11.10 Base Flow Estimation at the Stream Gauge Located at the Downstream Side Location in the Area of Interest During Non-Monsoon Season

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Day	Stream Discharge in cumecs	Direct Runoff Spell No.	Discharge at Start day in the spell in cumecs	Day No in the Spell	Slope of Discharge Straight line of the Spell in cumecs/day	Base Flow in cumecs	Base Flow in ham (8)*60*60*24/10^4
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Total Base Flow Contributed at the stream gauge located at Downstream side Location During Monsoon Season in ham								

Column(4) is zero if it is not part of any Direct Runoff Spell.
Column (6): Day in the spell starts with 0
Column (8) same as Column(3) if Spell Number 0
Else (5)+((6)*(7))

Table 11.11 Estimation of Base Flow in the Various sub units of the Assessment Units

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description	Parameters		
1	Area of the Catchment used for Base flow Estimation			
2	Area of this Catchment Falling in Command Sub Unit			
3	Area of the Catchment in Non-Command Sub Unit			
4	Area of the Catchment in Poor Ground Water Quality Sub Unit			
		Monsoon Season	Non-monsoon Season	Annual
5	Baseflow estimated at Upstream Stream Gauge [From Table 11.3, 11.8]			
6	Baseflow created at Downstream Stream Gauge [From Table 11.6, 11.10]			
7	Estimated Base flow from the entire catchment (6)-(5) i. Estimated Base Flow in the Command Area [(5)*(2)/(1)] ii. Estimated Base Flow in the Non-Command Area [(5)*(3)/(1)] iii. Estimated Base Flow in the Poor Ground Water Quality Area [(5)*(4)/(1)]			
Base Flow in the Assessment Unit [(8(i))+(8)(ii)+(8)(iii)]				

12

STREAM RECHARGE

12.1 GENERAL

When there is a difference between the stream stage and ground water head exists, there will be flow of water between these. If the aquifer contributes to stream it is called base flow and the contribution from stream to aquifer is called stream recharge. Base flow may be estimated using the base flow separation from stream hydrograph method as discussed in the Chapter 11. This method gives more accurate result and at the same time this will have coherence with what was computed by surface water people. In case the data of the stream discharges are not available sufficiently, then this method can be applied even for estimating base flow.

For assessing the stream recharge , there should be well distributed network of ground water level observation wells and sufficient data of the stream stage. If stream is dry then the elevation of the stream bed should be available at sufficient number of places. The stream stage is required at least at the peak direct runoff level and minimum level, so that the average monsoon season stage of the stream can be estimated.

As other components are normalized in one or other methods, this component also to be estimated for an average situation. Hence there is a requirement of minimum 5 sets of data during pre-monsoon and post-monsoon seasons for all the observation wells. Similarly, the stream stage data also is required for five years..

The computations of stream recharge in the assessment sub unit during a given season involves the following steps :

a) Computing average ground water head for both the seasons by taking the ground water head data of at least five years data.
b) Computing the Average Groundwater heads during monsoon season and non-monsoon season separately.
c) Average Stream Stage for the monsoon & non-monsoon seasons taking average of maximum and minimum of the seasons respectively.
d) Preparation of head contour with suitable contour intervals taking into consideration ground water heads for both the seasons taking into account the stream stage points as observation wells.
e) Incorporating stream stage data in preparing the map it will give more accurate estimation of flow. If river stage is not available, the estimation of flow can be estimated using only ground water heads.
f) Computation of Hydraulic gradient at required number of places for both the seasons on the stream line.

g) Depending on the variation in hydraulic gradients along the stream line, demarcation of sections on the river line for both the seasons may be made.
h) Computation of Flow of water through the stream line for each of the section for both the seasons.
i) Consider only those segments where the flow direction is from stream to aquifer.
j) Summation of the stream recharge from all the sections indicate the stream recharges to the aquifer system for both the seasons.
k) The base flow is to be estimated using hydrograph separation method. If it is not possible, this method may be used for estimating the base flow component by considering the segments where the flow direction is towards streams.

12.2 ASSUMPTIONS

The computations of the stream recharge are based on the following assumptions :

a) The average ground water head of pre monsoon season and the post monsoon season of the assessment year is considered as the ground water head during monsoon season. Similarly, the average ground water head of the post monsoon season of the current assessment year and ground water head of the pre monsoon season of the next assessment year is considered as the ground water head during non-monsoon season.
b) The average of the maximum and minimum of stream stage during monsoon season is considered as the stream discharge during monsoon season. And similarly the average between the maximum and minimum stage during non-monsoon season is considered as stream stage during non-monsoon season.
c) If stream is dry stream, the elevation of the stream bed should be considered as the stream stage.
d) These points of stream stage are considered as ground water head points for the preparation of contour maps.
e) The ground water flow from the stream can be obtained as the product of following:
    i) Transmissivity of the aquifer
    ii) Length of section
    iii) Hydraulic gradient across the section.
    iv) Number of days stream recharge takes place during the season.
f) The Stream Recharge into the assessment sub unit is obtained as the algebraic sum of the stream recharge from all the sections.
g) The stream recharge should be computed for both the seasons.

12.3 COMPUTATIONAL PROCEDURE

As per the existing density of network stations and the stream stage data, it may be difficult to compute the hydraulic gradient for each assessment sub unit separately. Depending on the availability of network stations and the stream stage data, the estimation of hydraulic gradient may be done for each assessment sub unit, assessment unit or to a group of assessment units. The computations of stream recharge in the assessment sub unit during a given season involves the following steps to be carried out:

12.3.1 Average Ground Water Head

For knowing the stream recharge in the assessment sub unit the average ground water heads for both the monsoon and non-monsoon seasons are needed. For computing the average ground water head in any season may be computed as the average of ground water head observed by taking the ground water head data of at least five years. The average groundwater heads during monsoon season and non-monsoon season are to be estimated separately.

12.3.2 Average Stream Stage

For knowing the stream recharge in the assessment sub unit the average stream stage for both the monsoon and non-monsoon seasons are needed. The average stream stage in any season may be computed as the average of maximum and minimum stream stage which are in turn average of at least five years data. The average stream stage during monsoon season and non-monsoon season are to be estimated separately. If stream stage data is not available, it can be attempted with only ground water heads, which may reduce the accuracy of the estimate.

12.3.3 Average Hydraulic Gradient

Hydraulic gradient is the ratio between change in head and the distance between the observation. For computing average hydraulic gradient, water table contour map with suitable contour interval is to be prepared. For preparing this map, stream elevations may be considered as water table data points. The hydraulic gradient at required number of places can be computed by calculating the head difference between contours along the flow direction and computing the distance between both the up and down contours. The average hydraulic gradient for monsoon season and non-monsoon seasons are to be estimated separately.

12.3.4 Stream Recharge

The Hydraulic gradient may not be uniform throughout the stream line. Hence it is essential to divide the entire stream line into various sections where the hydraulic gradient is constant. For each section, the ground water flows can be estimated by multiplying Transmissivity of the aquifer, hydraulic gradient and length of the section. Depending on the direction of flow, the flow should be given sign, positive sign for stream recharge and negative sign for base flows. The stream recharge for monsoon season and non-monsoon season are to be estimated separately. In this exercise, only stream recharge need to be computed.

12.4 FORMATS SUGGESTED FOR THE COMPUTATION

12.4.1 Monsoon Season and Non-Monsoon Seasons

Similar to the estimation of base flow, in the estimation of stream recharge also there are three possibilities. Depending on the availability of ground water monitoring stations and the alignment of the stream, the hydraulic gradient can be estimated directly for all sub units or for the entire assessment unit or for a group of assessment units. If it is estimated for the total assessment units or group of assessment units it should be summarised based on the assessment sub unit to which the recharge is taking place.

Water Level during monsoon and non-monsoon seasons is computed for all the years and the average monsoon season water level and non-monsoon water level is calculated as the average of at least last five years data and is presented in Table 12.1. The computed average water levels during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 12.2. The stream stage readings during monsoon and non-monsoon seasons is computed for all the years as the average of stream stage at the beginning and at the end of the season.The average monsoon season stream stage and non-monsoon stream stage is calculated as the average of at least last five years data and is presented in Table 12.3. The computed average stream stage during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 12.4.

Using both the water table data and the stream stage data head contour maps are prepared in Map 12.1 and Map 12.2 for monsoon season and non-monsoon seasons respectively. From these maps hydraulic gradient is to be computed for entire stream length. But the spacing between the contours vary with space. Hence the entire stream line is divided into number of sections, such that each section will have equal spacing and in turn same hydraulic gradient. Hydraulic gradients are calculated in Table 12.5 and Table 12.6 for monsoon season and non-monsoon season respectively.

Once the hydraulic gradient is computed and length of the section is noted using darcy's law stream recharge into the Aquifer during monsoon season is computed in Table 12.7 for command area and Table 12.8 for non-command area and 12.9 for poor ground water quality area. The Stream recharge during non-monsoon season is computed in Tables 12.10, 12.11,12.12 respectively for the command area, non-command area and poor ground water quality. Care must be taken to consider only the sections where the flow is from stream into aquifer.

12.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of stream recharge.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Flow section ID	Text	20	
3	Average Head in the Aquifer During monsoon Season	Number	7	2
4	Average Head in the Aquifer During Non-Monsoon Season	Number	7	2
5	Average Stage in the Stream During Monsoon Season	Number	7	2
6	Average Stage in the Stream During Non-Monsoon Season	Number	7	2
7	Transmissivity of the Aquifer	Number	8	2
8	Length of Recharge Section During Monsoon Season	Number	8	2
9	Length of Recharge Section During Non-Monsoon Season	Number	8	2
10	Recharge Due to Streams During Monsoon Season	Number	8	0

S.No	Parameter	Type	Size	Decimals
11	Recharge Due to Streams During Non-Monsoon Season	Number	8	0
12	Sub Unit Stream Recharge Due to Streams During Monsoon Season	Number	8	0
13	Sub Unit Stream Recharge Due to Streams During Non-Monsoon Season	Number	8	0

Table 12.1 Average Water Table Data of Each Well during Monsoon and Non-monsoon Seasons in the Area of Interest Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of observation well (For each of the wells are in the area of interest)	Year	water table head above mean sea level in meters			water table head above mean sea level in meters	
			in the current year during		in the immediate next year to the current year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Head For each well							

Table 12.2 Water Table Data During Monsoon and Non-monsoon Seasons in the Area of Interest

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of observation well (for all wells in the area of interest)	Longitude	Latitude	Ground Water head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

Table 12.3 Average Stream Stage Data at various of Various Stream Locations during Monsoon and Non-monsoon Seasons in the Area of Interest Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of Stream Gauge Point (For each of the Stream Gauge Points in the area of interest)	Year	Stream Stage above mean sea level in meters				Stream stage above mean sea level in meters	
			During Monsoon Season		During Non-Monsoon Season		During Monsoon Season	During Non-Monsoon Season
			At the beginning	At the Ebd	At the beginning	At the Ebd	$\frac{(4)+(5)}{2}$	$\frac{(6)+(7)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Average Stream Stage For each stream gauge point								

Table 12.4 Stream Stage Data During Monsoon and Non-monsoon Seasons in the Area of Interest

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the stream gauge point (for all stream gauge points in the area of interest)	Longitude	Latitude	Stream Stage in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 12.1: Head Contour During Monsoon Season in the Area of Interest

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 12.2: Head Contour During Non-Monsoon Season in the Area of Interest

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 12.5 Hydraulic Gradient during Monsoon Season in the Area of Interest

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Head Contour in meters above mean sea level During Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)		(5)/(6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 12.6 Hydraulic Gradient during Non-Monsoon Season in the Area of Interest

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No.	Head Contour in meters above mean sea level During Non-Monsoon Season			Distance between the two contours on ground in meters	Hydraulic Gradient
		Up Contour (m)	Down Contour (m)	Difference (m) (3)-(4)		(5)/(6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 12.7 Stream Recharge during Monsoon Season in the Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No. (for only those sections where flow is into the aquifer)	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Flow occurs into the Aquifer During Monsoon Season	Stream Recharge to the Aquifer through the section in ham. $\frac{(3)*(4)*(5)*(6)}{10000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Stream Recharge into the Aquifer through all the sections during Monsoon season in ham.						

Table 12.8 Stream Recharge during Non-Monsoon Season in the Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No. (for only those sections where flow is into the aquifer)	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Flow occurs into the Aquifer During Non-Monsoon Season	Stream Recharge to the Aquifer through the section in ham. $\frac{(3)*(4)*(5)*(6)}{10000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Stream Recharge into the Aquifer through all the sections during Non-Monsoon season in ham.						

Table 12.9 Stream Recharge during Monsoon Season in the Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No. (for only those sections where flow is into the aquifer)	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Flow occurs into the Aquifer During Monsoon Season	Stream Recharge to the Aquifer through the section in ham. $\frac{(3)*(4)*(5)*(6)}{10000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Stream Recharge into the Aquifer through all the sections during Monsoon season in ham.						

Table 12.10 Stream Recharge during Non-Monsoon Season in the Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No. (for only those sections where flow is into the aquifer)	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Flow occurs into the Aquifer During Non-Monsoon Season	Stream Recharge to the Aquifer through the section in ham. $\frac{(3)*(4)*(5)*(6)}{10000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Stream Recharge into the Aquifer through all the sections during Non-Monsoon season in ham.						

Table 12.11 Stream Recharge during Monsoon Season in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No. (for only those sections where flow is into the aquifer)	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Flow occurs into the Aquifer During Monsoon Season	Stream Recharge to the Aquifer through the section in ham. $\frac{(3)*(4)*(5)*(6)}{10000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Stream Recharge into the Aquifer through all the sections during Monsoon season in ham.						

Table 12.12 Stream Recharge during Non-Monsoon Season in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Section No. (for only those sections where flow is into the aquifer)	Hydraulic Gradient	Length of the Section in meters	Transmissivity of the unconfined aquifer in the section in square meters per day.	No of days Flow occurs into the Aquifer During Non-Monsoon Season	Stream Recharge to the Aquifer through the section in ham. $\frac{(3)*(4)*(5)*(6)}{10000}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Stream Recharge into the Aquifer through all the sections during Non-Monsoon season in ham.						

13

VERTICAL INTER AQUIFER FLOW

13.1 GENERAL

In areas where more than one aquifer is present, there is a possibility of ground water flow between the aquifers. This is possible only when the unconfined aquifer is underline by a semi confined aquifer. In GEC 1997 methodology, it was advised to carry out the ground water resources mainly for the unconfined aquifer and where ever feasible to assess the resources of confined and/or semi confined aquifer by applying flow concept. But the vertical inter aquifer flow was ignored. In GEC 2015 methodology it was suggested to use volume concept to estimate the ground water resources even in semi-confined and confined aquifers. This also mentions that where ever possible, to estimate the vertical inter aquifer flow.

For assessing the vertical inter aquifer flow, there should be well distributed network of ground water head observation wells in both the aquifers. As other components are normalized in one or other methods, this component also to be estimated for an average situation. Hence there is a requirement of minimum 5 sets of data during pre-monsoon and post-monsoon seasons for all the observation wells in both the aquifers. Except in small areas where proper demarcation of aquifers is done, the piezometric network is not available even today. Hence it is advised that aquifer wise network of monitoring stations should be established and monitored for assessing the inter aquifer flow.

The computations of vertical inter aquifer flow during a given season involves the following steps to be carried out :

a) Computing average ground water head of the unconfined aquifer and semi-confined aquifer for both the seasons by taking the ground water head data of at least five years.
b) Computing ground water head of the unconfined aquifer during monsoon and non-monsoon seasons.
c) Computing piezometric head the semi-confined aquifer during monsoon and non-monsoon seasons.
d) Preparation of Ground water Table contours of unconfined aquifer with suitable contour interval for both the seasons.
e) Preparation of piezometric contours of semi-confined aquifer with suitable contour interval for both the seasons.
f) Preparation of head difference map for both the seasons. This can be done by GIS packages or taking the approximate head difference manually and preparing the contour maps manually

g) Computation of Flow through aquitard for each of the sub area for both the seasons.
h) Summation of the flow through aquitard for each of the subarea is the resultant vertical inter aquifer flow into the unconfined aquifer for both the seasons.

13.2 ASSUMPTIONS

The computations of vertical inter aquifer flow through the aquitard are based on the following assumptions :

a) The average ground water head of pre monsoon season and the post monsoon season of the assessment year is considered as the ground water head during monsoon season. Similarly, the average ground water head of the post monsoon season of the current assessment year and ground water head of the pre monsoon season of the next assessment year is considered as the ground water head during non-monsoon season.
b) Similarly the piezometric head during monsoon season and non-monsoon seasons are computed.
c) The difference between piezometric head of the semi confined aquifer and the ground water head in the unconfined aquifer at any place is the change in head. If observation wells monitoring both the aquifers are at one place, the computation will be easy In other cases, it can be attempted by taking approximate values manually Otherwise using GIS techniques a map calculation can be applied to generate the map of head difference. Based on the contour values different sub areas are to be demarcated. The ground water flow through the aquitard can be estimated using the following formula.

$$Vertival\ Inter\ Aquifer\ Flow = \frac{Area \times head\ difference \times Hydraulic\ Conductivity\ of\ Aquitrd}{Thickness\ of\ Aquitard}$$

d) Multiplying this with the number of days water flow occurs between these aquifers in a season will give the flow in a particular season.
e) The Vertical Inter Aquifer Flow from the assessment sub unit is obtained as the algebraic sum of the vertical inter aquifer flow of all the sub areas.
f) The vertical inter aquifer flow through the aquitard should be computed for both the seasons.

13.3 COMPUTATIONAL PROCEDURE

For assessing the vertical inter aquifer flow, there should be well distributed network of ground water head observation wells in both the aquifers. If the network is insufficient, it is advised that aquifer wise network of monitoring stations should be established and monitored for assessing the inter aquifer flow. The computations of inter aquifer flow to or from the aquifer in the assessment sub unit during a given season involves the following steps to be carried out :

13.3.1 Average Ground Water Heads in Unconfined and Semi Confined Aquifers

For knowing the most probable inter aquifer flow from/into assessment sub unit the average ground water heads in unconfined aquifer and piezometric heads in semi confined aquifer for both the monsoon and non-monsoon seasons are needed. The average ground water head or piezometric head in any season may be computed as the average of ground water head or piezometric head respectively of at least five years. The average groundwater heads and piezometric heads during monsoon season and non-monsoon season are to be estimated separately.

13.3.2 Average Head Difference

To prepare Average head difference map it is required to have ground water heads in both the aquifers at the same location. But normally it is not possible to get like that. If they are available, the head difference contour map may be prepared easily and can be used in the computation. In the absence of such data, GIS map calculation techniques can be used to prepare a difference map between the ground water head maps of semi-confined aquifer and unconfined aquifer. From the head difference map, various sub areas are demarcated and for each sub area average head difference is marked. This is the average of up contour and down contour values.

13.3.3 Vertical Inter Aquifer Flow

For each of the sub area, the hydraulic conductivity of the aquitard, area of the sub area and average head difference are multiplied and divided by the thickness of the aquitard to obtain the inter aquifer flow for each of the sub area. It will give the flow per day and when multiplied with number of days water flow occurs between these aquifers in a season it will give the ground water flow across the aquifers in the particular season. The total of the inter aquifer flow for all sub areas is the total inter aquifer flow into the sub unit.

13.4 FORMATS SUGGESTED FOR THE COMPUTATION

13.4.1 Command Area

Water Table data of the unconfined aquifer during monsoon and non-monsoon seasons is computed for all the years and the average monsoon season water table and non-monsoon water table is calculated as the average of at least last five years data and is presented in Table 13.1. The computed average water tables during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 13.2. Using the water table data, water table contour maps are prepared in Map 13.1 and Map 13.2 for monsoon season and non-monsoon seasons respectively. Similarly, the average monsoon season piezometric head of the semi confined aquifer and non-monsoon piezometric head of the semi-confined aquifer is calculated as the average of at least last five years data and is presented in Table 13.3. The computed average piezometric head during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 13.4. Using the piezometric data, piezometric head contour maps are prepared in Map 13.3 and

Map 13.4 for monsoon season and non-monsoon seasons respectively. Using any of the methods mentioned above, ground water head difference maps are prepared in Map 13.5 and Map 13.6.

Once the head difference maps are prepared, for each sub area, the inter aquifer flow can be estimated in Table 13.5 and Table 13.6 using the area, thickness of aquitard, hydraulic conductivity of the aquitard, average head difference and number of days water flow occurs between these aquifers in a season for monsoon season and non-monsoon season respectively. The head difference in the difference is between piezometric head in the semi confined aquifer and ground water head in unconfined aquifer. Then the positive values indicate the flow is into the unconfined aquifer and negative values indicate that the flow is out of unconfined aquifer.

13.4.2 Non-Command Area

The computational scheme to be adopted for estimating the inter aquifer flow through the aquitard in the non-command area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 13.4.1 for the command area. The computations are presented in Tables 13.7 to 13.12 and the maps are presented in Maps 13.7 and 13.12.

13.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating the inter aquifer flow through the aquitard in the poor ground water quality area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 13.4.1 for the command area. The computations are presented in Tables 13.13 to 13.18 and the maps are presented in Maps 13.13 and 13.18.

13.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Vertical inter aquifer flow.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Leakage subarea ID	Text	20	
3	Average Head in the Aquifer During monsoon Season	Number	7	2
4	Average Head in the Aquifer During Non-Monsoon Season	Number	7	2
5	Average Head in the Top/Bottom Aquifer During Monsoon Season	Number	7	2
6	Average Head in the Top/Bottom Aquifer During Non-Monsoon Season	Number	7	2
7	Hydraulic Conductivity of the Aquitard	Number	8	2
8	Thickness of the Aquitard	Number	8	2
9	Seepage Effected Area	Number	7	0
10	Vertical flow During Monsoon Season	Number	8	0
11	Vertical flow During Non-Monsoon Season	Number	8	0
12	Sub Unit Resultant Vertical flow During Monsoon Season	Number	8	0
13	Sub Unit Resultant Vertical flow During Non-Monsoon Season	Number	8	0
14	No of days Monsoon	Number	3	0
15	No of days Non Monsoon	Number	3	0

Table 13.1 Average Water Table Data of Each Well during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Name of the observation well (For each of the wells in command area)	Year	Water table head above mean sea level in meters			Water table head above mean sea level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Head For each well							

Table 13.2 Water Table Data during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all wells in command area)	Longitude	Latitude	Ground Water head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 13.1: Water Table Contour During Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:
Principal Aquifer	:		Major Aquifer	:
Index Number of Ground Water Assessment Unit	:			

MAP 13.2: Water Table Contour During Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 13.3 Average Piezometric Head of Each Piezometer during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Name of the Piezometer (For each of the Piezometers in command area)	Year	Piezometric head above mean sea level in meters			Piezometric head above mean sea level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Piezometric Head For each Piezometer							

Table 13.4 Piezometric Head during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the Piezometer (for all piezometers in command area)	Longitude	Latitude	Piezometric head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 13.3: Piezometric Head Contour During Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:	
Principal Aquifer	:		Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:				

MAP 13.4: Piezomteric Head Contour During Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.5: Head Difference Between the Unconfined and Semi-Confined Aquifers During Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.6: Head Difference Between the Unconfined and Semi-Confined Aquifers During Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 13.5 Vertical Inter Aquifer flow during Monsoon Season in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Sub Area No.	Area in Ha	Head Difference in meters	Thickness of Aquitard in meters	Hydraulic Conductivity in meters/day	Number of days water flow occurs between these aquifers in monsoon season	Vertical Inter Aquifer Flow through the aquitard in sub area in hectare meters [(3)*(4)*(6)*(7)/(5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)
1							
2							
3							
Vertical Inter Aquifer Flow through the aquitard from all sub areas during Monsoon season in hectare meters.							

Table 13.6 Vertical Aquifer Interflow during Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Sub Area No.	Area in Ha	Head Difference in meters	Thickness of Aquitard in meters	Hydraulic Conductivity in meters/day	Number of days water flow occurs between these aquifers in non-monsoon season	Vertical Inter Aquifer Flow through the aquitard in sub area in hectare meters [(3)*(4)*(6)*(7)/(5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)
1							
2							
3							
Vertical Inter Aquifer Flow through the aquitard from all sub areas during Non-Monsoon season in hectare meters.							

Table 13.7 Average Water Table Data of Each Well during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

<table>
<tr><th rowspan="3">S. No.</th><th rowspan="3">Name of the observation well (For each of the wells are in non-command area)</th><th rowspan="3">Year</th><th colspan="3">Water table head above mean sea level in meters</th><th colspan="2">Water table head above mean sea level in meters</th></tr>
<tr><th colspan="2">in ground water assessment year during</th><th>in ground water year immediately following the ground water assessment year during</th><th rowspan="2">During Monsoon Season $\frac{(4)+(5)}{2}$</th><th rowspan="2">During Non-Monsoon Season $\frac{(5)+(6)}{2}$</th></tr>
<tr><th>Pre - monsoon monitoring month</th><th>Post - monsoon monitoring month</th><th>Pre - monsoon monitoring month</th></tr>
<tr><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td><td>(6)</td><td>(7)</td><td>(8)</td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Average Ground Water Head For each well</td><td></td><td></td></tr>
</table>

Table 13.8 Water Table Data during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all wells in non-command area)	Longitude	Latitude	Ground Water head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 13.7: Water Table Contour During Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.8: Water Table Contour During Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:	
Principal Aquifer	:		Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:				

Table 13.9 Average Piezometric Head of Each Piezometer during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the Piezometer (For each of the Piezometers in non-command area)	Year	Piezometric head above mean sea level in meters – in ground water assessment year during – Pre - monsoon monitoring month	Piezometric head above mean sea level in meters – in ground water assessment year during – Post - monsoon monitoring month	Piezometric head above mean sea level in meters – in ground water year immediately following the ground water assessment year during – Pre - monsoon monitoring month	Piezometric head above mean sea level in meters – During Monsoon Season $\frac{(4)+(5)}{2}$	Piezometric head above mean sea level in meters – During Non-Monsoon Season $\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Piezometric Head For each Piezometer							

Table 13.10 Piezometric Head during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the Piezometer (for all the piezometers in non-command area)	Longitude	Latitude	Piezometric head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 13.9: Piezometric Head Contour During Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:	
Principal Aquifer	:		Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:				

MAP 13.10: Piezomteric Head Contour During Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.11: Head Difference Between the Unconfined and Semi-Confined Aquifers During Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.12: Head Difference Between the Unconfined and Semi-Confined Aquifers During Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 13.11 Vertical Inter Aquifer flow during Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Sub Area No.	Area in Ha	Head Difference in meters	Thickness of Aquitard in meters	Hydraulic Conductivity in meters/day	Number of days water flow occurs between these aquifers in monsoon season	Vertical Inter Aquifer Flow through the aquitard in sub area in hectare meters [(3)*(4)*(6)*(7)/(5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)
1							
2							
3							
Vertical Inter Aquifer Flow through the aquitard from all sub areas during Monsoon season in hectare meters.							

Table 13.12 Vertical Inter Aquifer flow during Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Sub Area No.	Area in Ha	Head Difference in meters	Thickness of Aquitard in meters	Hydraulic Conductivity in meters/day	Number of days water flow occurs between these aquifers in non-monsoon season	Vertical Inter Aquifer Flow through the aquitard in sub area in hectare meters [(3)*(4)*(6)*(7)/(5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)
1							
2							
3							
Vertical Inter Aquifer Flow through the aquitard from all sub areas during Non-Monsoon season in hectare meters.							

Table 13.13 Average Water Table Data of Each Well during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the observation well (For each of the wells in poor ground water quality area)	Year	Water table head above mean sea level in meters			Water table head above mean sea level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Head For each well							

Table 13.14 Water Table Data during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in poor ground water quality area)	Longitude	Latitude	Ground Water head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 13.13: Water Table Contour During Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.14: Water Table Contour During Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 13.15 Average Piezometric Head of Each Piezometer during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the Piezometer (For each of the Piezometers in poor ground water quality area)	Year	Piezometric head above mean sea level in meters			Piezometric head above mean sea level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Piezometric Head For each Piezometer							

Table 13.16 Piezometric Head during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the Piezometer (for all piezometers in poor ground water quality area)	Longitude	Latitude	Piezometric head in meters above mean sea level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 13.15: Piezometric Head Contour During Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.16: Piezomteric Head Contour During Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.17: Head Difference Between the Unconfined and Semi-Confined Aquifers During Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 13.18: Head Difference Between the Unconfined and Semi-Confined Aquifers During Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 13.17 Vertical Aquifer Interflow during Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Sub Area No.	Area in Ha	Head Difference in meters	Thickness of Aquitard in meters	Hydraulic Conductivity in meters/day	Number of days water flow occurs between these aquifers in monsoon season	Vertical Inter Aquifer Flow through the aquitard in sub area in hectare meters [(3)*(4)*(6)*(7)/(5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)
1							
2							
3							
Vertical Inter Aquifer Flow through the aquitard from all sub areas during Monsoon season in hectare meters.							

Table 13.18 Vertical Aquifer Interflow during Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Sub Area No.	Area in Ha	Head Difference in meters	Thickness of Aquitard in meters	Hydraulic Conductivity in meters/day	Number of days water flow occurs between these aquifers in non-monsoon season	Vertical Inter Aquifer Flow through the aquitard in sub area in hectare meters [(3)*(4)*(6)*(7)/(5)]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(7)
1							
2							
3							
Vertical Inter Aquifer Flow through the aquitard from all sub areas during Non-Monsoon season in hectare meters.							

14

EVAPORATION

14.1 GENERAL

Evaporation normally takes place from surface water bodies. As the ground water is not exposed to surface, there is less possibility for evaporation from ground water bodies. But in situations where the ground water levels are less than the capillary rise of the aquifer material, it will lead to evaporation. If the water levels are shallow and less than the capillary rise, then only evaporation is to be estimated. In all other cases, Evaporation will be zero. In GEC 1997 methodology it is not recommended to estimate this component separately instead there was a provision of unaccounted natural discharges which includes base flow, evaporation and transpiration. GEC 2015 suggested to compute the Evaporation and use in general mass balance equation.

As other components are normalized in one or other methods, this component also to be estimated for an average situation. Hence there is a requirement of minimum 5 sets of water level data

The computations of Evaporation from the ground water reservoir in the assessment sub unit during a given season involves the following steps to be carried out :

a) Computing average ground water level for both the seasons by taking the ground water level data of at least five years.
b) Computing the Average Groundwater levels during monsoon season and non-monsoon season separately.
c) Preparation of Ground water level contour with suitable contour interval preferably less than 0.5m for both the seasons.
d) Demarcating the area in various zones of water level, which is less than capillary rise.
e) Computation of Evaporation From ground water reservoir for each of the zone for both the seasons.
f) Summation of the Evaporation for each of the zones to compute the total Evaporation from the assessment sub unit for both the seasons.

14.2 ASSUMPTIONS

The computations of Evaporation are based on the following assumptions :

a) The average ground water level of pre monsoon season and the post monsoon season of the assessment year is considered as the ground water level during monsoon season. Similarly, the average ground water level of the post monsoon season of the current assessment year and ground water level of the pre monsoon season of the next assessment year is considered as the ground water level during non-monsoon season.
b) The capillary rise in the area is to be obtained from field studies or literature. In the absence of the same it is considered as 1m.
c) The Evaporation can be obtained by the following formula for all the sub areas where water level is less than capillary rise:

$$Evaporation = Area \times Evaporation\ Rate \times \frac{(Capillary\ Rise - Ground\ Water\ Level)}{Capillary\ Rise}$$

d) If this is multiplied with number of days evaporation takes place during a season will give the evaporation during the season.
e) The Evaporation from the assessment sub unit is obtained as the sum of the evaporation from all the evaporating zones.
f) The Evaporation should be computed for both the seasons.

14.3 COMPUTATIONAL PROCEDURE

For computing the Evaporation, the data from all the existing network stations should be used. The computations of Evaporation from the assessment sub unit during a given season involves the following steps to be carried out :

14.3.1 Average Ground Water Level

For knowing the most probable Evaporation from the assessment sub unit the average ground water levels for both the monsoon and non-monsoon seasons are needed. For computing the average ground water level in any season may be computed as the average of ground water level observed by taking the ground water level data of at least five years. The average groundwater levels during monsoon season and non-monsoon season are to be estimated separately.

14.3.2 Evaporating Area

For computing evaporating area, water level contour map with suitable contour interval is to be prepared. The area of interest will be the area where water levels are less than the capillary rise. In the absence of capillary rise of the area it should be considered as 1 meter. The evaporating area for monsoon season and non-monsoon seasons are to be demarcated separately.

14.3.3 Evaporation

The Evaporation from the assessment sub unit is the total of the evaporation from all the evaporating zones. For each evaporating zone, the evaporation can be estimated by the following formula.

$$Evaporation = Area \times Evaporation\ Rate \times \frac{(Capillary\ Rise - Ground\ Water\ Level)}{Capillary\ Rise}$$

When it is multiplied with number of days evaporation takes place in the evaporating zone, it gives the evaporation losses from the zone during that particular season. The Evaporation for monsoon season and non-monsoon season are to be estimated separately.

14.4 FORMATS SUGGESTED FOR THE COMPUTATION

14.4.1 Command Area

Water Level during monsoon and non-monsoon seasons is computed for all the years and the average monsoon season water level and non-monsoon water level is calculated as the average of at least last five years and is presented in Table 14.1. The computed average water levels during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 14.2. Using the water table data, water level contour maps are prepared in Map 14.1 and Map 14.2 for monsoon season and non-monsoon seasons respectively. From these maps Evaporating areas are zoned wherever the water levels are less than the capillary rise. Suitable contour interval may be selected to get more accurate results. The Evaporation is computed in Table 14.3 and Table 14.4 for monsoon season and non-monsoon season respectively.

14.4.2 Non-Command Area

The computational scheme to be adopted for estimating the Evaporation in the non-command area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 14.4.1 for the command area. The computations are presented in Tables 14.5 to 14.8 and the maps are presented in Maps 14.3 and 14.4.

14.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating the Evaporation in the poor ground water quality area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 14.4.1 for the command area. The computations are presented in Tables 14.9 to 14.12 and the maps are presented in Maps 14.5 and 14.6.

14.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Evaporation.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Evaporating Area During Monsoon Season	Number	7	0
3	Evaporating Area During Non-Monsoon Season	Number	7	0
4	Evaporation Rate During Monsoon Season	Number	7	2
5	Evaporation Rate During Non-Monsoon Season	Number	7	2
6	Sub Unit Evaporation During Monsoon Season	Number	8	0
7	Sub Unit Evaporation During Monsoon Season	Number	8	0
8	Evaporating Zone Id	Text	20	
9	Evaporation during monsoon	Number	8	0
10	Evaporation during non-monsoon	Number	8	0
11	No of Monsoon days	Number	3	
12	No of Non-monsoon days	Number	3	

Table 14.1 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Name of the observation well (For each of the wells in command area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Level For each well in meter below ground level							

Table 14.2 Ground Water Level during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in command area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 14.1: Ground Water Level Contour During Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 14.2: Ground Water Level Contour During Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 14.3 Evaporation for the Ground Water Reservoir during Monsoon Season in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evaporating Zone No.	Area in hectares	Evaporation Rate in mm/day	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evaporation takes place during monsoon season	Evaporation from the zone hectare meters. $\frac{(3)\times(4)\times((5)-(6))\times(7)}{1000\times(5)}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Evaporation through all the zones during Monsoon season in hectares meters.							

Table 14.4 Evaporation for the Ground Water Reservoir during Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evaporating Zone No.	Area in hectares	Evaporation Rate in mm/day	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evaporation takes place during non-monsoon season	Evaporation from the zone hectare meters. $\frac{(3)\times(4)\times((5)-(6))\times(7)}{1000\times(5)}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Evaporation through all the zones during Non-Monsoon season in hectares meters.							

Table 14.5 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the observation well (For each of the wells in non-command area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Level For each well in meter below ground level							

Table 14.6 Ground Water Level during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in non-command area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 14.3: Ground Water Level Contour During Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 14.4: Ground Water Level Contour During Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:	
Principal Aquifer	:		Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:				

Table 14.7 Evaporation for the Ground Water Reservoir during Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evaporating Zone No.	Area in hectares	Evaporation Rate in mm/day	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evaporation takes place during monsoon season	Evaporation from the zone hectare meters. $\frac{(3)\times(4)\times((5)-(6))\times(7)}{1000\times(5)}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Evaporation through all the zones during Monsoon season in hectares meters.							

Table 14.8 Evaporation for the Ground Water Reservoir during Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evaporating Zone No.	Area in hectares	Evaporation Rate in mm/day	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evaporation takes place during non-monsoon season	Evaporation from the zone hectare meters. $\frac{(3)\times(4)\times((5)-(6))\times(7)}{1000\times(5)}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Evaporation through all the zones during Non-Monsoon season in hectares meters.							

Table 14.9 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the observation well (For each of the wells in poor ground water quality area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Level For each well in meter below ground level							

Table 14.10 Ground Water Level during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in poor ground water quality area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 14.5: Ground Water Level Contour During Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 14.6: Ground Water Level Contour During Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 14.11 Evaporation for the Ground Water Reservoir during Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evaporating Zone No.	Area in hectares	Evaporation Rate in mm/day	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evaporation takes place during monsoon season	Evaporation from the zone hectare meters. $\frac{(3)\times(4)\times((5)-(6))\times(7)}{1000\times(5)}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Evaporation through all the zones during Monsoon season in hectares meters.							

Table 14.12 Evaporation for the Ground Water Reservoir during Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evaporating Zone No.	Area in hectares	Evaporation Rate in mm/day	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evaporation takes place during non-monsoon season	Evaporation from the zone hectare meters. $\frac{(3)\times(4)\times((5)-(6))\times(7)}{1000\times(5)}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Evaporation through all the zones during Non-Monsoon season in hectares meters.							

15

TRANSPIRATION

15.1 GENERAL

Transpiration normally takes place from the ground water reservoir if the roots reach the ground water table. If the water table is deep below, ground water cannot be wasted through transpiration. But in the situations where the roots extend up to the capillary rise of ground water levels, it will lead to transpiration as ground water is available to roots through capillary rise. If the water levels are shallow and less than the capillary rise added to the root depth, then only transpiration is to be estimated. In all other cases, transpiration will be zero. In GEC 1997 methodology it is not recommended to estimate this component separately instead there was a provision of unaccounted natural discharges which includes base flow, evaporation and transpiration. GEC 2015 suggested to compute the Transpiration separately and use in general mass balance equation.

As other components are normalized in one or other methods, this component is also to be estimated for an average situation. Hence there is a requirement of minimum 5 sets of water level data

The computations of Transpiration from the ground water reservoir in the assessment sub unit during a given season involves the following steps to be carried out :

a) Computing average ground water level for both the seasons by taking the ground water level data of at least five years data.
b) Computing the Average Groundwater levels during monsoon season and non-monsoon season separately.
c) Preparation of Ground water level contour with suitable contour interval preferably less than 0.5m for both the seasons.
d) Demarcating the area in various zones of water level.
e) Computation of Transpiration from ground water reservoir for each of the zone for both the seasons.
f) This transpiration multiplied by the number of days ground water available for transpiration in a season results in Transpiration losses throughout the particular season.
g) Summation of the Transpiration for each of the zones to compute the total Transpiration from the assessment sub unit for both the seasons.

15.2 ASSUMPTIONS

The computations of Transpiration are based on the following assumptions :

a) The average ground water level of pre monsoon season and the post monsoon season of the assessment year is considered as the ground water level during monsoon season. Similarly, the average ground water level of the post monsoon season of the current assessment year and ground water level of the pre monsoon season of the next assessment year is considered as the ground water level during non-monsoon season.
b) The capillary rise in the area is to be obtained from field studies or literature. In the absence of the same it is considered as 1m.
c) The average root depth is to be obtained from the field studies or literature. In the absence of the same this can be assumed as 2.5m.
d) The Transpiration can be obtained by the following formula for all the area where water level is less than the total of root depth and capillary rise:

$$Transpiration = Area \times Transpiration\ Rate \times \frac{(Root\ Depth + Capillary\ Rise - Ground\ Water\ Level)}{(Root\ Depth + Capillary\ Rise)}$$

e) This transpiration multiplied by the number of days ground water available for transpiration in a season results in Transpiration losses throughout the particular season.
f) The Transpiration from the assessment sub unit is obtained as the algebraic sum of the transpiration from all the zones.

15.3 COMPUTATIONAL PROCEDURE

For computing the Transpiration, the data from all the existing network stations should be used. The computations of Transpiration from the assessment sub unit during a given season involves the following steps to be carried out :

15.3.1 Average Ground Water Level

For knowing the most probable Transpiration from the assessment sub unit the average ground water levels for both the monsoon and non-monsoon seasons are needed. The average ground water level in any season may be computed as the average of ground water level observed by taking the ground water level data of at least five years. The average groundwater levels during monsoon season and non-monsoon season are to be estimated separately.

15.3.2 Transpiring Area

For computing transpiring area, water level contour map with suitable contour interval is to be prepared. The area of interest will be the area where water levels are less than the total of root depth and capillary rise. In the absence of data on root depth and capillary rise of the area it should be considered as 3.5 meters. The transpiring area for monsoon season and non-monsoon season are to be demarcated separately.

15.3.3 Transpiration

The Transpiration from the assessment sub unit is the total of the transpiration from all the transpiring zones. For each transpiring zone, the transpiration can be estimated by the following formula.

$$Transpiration = Area \times Transpiration\ Rate \times \frac{(Root\ Depth + Capillary\ Rise - Ground\ Water\ Level)}{(Root\ Depth + Capillary\ Rise)}$$

This transpiration multiplied by the number of days ground water available for transpiration in a season results in Transpiration losses throughout the particular season. The Transpiration for monsoon season and non-monsoon season are to be estimated separately.

15.4 FORMATS SUGGESTED FOR THE COMPUTATION

15.4.1 Command Area

Water Level during monsoon and non-monsoon seasons is computed for all the years and the average monsoon season water level and non-monsoon water level is calculated as the average of at least last five years data and is presented in Table 15.1. The computed average water levels during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 15.2. Using this data, water level contour maps are prepared in Map 15.1 and Map 15.2 for monsoon season and non-monsoon seasons respectively. From these maps Transpiring areas are zoned wherever the water levels are less than the total of root depth and capillary rise. Suitable contour interval may be selected to get more accurate results. The Transpiration is computed in Table 15.3 and Table 15.4 for monsoon season and non-monsoon season respectively.

15.4.2 Non-Command Area

The computational scheme to be adopted for estimating the transpiration in the non-command area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 15.4.1 for the command area. The computations are presented in Tables 15.5 to 15.8 and the maps are presented in Maps 15.3 and 15.4.

15.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating the Transpiration in the poor ground water quality area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 15.4.1 for the command area. The computations are presented in Tables 15.9 to 15.12 and the maps are presented in Maps 15.5 and 15.6.

15.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Transpiration.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Transpiring Area During Monsoon Season	Number	7	0

S.No	Parameter	Type	Size	Decimals
3	Transpiring Area During Non-Monsoon Season	Number	7	0
4	Transpiration Rate During Monsoon Season	Number	7	2
5	Transpiration Rate During Non-Monsoon Season	Number	7	2
6	Sub Unit Transpiration During Monsoon Season	Number	8	0
7	Sub Unit Transpiration During Non-Monsoon Season	Number	8	0
8	Transpiring Zone Id	Text	20	
9	No of days During Monsoon	Number	3	
10	No of days During Non-Monsoon	Number	3	
11	Zone Transpiration During Monsoon	Number	8	0
12	Zone Transpiration During Non-Monsoon	Number	8	0

Table 15.1 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

<table>
<tr><td rowspan="3">S. No.</td><td rowspan="3">Name of the observation well (For each of the wells in command area)</td><td rowspan="3">Year</td><td colspan="3">Ground water level below ground level in meters</td><td colspan="2">Ground Water level below ground level in meters</td></tr>
<tr><td colspan="2">in ground water assessment year during</td><td>in ground water year immediately following the ground water assessment year during</td><td rowspan="2">During Monsoon Season
$\frac{(4)+(5)}{2}$</td><td rowspan="2">During Non-Monsoon Season
$\frac{(5)+(6)}{2}$</td></tr>
<tr><td>Pre - monsoon monitoring month</td><td>Post - monsoon monitoring month</td><td>Pre - monsoon monitoring month</td></tr>
<tr><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td><td>(6)</td><td>(7)</td><td>(8)</td></tr>
<tr><td>1
2
3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="6">Average Ground Water Level For each well in meter below ground level</td><td></td><td></td></tr>
</table>

Table 15.2 Ground Water Level during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all wells in command area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 15.1: Ground Water Level Contour During Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 15.2: Ground Water Level Contour During Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 15.3 Transpiration from the Ground Water Reservoir during Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Transpiring Zone No.	Area in hectares	Transpiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Transpiration takes place during monsoon season	Transpiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Transpiration through all the zones during Monsoon season in hectares meters.								

Table 15.4 Transpiration from the Ground Water Reservoir during Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Transpiring Zone No.	Area in hectares	Transpiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Transpiration takes place during non-monsoon season	Transpiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Transpiration through all the zones during Non-Monsoon season in hectares meters.								

Table 15.5 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the observation well (For each of the wells in non-command area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Level For each well in meter below ground level							

Table 15.6 Ground Water Level during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in non-command area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 15.3: Ground Water Level Contour During Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:
Principal Aquifer	:		Major Aquifer	:
Index Number of Ground Water Assessment Unit	:			

MAP 15.4: Ground Water Level Contour During Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 15.7 Transpiration from the Ground Water Reservoir during Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit :
Ground Water Assessment Year :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Transpiring Zone No.	Area in hectares	Transpiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Transpiration takes place during monsoon season	Transpiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Transpiration through all the zones during Monsoon season in hectares meters.								

Table 15.8 Transpiration from the Ground Water Reservoir during Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Transpiring Zone No.	Area in hectares	Transpiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Transpiration takes place during non-monsoon season	Transpiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Transpiration through all the zones during Non-Monsoon season in hectares meters.								

Table 15.9 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the observation well (For each of the wells in poor ground water quality area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Level For each well in meter below ground level							

Table 15.10 Ground Water Level during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in poor ground water quality area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 15.5: Ground Water Level Contour During Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 15.6: Ground Water Level Contour During Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 15.11 Transpiration from the Ground Water Reservoir during Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Transpiring Zone No.	Area in hectares	Transpiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Transpiration takes place during monsoon season	Transpiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Transpiration through all the zones during Monsoon season in hectares meters.								

Table 15.12 Transpiration from the Ground Water Reservoir during Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Transpiring Zone No.	Area in hectares	Transpiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Transpiration takes place during non-monsoon season	Transpiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Transpiration through all the zones during Non-Monsoon season in hectares meters.								

16

EVAPOTRANSPIRATION

16.1 GENERAL

Sometimes it will be difficult to get evaporation and transpiration rates separately. It may be possible to get a single rate of evapotranspiration which is the cumulative effect of evaporation and transpiration. In these situations instead of using two terms viz. evaporation and transpiration in the equation only one term is used i.e. evapotranspiration. As the ground water is not exposed to surface, there is a less possibility for evaporation from ground water bodies. But in situations where the ground water levels are less than the capillary rise of the aquifer material, it will lead to evaporation. If the water levels are shallow and less than the capillary rise, then only evaporation is to be estimated. In all other cases, Evaporation will be zero. Similarly transpiration normally takes place from the ground water reservoir if the roots reach the ground water table. If the water table is deep below, ground water cannot be wasted through transpiration. But in situations where the roots extend up to the capillary rise of ground water levels, it will lead to transpiration. If the water levels are shallow and less than the capillary rise added to the root depth, then only transpiration is to be estimated. In all other cases, transpiration will be zero. In GEC 1997 methodology it is not recommended to estimate this component separately instead there was a provision of unaccounted natural discharges which includes base flow, evaporation and transpiration. GEC 2015 suggested to compute both evaporation and transpiration separately and use in general mass balance equation. In case where the evaporation and transpiration rates are not available, it can be assessed by using the available evapotranspiration rates.

As other components are normalized in one or other methods, this component also to be estimated for an average situation. Hence there is a requirement of minimum 5 sets of water level data

The computations of Evapotranspiration from the ground water reservoir in the assessment sub unit during a given season involves the following steps to be carried out:

a) Computing average ground water level for both the seasons by taking the ground water level data of at least five years data.
b) Computing the Average ground water levels during monsoon season and non-monsoon season separately.
c) Preparation of Ground water level contour with suitable contour interval preferably less than 0.5m for both the seasons.
d) Demarcating the area in various zones of water level.

e) Computation of Evapotranspiration from ground water reservoir for each of the zone for both the seasons.
f) This is multiplied with Number of days evapotranspiration takes place from ground water reservoir in a season to compute Evapotranspiration throughout the season.
g) Summation of the Evapotranspiration from each of the zones to compute the total Evapotranspiration from the assessment sub unit for both the seasons.

16.2 ASSUMPTIONS

The computations of Evapotranspiration are based on the following assumptions :

a) The average ground water level of pre monsoon season and the post monsoon season of the assessment year is considered as the ground water level during monsoon season. Similarly, the average ground water level of the post monsoon season of the current assessment year and ground water level of the pre monsoon season of the next assessment year is considered as the ground water level during non-monsoon season.
b) The capillary rise in the area is to be obtained from field studies or literature. In the absence of the same it is considered as 1m.
c) The average root depth is to be obtained from the field studies or literature. In the absence of the same this can be assumed as 2.5m.
d) The Evapotranspiration can be obtained by the following formula for all the area where water level is less than the total of root depth and capillary rise:

$$Evapotranspiration = Area \times Evapotranspiration\ Rate \times \frac{(Root\ Depth + Capillary\ Rise - Ground\ Water\ Level)}{(Root\ Depth + Capillary\ Rise)}$$

e) This is multiplied with Number of days evapotranspiration takes place from ground water reservoir in a season to compute Evapotranspiration throughout the season.
f) The Evapotranspiration from the assessment sub unit is obtained as the algebraic sum of the evapotranspiration from all the zones.

16.3 COMPUTATIONAL PROCEDURE

For computing the Evapotranspiration, the data from all the existing network stations should be used. The computations of Evapotranspiration from the assessment sub unit during a given season involves the following steps to be carried out :

16.3.1 Average Ground Water Level

For knowing the most probable Evapotranspiration from the assessment sub unit the average ground water levels for both the monsoon and non-monsoon seasons are needed. For computing the average ground water level in any season may be computed as the average of ground water level observed by taking the ground water level data of at least five years. The average groundwater levels during monsoon season and non-monsoon season are to be estimated.

16.3.2 Area Where Evapotranspiration Takes place

For computing the area where evapotranspiration takes place, water level contour map with suitable contour interval is to be prepared. The area of interest will be the area where water levels are less than the total of root depth and capillary rise. In the absence of data on root depth and capillary rise of the area it should be considered as 3.5 meters. The area where evapotranspiration takes place during monsoon season and non-monsoon seasons are to be demarcated separately.

16.3.3 Evapotranspiration

The Evapotranspiration from the assessment sub unit is the total of the evapotranspiration from all the evapotranspiration zones. For each evapotranspiration zone, the evapotranspiration can be estimated by the following formula.

a)

$$Evapotranspiration = Area \times Evapotranspiration\ Rate \times \frac{(Root\ Depth + Capillary\ Rise - Ground\ Water\ Level)}{(Root\ Depth + Capillary\ Rise)}$$

This is multiplied with Number of days evapotranspiration takes place from ground water reservoir in a season to compute Evapotranspiration throughout the season. The Evapotranspiration for monsoon season and non-monsoon season are to be estimated separately.

16.4 FORMATS SUGGESTED FOR THE COMPUTATION

16.4.1 Command Area

Water Level during monsoon and non-monsoon seasons is computed for all the years and the average monsoon season water level and non-monsoon water level is calculated as the average of at least last five years data and is presented in Table 16.1. The computed average water levels during monsoon season and non-monsoon seasons along with latitude and longitudes are presented in Table 16.2. Using this data, water level contour maps are prepared in Map 16.1 and Map 16.2 for monsoon season and non-monsoon seasons respectively. From these maps Evapotranspiration areas are zoned wherever the water levels are less than the total of root depth and capillary rise. Suitable contour interval may be selected to get more accurate results. The Evapotranspiration is computed in Table 16.3 and Table 16.4 for monsoon season and non-monsoon season respectively.

16.4.2 Non-Command Area

The computational scheme to be adopted for estimating the evapotranspiration in the non-command area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 16.4.1 for the command area. The computations are presented in Tables 16.5 to 16.8 and the maps are presented in Maps 16.3 and 16.4.

16.4.3 Poor Ground Water Quality Area

The computational scheme to be adopted for estimating the Evapotranspiration in the poor ground water quality area during monsoon and non-monsoon seasons is identical to what has been described earlier in Section 16.4.1 for the command area. The computations are presented in Tables 16.9 to 16.12 and the maps are presented in Maps 16.5 and 16.6.

16.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Evapotranspiration.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Evapotranspiring Area During Monsoon Season	Number	7	0
3	Evapotranspiring Area During Non-Monsoon Season	Number	7	0
4	Evapotranspiration Rate During Monsoon Season	Number	7	2
5	Evapotranspiration Rate During Non-Monsoon Season	Number	7	2
6	Sub Unit Evapotranspiration During Monsoon Season	Number	8	0
7	Sub Unit Evapotranspiration During Non-Monsoon Season	Number	8	0
8	EVT Zone Id	Text	20	
9	No of Days Monsoon	Number	3	
10	No of Days Non Monsoon	Number	3	
11	Zone EVT Monsoon	Number	8	0
12	Zone EVT Non Monsoon	Number	8	0

Table 16.1 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Name of the observation well (For each of the wells in command area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
	Average Ground Water Level For each well in meter below ground level						

Table 16.2 Ground Water Level during Monsoon and Non-monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in command area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 16.1: Ground Water Level Contour During Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 16.2: Ground Water Level Contour During Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit	:		Ground Water Assessment Year	:	
Principal Aquifer	:		Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:				

Table 16.3 Evapotranspiration from the Ground Water Reservoir during Monsoon Season in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evapotranspiration Zone No.	Area in hectares	Evapotranspiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evapotranspiration takes place during monsoon season	Evapotranspiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Evapotranspiration through all the zoness during Monsoon season in hectares meters.								

Table 16.4 Evapotranspiration from the Ground Water Reservoir during Non-Monsoon Season in Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evapotranspiration Zone No.	Area in hectares	Evapotranspiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evapotranspiration takes place during non-monsoon season	Evapotranspiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Evapotranspiration through all the zones during Non-Monsoon season in hectares meters.								

Table 16.5 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the observation well (For each of the wells in non-command area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Level For each well in meter below ground level							

Table 16.6 Ground Water Level during Monsoon and Non-monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in non-command area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 16.3: Ground Water Level Contour During Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 16.4: Ground Water Level Contour During Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 16.7 Evapotranspiration from the Ground Water Reservoir during Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evapotranspiration Zone No.	Area in hectares	Evapotranspiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evapotranspiration takes place during monsoon season	Evapotranspiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Evapotranspiration through all the zones during Monsoon season in hectares meters.								

Table 16.8 Evapotranspiration from the Ground Water Reservoir during Non-Monsoon Season in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evapotranspiration Zone No.	Area in hectares	Evapotranspiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evapotranspiration takes place during non-monsoon season	Evapotranspiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Evapotranspiration through all the zones during Non-Monsoon season in hectares meters.								

Table 16.9 Average Water Level of Each Well during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the observation well (For each of the wells in poor ground water quality area)	Year	Ground water level below ground level in meters			Ground Water level below ground level in meters	
			in ground water assessment year during		in ground water year immediately following the ground water assessment year during	During Monsoon Season	During Non-Monsoon Season
			Pre - monsoon monitoring month	Post - monsoon monitoring month	Pre - monsoon monitoring month	$\frac{(4)+(5)}{2}$	$\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1							
2							
3							
Average Ground Water Level For each well in meter below ground level							

Table 16.10 Ground Water Level during Monsoon and Non-monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in poor ground water quality area)	Longitude	Latitude	Ground Water level in meters below ground level	
				During Monsoon Season	During Non-Monsoon Season
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					

MAP 16.5: Ground Water Level Contour During Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

MAP 16.6: Ground Water Level Contour During Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 16.11 Evapotranspiration from the Ground Water Reservoir during Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Evapotranspiration Zone No.	Area in hectares	Evapotranspiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evapotranspiration takes place during monsoon season	Evapotranspiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Evapotranspiration through all the zones during Monsoon season in hectares meters.								

Table 16.12 Evapotranspiration from the Ground Water Reservoir during Non-Monsoon Season in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Evapotranspiration Zone No.	Area in hectares	Evapotranspiration Rate in mm/day	Average root depth in the zone in meters	Capillary rise in the zone in meters	Average ground water level in the zone in meters below ground level	No of days Evapotranspiration takes place during non-monsoon season	Evapotranspiration from the zone hectare meters. $\frac{(3)\times(4)\times((5)+(6)-(7))\times(8)}{1000\times((5)+(6))}$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1								
2								
3								
Evapotranspiration through all the zone during Non-Monsoon season in hectares meters.								

17

RESULTANT FLOWS

17.1 GENERAL

The resultant inflows can be from the following inflow outflow components. These are listed below:

a) **Lateral Flow Along the aquifer system or through flow**
b) **Base flow**
c) **Stream Recharge**
d) **Vertical Inter Aquifer Flow**
e) **Evaporation**
f) **Transpiration**
g) **Evapotranspiration**

The above seven flow components are together referred to as **'Resultant Flows**'. The estimation of these components have been presented in Chapters 10 to 16. Resultant flows in a given sub-unit is obtained as the algebraic sum of the individual inflow out flow components.

The estimation of the resultant flows into the assessment unit may be done by taking the following few points into consideration.

a) Lateral Flow along the Aquifer System (Through Flow) : Where ever the assessment unit is not hydrological boundary, there will be flow across the boundaries. The inflows should be taken as positive and out flows should be taken as negative and the resultant flow should be computed. Even though the assessment unit is a hydrological boundary if the water divide is of low relief, then also there is a possibility of flow across the boundary.
b) Base Flow: This is only an outflow, it should be estimated where ever possible.
c) Stream Recharge: At any place there is only one possibility that either there will be base flow or there will be stream recharge. Care must be taken for not taking into account the base flow twice.
d) Vertical Inter aquifer Flow: This flow is possible only when the unconfined aquifer is underlain by a semi confined aquifer. Here also the convention is that the inflow into the unconfined aquifer is considered as positive and outflow from the unconfined aquifer is negative.
e) Evaporation: If evaporation and transpiration rates are available, then this component can be estimated and it is always outflow.
f) Transpiration: If evaporation and transpiration rates are available, then this component can be estimated and it is always outflow.

g) Evapotranspiration: If evaporation and transpiration rates are not available, then this component can be attempted by knowing the evapotranspiration rate and it is always outflow. In these three components either the evaporation and transpiration are estimated separately or only evapotranspiration is estimated.
h) Resultant flows in all the sub-units during the monsoon season of the current ground water assessment year will be made use of for computing rainfall recharge by the water table fluctuation method (Chapter 19).

17.2 FORMATS SUGGESTED FOR THE COMPUTATION

The resultant flows are summarised in Tables 17.1 to 17.3, one table for each sub-unit.

17.3 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Resultant Flows.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Total Sub Unit Monsoon Lateral Flows	Number	7	0
3	Total Sub Unit Non-Monsoon Lateral Flows	Number	7	0
4	Total Sub Unit Annual Lateral Flows	Number	7	0
5	Total Sub Unit Monsoon Base Flow	Number	7	0
6	Total Sub Unit Non-Monsoon Base Flow	Number	7	0
7	Total Sub Unit Annual Base Flow	Number	7	0
8	Total Sub Unit Monsoon Stream Recharge	Number	7	0
9	Total Sub Unit Non-Monsoon Stream Recharge	Number	7	0
10	Total Sub Unit Annual Stream Recharge	Number	7	0
11	Total Sub Unit Monsoon Vertical flow	Number	7	0
12	Total Sub Unit Non-Monsoon Vertical flow	Number	7	0
13	Total Sub Unit Annual Vertical flow	Number	7	0
14	Total Sub Unit Monsoon Evaporation	Number	7	0
15	Total Sub Unit Non-Monsoon Evaporation	Number	7	0
16	Total Sub Unit Annual Evaporation	Number	7	0
14	Total Sub Unit Monsoon Transpiration	Number	7	0
15	Total Sub Unit Non-Monsoon Transpiration	Number	7	0
16	Total Sub Unit Annual Transpiration	Number	7	0
14	Total Sub Unit Monsoon Evapotranspiration	Number	7	0
15	Total Sub Unit Non-Monsoon Evapotranspiration	Number	7	0
16	Total Sub Unit Annual Evapotranspiration	Number	7	0
17	Total Sub Unit Monsoon Resultant Flows	Number	8	0
18	Total Sub Unit Non-Monsoon Resultant Flows	Number	8	0
19	Total Sub Unit Annual Resultant Flows	Number	8	0

Table 17.1 Resultant flows in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the component	Flow in hectare meters during			
		Monsoon Season		Non-monsoon Season	
		Inflow (+)	Outflow (-)	Inflow (+)	Outflow (-)
1	Lateral Flow Along the Aquifer System (Through Flow) [From Table 10.5,10.6]				
2	Base Flow [From Table 11.13]				
3	Recharge from Streams [From Table 12.7,12.8]				
4	Vertical Inter Aquifer Flow [From Table 13.5, 13.6]				
5	Evaporation [From Table 14.3,14.4]				
6	Transpiration [From Table 15.3,15.4]				
7	Evapotranspiration [from Table 16.3,16.4] (If Evaporation & Transpiration are not estimated separately)				
	Total Flows				
Resultant Flows in command area					

a) Annual Resultant Flows in command area in hectare metres =
[Algebraic Sum of Resultant Flows during monsoon and non-monsoon seasons]

Table 17.2 Resultant flows in Non - Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the component	Flow in hectare meters during			
		Monsoon Season		Non-monsoon Season	
		Inflow (+)	Outflow (-)	Inflow (+)	Outflow (-)
1	Lateral Flow Along the Aquifer System (Through Flow) [From Table 10.5,10.6]				
2	Base Flow [From Table 11.13]				
3	Recharge from Streams [From Table 12.9,12.10]				
4	Vertical Inter Aquifer Flow [From Table 13.5, 13.6]				
5	Evaporation [From Table 14.3,14.4]				
6	Transpiration [From Table 15.3,15.4]				
7	Evapotranspiration [from Table 16.3,16.4] (If Evaporation & Transpiration are not estimated separately)				
	Total Flows				
Resultant Flows in non-command area					

a) Annual Resultant Flows in non-command area in hectare metres
[Algebraic Sum of Resultant Flows during monsoon and non-monsoon seasons]

Table 17.3 Resultant flows in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the component	Flow in hectare meters during			
		Monsoon Season		Non-monsoon Season	
		Inflow (+)	Outflow (-)	Inflow (+)	Outflow (-)
1	Lateral Flow Along the Aquifer System (Through Flow) [From Table 10.5,10.6]				
2	Base Flow [From Table 11.13]				
3	Recharge from Streams [From Table 12.11,12.12]				
4	Vertical Inter Aquifer Flow [From Table 13.5, 13.6]				
5	Evaporation [From Table 14.3,14.4]				
6	Transpiration [From Table 15.3,15.4]				
7	Evapotranspiration [from Table 16.3,16.4] (If Evaporation & Transpiration are not estimated separately)				
	Total Flows				
Resultant Flows in poor ground water quality area					

a) Annual Resultant Flows in poor ground water quality area in hectare metres
[Algebraic Sum of Resultant Flows during monsoon and non-monsoon seasons]

18

RAINFALL RECHARGE BY RAINFALL INFILTRATION FACTOR METHOD

18.1 GENERAL

Rainfall is a natural phenomenon showing considerable variations from year to year. The 'Normal Rainfall', obtained as the average rainfall over a sufficiently long number of ground water years will be therefore the most appropriate basis for computing rainfall recharge.

The following two methods can be employed for computing rainfall recharge :

- **a) Rainfall infiltration factor method**
- **b) Water table fluctuation method**

The rainfall infiltration factor method alone needs to be employed in each ground water assessment unit for the following cases :

- a) command and non-command areas during non-monsoon season
- b) poor ground water quality area during non-monsoon season. If observation network stations are not available in the sub unit, the same method may be applied in monsoon season also.

As far as possible, the water table fluctuation method is to be employed in each ground water assessment unit for the remaining cases mentioned below:

- a) command area during monsoon season
- b) non-command area during monsoon season
- c) Poor ground water quality are during monsoon season if sufficient monitoring network is available.

Even in the above cases where the recommended method to be employed is the water table fluctuation method, it is necessary to compute the rainfall recharge by the rainfall infiltration factor method also, because of one or other of the following reasons :

- a) Adequate data on depth to water table during pre-monsoon and post-monsoon monitorings of a ground water year may not be available as a result of which the water table fluctuation method cannot be employed, and only the rainfall infiltration factor method has to be made use of.
- b) The computed rainfall recharge values corresponding to different monsoon season rainfall values through the use of the water balance approach in the water table fluctuation method may be such that all of them are consistently negative or nearly zero. In such a situation, the water table fluctuation method

has to be dispensed with, and instead the rainfall infiltration factor method will have to be used. This point will be elaborated in the next chapter.

c) The rainfall recharge as computed by the water table fluctuation method has to be any way compared with that computed by the rainfall infiltration factor method and finally the rainfall recharge during monsoon season will have to be assigned a value on the basis of a set of criteria so as to avoid unreasonably high or low estimates. This point will be elaborated in the next chapter.

This chapter is concerned with computing rainfall recharge by the rainfall infiltration factor method. The water table fluctuation method will be dealt with in the next chapter.

The computational procedure for estimating rainfall recharge by the rainfall infiltration factor method for the three sub-units of command, non-command and poor ground water quality areas during the monsoon as well as non-monsoon seasons essentially comprises of the following steps :

a) Estimating the normal monsoon and the normal non-monsoon season rainfall applicable for the three sub-units
b) Deciding on the minimum and maximum threshold values for the estimation.
c) Assigning a rainfall infiltration factor for the three sub-units
d) Computing the rainfall recharge during monsoon as well as non-monsoon seasons for the three sub-units using results from 'a' , 'b'and 'c' above

18.2 ASSUMPTIONS

The estimation of rainfall recharge by the rainfall infiltration factor method is based on the following assumptions :

a) The rainfall recharge in a given sub-unit during a given season is considered to be a linear function of only the quantum of rainfall during that season between the minimum and maximum threshold values. The distribution of rainfall within the season is therefore ignored.
b) The rainfall recharge during any season is considered to be nil if the normal rainfall is less than or equal to minimum threshold .
c) The rainfall during any season is considered equal to the maximum threshold if the rainfall is more than maximum threshold .
d) Rainfall recharge in hectare metres can be computed as the product of the following three parameters :
    i) Rainfall infiltration factor as a fraction applicable for the sub-unit under consideration
    ii) Quantum of normal rainfall above minimum threshold in metres applicable for the sub-unit and season under consideration
    iii) Area of the sub-unit under consideration in hectares
e) The rainfall infiltration factor for the given sub-unit depends only on the major aquifer in that area. Even though factors like geomorphology, vegetal cover, antecedent moisture status etc., (which may be equally important) have been ignored primarily because the variation of rainfall infiltration factor in quantitative terms with variation in these factors are not widely available

f) The rainfall recharge factor mentioned in ‘e’ above is to be the assigned a value on the basis of norms given in Annexure IV. The recommended value given in the norms should be alone made use of unless, results from documented field studies indicate that a different value can be used. In the latter case also, the rainfall infiltration factor assigned should be within the range of the maximum and the minimum values as specified in the norms.

18.3 COMPUTATIONAL PROCEDURE

For computing the rainfall recharge by rainfall infiltration factor method, the data from all the available rain gauge stations should be used. The computations of rainfall recharge using rainfall infiltration factor method in the assessment sub unit during a given season involves the following steps to be carried out :

18.3.1 Normal Rainfall

Each state/union Territory has a number of rain gauges for each of which normal monsoon and non-monsoon season rainfall values are available. All such rain gauges are assigned a unique name. Each such rain gauge also has a certain area of influence over which the rainfall as recorded in that rain gauge can be assumed to be uniformly applicable. Those rain gauges which fulfil the condition that, a portion of their respective area of influence fall within the area under consideration are first identified. The normal rainfall data pertaining to these identified rain gauges form the basis for estimating the normal monsoon and non-monsoon season rainfall applicable for the area under consideration.

18.3.2 Threshold Values

Initial rainfall in any area may not contribute to ground water recharge. To certain quantum of rainfall, the rainfall is sufficient to cater soil moisture needs. This minimum value is known as minimum threshold value of rainfall for the recharge. Similarly after certain quantum of rainfall, whatever may the rainfall, that rainfall will go as runoff. It will not make any recharge. This maximum value is known as maximum threshold. These values are to be established for each of the area. But in case these values of not available for any area, 10% of the normal annual rainfall may be considered as Minimum threshold value and 3000mm may be considered as maximum threshold value.

18.3.3 Rainfall Infiltration Factor

The rainfall infiltration factor for the sub unit during monsoon and non-monsoon seasons are obtained either on the basis of the norms as given in Annexure IV or on the basis of results from documented field studies.

18.3.4 Rainfall Recharge

The rainfall recharge for any season is calculated using the following formula .

$$Rainfall\ Recharge = (Rainfall - minimum\ threshold) * RFIF * Area$$

In the above equation, if rainfall is more than maximum threshold then instead of actual rainfall only maximum threshold value is taken.

18.4 FORMATS SUGGESTED FOR THE COMPUTATION

18.4.1 Command Area

The location details of the rain gauge stations existing in the sub unit are presented in Table 18.1. The Normal rainfall during monsoon and non-monsoon seasons are presented in Table 18.2. The procedure followed for assigning the value for the rainfall infiltration factor applicable for the command area is presented in Table 18.3. The computations of rainfall recharge by the rainfall infiltration factor method for the command area during monsoon and non-monsoon seasons are presented in Table 18.4.

18.4.2 Non-command Area.

The computational procedure for obtaining rainfall recharge during monsoon and non-monsoon seasons by the rainfall infiltration factor method for the non-command area is identical to that described earlier in Section 18.4.1 for the command area. The necessary computations are presented in Tables 18.5 to 18.8.

18.4.3 Poor Ground Water Quality Area

The computational procedure of obtaining rainfall recharge during monsoon and non-monsoon seasons by the rainfall infiltration factor method for the poor ground water quality area is also identical to that described earlier in Section 18.4.1 for the command area. The necessary computations are presented in Tables 18.9 to 18.12.

18.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Rainfall Recharge by Rainfall Infiltration Factor Method.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Rain gauge	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	No. of Years Data Available	Number	3	0
6	Start Year	Number	4	0
7	End Year	Number	4	0
8	Normal Monsoon Rainfall	Number	7	2
9	Normal Non-Monsoon Rainfall	Number	7	2
10	Normal Annual Rainfall	Number	7	2
11	Average Normal Monsoon Rainfall	Number	7	2
12	Average Normal Non-Monsoon Rainfall	Number	7	2
13	Average Normal Annual Rainfall	Number	7	2
14	Percentage of Non-Monsoon rainfall	Number	5	2
15	Predominant Rock Terrain	Text	30	
16	Geographic location	Text	20	
17	Hard rock type	Text	30	
18	Watershed Development Activity Present	Logical		
19	Rainfall Infiltration Factor	Number	5	2
20	Area	Number	7	0
11	Total Sub Unit Monsoon RF Recharge RFIF	Number	8	0

S.No	Parameter	Type	Size	Decimals
12	Total Sub Unit Non-Monsoon RF Recharge RFIF	Number	8	0
13	Total Sub Unit Annual RF Recharge RFIF	Number	8	0
14	Total Sub Unit Monsoon RF Recharge RFIF m	Number	7	3
15	Total Sub Unit Non-Monsoon RF Recharge RFIF m	Number	7	3
16	Total Sub Unit Annual RF Recharge RFIF m	Number	7	3

Table 18.1 Location Details and Availability of Rainfall Data for All Rain Gauges Applicable for the Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :

Principal Aquifer : Major Aquifer :

Index Number of Ground Water Assessment Unit :

S. No.	Rain Gauges applicable for the Command Area					
	Location Details			Availability of rainfall data on the basis of which normal rainfall for the rain gauge has been computed		
	Name of the Rain Gauge	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 18.2 Normal Rainfall During Monsoon and Non - monsoon Seasons in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Names of rain gauges applicable for command area	Normal rainfall in mm as obtained for the rain gauge during	
		Monsoon Season	Non-monsoon Season
(1)	(2)	(3)	`(4)
1			
2			
3			
Average of all rain gauges considered			

a) Normal monsoon season rainfall in mm for the command area [average value in Col. (3)] =

b) Normal non - monsoon season rainfall in mm for the command area [average value in Col. (4)] =

c) Annual normal rainfall in mm for the command area [(a) + (b)] =

d) Maximum Threshold Rainfall for the command area If Studies are not there 3000mm =

e) Minimum Threshold Rainfall for the command area If studies are not there [(c)*0.10) =

Table 18.3 Rainfall Infiltration Factor in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of Items (in command area)	Quantity
(1)	(2)	(3)
1	Major Aquifer	
2	Are results from documented field studies available for rainfall infiltration factor in the sub - unit (Yes/ No)	
3	If response to (5) above is 'Yes', a) Rainfall infiltration factor from field studies as a fraction b) Is the value given in '6a' above less than the minimum or greater than the maximum as specified in the norms given in Annexure IV (Yes / No)	
4	Rainfall Infiltration Factor in 'Command Area'	

Table 18.4 Rainfall Recharge in Command Area By Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for command area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Normal rainfall during [From Table 18.2] a) Monsoon season in mm b) Non - monsoon season in mm c) Minimum Threshold Rainfall in mm d) Maximum Threshold Rainfall in mm	
3	Rainfall infiltration factor as a fraction [From Table 18.3]	
4	Rainfall recharge in command area by rainfall infiltration factor method in hectare meters during a) Monsoon season [(1) * {(2d)-(2c)} * (3)/1000 if (2a) > (2d) (1) * {(2a)-(2c)} * (3)/1000 if (2a) <=(2d)] b) Non - monsoon season [= 0 if (2b) <=(2c) = (1) * {(2b)-(2c)} * (3)/1000 if (2b)>(2c)]	

Table 18.5 Location Details and Availability of Rainfall Data for All Rain Gauges Applicable for the Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Rain Gauges applicable for the Non-Command Area					
	Location Details			Availability of rainfall data on the basis of which normal rainfall for the rain gauge has been computed		
	Name of the Rain Gauge	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 18.6 Normal Rainfall During Monsoon and Non - monsoon Seasons in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Names of rain gauges applicable for non-command area	Normal rainfall in mm as obtained for the rain gauge during	
		Monsoon Season	Non-monsoon Season
(1)	(2)	(3)	`(4)
1			
2			
3			
Average of all rain gauges considered			

a) Normal monsoon season rainfall in mm for the non-command area [average value in Col. (3)] =

b) Normal non - monsoon season rainfall in mm for the non-command area [average value in Col. (4)] =

c) Annual normal rainfall in mm for the non-command area [(a) + (b)] =

d) Maximum Threshold Rainfall for the non-command area If Studies are not there 3000mm =

f) Minimum Threshold Rainfall for the non-command area If studies are not there [(c)*0.10) =

Table 18.7 Rainfall Infiltration Factor in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of Items (in non-command area)	Quantity
(1)	(2)	(3)
1	Major Aquifer	
2	Are results from documented field studies available for rainfall infiltration factor in the sub - unit (Yes/ No)	
3	If response to (5) above is 'Yes',	
	a) Rainfall infiltration factor from field studies as a fraction	
	b) Is the value given in '6a' above less than the minimum or greater than the maximum as specified in the norms given in Annexure IV (Yes / No)	
4	Rainfall Infiltration Factor in 'Non-Command Area'	

Table 18.8 Rainfall Recharge in Non-Command Area By Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for non-command area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Normal rainfall during [From Table 18.6] a) Monsoon season in mm b) Non - monsoon season in mm c) Minimum Threshold Rainfall in mm e) Maximum Threshold Rainfall in mm	
3	Rainfall infiltration factor as a fraction [From Table 18.7]	
4	Rainfall recharge in non-command area by rainfall infiltration factor method in hectare meters during a) Monsoon season [(1) * {(2d)-(2c)} * (3)/1000 if (2a) > (2d) (1) * {(2a)-(2c)} * (3)/1000 if (2a) <=(2d)] b) Non - monsoon season [= 0 if (2b) <=(2c) = (1) * {(2b)-(2c)} * (3)/1000 if (2b)>(2c)]	

Table 18.9 Location Details and Availability of Rainfall Data for All Rain Gauges Applicable for the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Rain Gauges applicable for the Poor Ground Water Quality Area					
	Location Details			Availability of rainfall data on the basis of which normal rainfall for the rain gauge has been computed		
	Name of the Rain Gauge	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 18.10 Normal Rainfall During Monsoon and Non - monsoon Seasons in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Names of rain gauges applicable for poor ground water quality area	Normal rainfall in mm as obtained for the rain gauge during	
		Monsoon Season	Non-monsoon Season
(1)	(2)	(3)	`(4)
1			
2			
3			
Average of all rain gauges considered			

a) Normal monsoon season rainfall in mm for the poor ground water quality area [average value in Col. (3)] =

b) Normal non - monsoon season rainfall in mm for the poor ground water quality area [average value in Col. (4)] =

c) Annual normal rainfall in mm for the poor ground water quality area [(a) + (b)] =

d) Maximum Threshold Rainfall for the poor ground water quality area =
If Studies are not there 3000mm

g) Minimum Threshold Rainfall for the **poor ground water quality** area=
If studies are not there [(c)*0.10)

Table 18.11 Rainfall Infiltration Factor in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of Items (in poor ground water quality area)	Quantity
(1)	(2)	(3)
1	Major Aquifer	
2	Are results from documented field studies available for rainfall infiltration factor in the sub - unit (Yes/ No)	
3	If response to (5) above is 'Yes',	
	a) Rainfall infiltration factor from field studies as a fraction	
	b) Is the value given in '6a' above less than the minimum or greater than the maximum as specified in the norms given in Annexure IV (Yes / No)	
4	Rainfall Infiltration Factor in 'poor ground water quality area'	

Table 18.12 Rainfall Recharge in Poor Ground Water Quality Area By Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (for poor ground water quality area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Normal rainfall during [From Table 18.10] a) Monsoon season in mm b) Non - monsoon season in mm c) Minimum Threshold Rainfall in mm f) Maximum Threshold Rainfall in mm	
3	Rainfall infiltration factor as a fraction [From Table 18.11]	
4	Rainfall recharge in poor ground water quality area by rainfall infiltration factor method in hectare meters during a) Monsoon season [(1) * {(2d)-(2c)} * (3)/1000 if (2a) > (2d) (1) * {(2a)-(2c)} * (3)/1000 if (2a) <=(2d)] b) Non - monsoon season [= 0 if (2b) <=(2c) = (1) * {(2b)-(2c)} * (3)/1000 if (2b)>(2c)]	

19

RAINFALL RECHARGE BY WATER TABLE FLUCTUATION METHOD

19.1 GENERAL

The water table fluctuation method is to be employed for computing rainfall recharge only for the monsoon season. The water table fluctuation method is based on a water balance approach in which, all the components of the water balance equation are used. The only component which is considered to be unknown is the rainfall recharge. Another major component in the water balance equation is the change in ground water storage during the monsoon season and this is to be estimated in this chapter. The estimation of this particular component requires the use of the water table fluctuation due to the monsoon. It is for this reason that, the method has always been somehow referred to as the water table fluctuation method. A more appropriate name for the method could however, have been, 'Rainfall Recharge by Ground Water Balance Method'.

The computational procedure in the application of the water table fluctuation method for estimating rainfall recharge during the monsoon season involves the following steps to be carried out :

a) Computing the monsoon season rainfall during the current ground water assessment year as applicable to the sub-unit.
b) Computing the water table fluctuation during the monsoon season of the current ground water assessment year as applicable to the sub-unit.
c) Assigning the specific yield value applicable to the sub-unit.
d) Application of water balance equation to compute the rainfall recharge during monsoon season of the current ground water assessment year, i.e., corresponding to the monsoon season rainfall of the current ground water assessment year.
e) Application of a normalisation procedure to compute the rainfall recharge during monsoon season corresponding to the normal monsoon season rainfall applicable for the sub-unit.
f) Compare the estimate of rainfall recharge corresponding to normal monsoon seasons rainfall as obtained in 'e' above with estimate of rainfall recharge obtained by the rainfall infiltration factor method and finally based on a set of criteria estimate the rainfall recharge during monsoon season in the sub units of the ground water assessment unit. This is done to avoid unreasonably high or low estimates of rainfall recharge.

19.2 ASSUMPTIONS

a) The water balance approach followed in the method is essentially a lumped parameter approach. Hence, the spatial variations of individual components in the water balance equation are not considered, and only a single lumped value of each component for the sub-unit as a whole is considered.

b) The specific yield of a particular sub-unit is to be assigned a value on the basis of the set of norms given in Annexure V. The recommended value specified in the norms alone are to be used, unless results from pump tests (each being of duration not less than 1000 minutes) indicate that a different value can be used. In the latter case also, the specific yield which is assigned should be within the range of the maximum and minimum values as specified in the norms. These norms also assume that the specific yield depends only on the Major aquifer of the sub unit.

c) The rainfall recharge is considered as a linear function of rainfall while carrying out the normalisation procedure for estimating the rainfall recharge during monsoon season corresponding to the normal monsoon season rainfall as applicable to the sub-unit.

19.3 COMPUTATIONAL PROCEDURE

For computing the rainfall recharge by water table fluctuation method, the data from all the available rain gauge stations and ground water monitoring stations should be used. The computations of rainfall recharge using water table fluctuation method in the assessment sub unit during monsoon season involves the following steps to be carried out :

19.3.1 Water Table Fluctuation

All the ground water monitoring stations which represent the sub unit are to be considered for computing the average fluctuation during the current assessment year as well as for the previous ground water years.

19.3.2 Specific Yield

The specific yield for the sub unit during monsoon and non-monsoon seasons are obtained either on the basis of the norms as given in Annexure V or on the basis of results from documented field studies.

19.3.3 Change in Storage

The change is storage during monsoon season is calculated using the following formula

$$Change\ in\ Storage = Area \times Specific\ Yield \times Water\ Table\ Fluctuation$$

This change in storage is not only because of the rainfall recharge but also due to recharge from other sources and the resultant inflows and it has the influence of Gross ground water extraction. Hence to calculate the rainfall recharge there is a need to apply ground water balance equation.

19.3.4 Ground Water Balance

To compute the rainfall recharge during Monsoon season the ground water balance equation to be applied. In this equation if all the other parameters are known, the rainfall recharge can be estimated. It can be done using the following equations for Command area and non-command areas respectively. The same equation used for command area can be used for poor ground water quality area also.

The ground water balance equation for command areas and poor ground water quality areas is as given below:

$$R_{RF} = h \times Sy \times A - R_{STR} - R_{C} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B$$

The ground water balance equation for non-command areas is as given below:

$$R_{RF} = h \times Sy \times A - R_{STR} - R_{SWI} - R_{GWI} - R_{TP} - R_{WCS} \pm VF \pm LF + GE + T + E + B$$

Where,

Δh - rise in water level in the monsoon season

A - area for computation of recharge

Sy - Specific Yield

R_{RF} – Rainfall recharge

Rc – Recharge from canals

R_{STR}- Recharge from streams

R_{SWI} – Recharge from surface water irrigation including lift irrigation

R_{GWI}- Recharge from ground water irrigation

R_{TP}- Recharge from tanks & ponds

R_{WCS} – Recharge from water conservation structures

VF – Vertical inter aquifer flow

LF- Lateral flow along the aquifer system (through flow)

GE-Ground water Extraction

T- Transpiration

E- Evaporation

B-Base flow

The above equations can be simplified as below:

$$\text{Rainfall Recharge} = \text{Change in Storage} - \text{Recharge due to other sources} - \text{Resultant Flows} + \text{Gross Extraction}$$

19.3.5 Normalisation Procedure

The rainfall recharge computed through the water balance approach as described in the previous section corresponds to the monsoon season rainfall of the current ground water assessment year. Similar computations made earlier for other previous ground water assessment years will have given estimates of rainfall recharge corresponding to the monsoon season rainfall of those respective ground water assessment years. All of them together result in a set of ordered pairs of data on monsoon season rainfall and their associated rainfall recharge. Each time a ground water assessment is made, one pair of data on monsoon season rainfall and its associated recharge gets added to this set.

The normalisation procedure is one in which the set of ordered pairs of data are used to estimate the rainfall recharge during monsoon season for the area corresponding to the normal monsoon season rainfall applicable to it. The rainfall recharge thus estimated after carrying out the normalisation procedure is referred to as the rainfall recharge in the area during monsoon season by the water table fluctuation method. The following scheme can be followed to carry out the normalisation procedure:

a) If the set of ordered pairs of data are such that all the rainfall recharge values are negative or nearly zero, the water table fluctuation method is dispensed with, and the rainfall recharge in the area during monsoon season is adopted as the one obtained by the rainfall infiltration factor method.

b) From among the set of ordered pairs of data, all those pairs in which the rainfall recharge values are negative or nearly zero are eliminated, and only the remaining pairs of data are used for further computations in the normalisation procedure.

c) The deviation of each monsoon season rainfall (for which the recharge has been computed) from the normal monsoon season rainfall as a percentage of the latter is to be computed. A monsoon season rainfall is normal if the deviation as defined above is between +20% and -20%. However, if the deviation is less than -20%, the associated monsoon season rainfall is below normal, and if deviation is greater than +20%, the associated monsoon season rainfall is above normal. It is ideal that the set of ordered pairs of data contain some monsoon season rainfall values which are above normal, and some others which are below normal. This will ensure that, the normalisation procedure, which is some form of interpolation, is more accurate.

d) With the rainfall recharge ordered pairs data, two methods can be followed for the normalisation procedure.

e) The first method which is relatively more simple allows rainfall recharge for normal monsoon season rainfall to be obtained directly from each pair of rainfall and recharge data. This method can be therefore followed even if only one ordered pair of rainfall and recharge data is available. If more than one pair of data are available, the rainfall recharge corresponding to normal monsoon season rainfall can be calculated for each pair, and an average of those values can be then obtained.

f) The second method involves application of linear regression analysis. Though this method can be theoretically applied even if the number of ordered pairs of data, is only two, it is recommended that, this method should be made use of only if the data pairs are greater than or equal to 5. The linear regression analysis makes use of the pairs of data on monsoon season rainfall, r(i) and its associated rainfall recharge R(i). In order to avoid handling numbers with large magnitude, the rainfall, r(i) is expressed in metres (with an accuracy of 3 decimal places), and the recharge, R(i) is expressed in thousand hectare metres (with an accuracy of 3 decimal places).

19.3.6 Rainfall Recharge

The water table fluctuation method as described above may yield rainfall recharge estimates which are either unreasonably high or unreasonably low. This is taken care of by:

a) first computing a term Percent Deviation (PD) which is the difference between the rainfall recharge by the water table fluctuation method and that by the rainfall infiltration factor method expressed as a percentage of the latter
b) finally assigning a value for the rainfall recharge during monsoon season in the sub unit on the basis of a set of criteria which depends on the computed value of PD.
c) The set of criteria to be adopted in the above scheme are
    i) if PD is greater than or equal to -20%, and less than or equal to +20%, the rainfall recharge is taken as that obtained by the water table fluctuation method.
    ii) if PD is less than -20%, the rainfall recharge is taken as equal to 0.8 times the value obtained by the rainfall infiltration factor method.
    iii) if PD is greater than +20%, the rainfall recharge is taken as equal to 1.2 times the value obtained by the rainfall infiltration factor method.

19.4 FORMATS SUGGESTED FOR THE COMPUTATION

19.4.1 Command Area

The computation of monsoon season rainfall for the current ground water assessment year as applicable to the command area is presented in Table 19.1. The computations of water table fluctuation during the monsoon season of the current ground water assessment year as applicable to the command area is presented in Table 19.2. The procedure followed for assigning a value for the specific yield as applicable for the command area is presented in Table 19.3.

The computations of rainfall recharge during monsoon season of the current ground water assessment year for the command area through the use of ground water balance equation is presented in Table 19.4. Similarly for the previous years based on the data of recharges, ground water extraction, resultant flows and the change in storage the rainfall recharge can be assessed. This computation is done in Table 19.5.

The set of ordered pairs of data on monsoon season rainfall and their associated rainfall recharge for the command area is presented in Table 19.6. From this valid set of ordered pairs of data is prepared in Table 19.7. There can be two methods of normalization. The first method which is relatively more simple allows rainfall recharge for normal monsoon season rainfall to be obtained directly from each pair of rainfall and recharge data. The computational procedure followed in this method is presented in Table 19.8. The computational procedure followed in the second method is presented in Table 19.9. The computational procedure for deciding on the final rainfall recharge is presented in Table 19.10. The summary of the rainfall recharge in the assessment sub unit is presented in Table 19.11.

19.4.2 Non-command Area

The computational procedure for obtaining rainfall recharge during monsoon season using water table fluctuation method for the non-command area is identical to that described earlier in Section 19.4.1 for the command area. The necessary computations are presented in Tables 19.12 to 19.22.

19.4.3 Poor Groundwater Quality Area

The computational procedure of obtaining rainfall recharge during monsoon season using water table fluctuation method for the poor ground water quality area is also identical to that described earlier in Section 19.4.1 for the command area. The necessary computations are presented in Tables 19.23 to 19.33.

19.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Rainfall Recharge by Water Table Fluctuation Method.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Rain gauge	Text	50	
3	Current year Monsoon Rainfall	Number	7	2
4	Average Current Year Monsoon Rainfall	Number	7	2
5	Name of Observation well	Text	50	
6	Current year Pre Monsoon WL	Number	6	2
7	Current year Post Monsoon WL	Number	6	2
8	Average Current Year Pre Monsoon WL	Number	6	2
9	Average Current Year Post Monsoon WL	Number	6	2
10	Average Current Year WL Fluctuation	Number	6	2
11	Predominant Rock Terrain	Text	30	
12	Soil Type	Text	20	
13	Hard rock type	Text	30	
14	Specific Yield	Number	5	2
15	Area	Number	7	0
16	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
17	Total Sub Unit All Uses Monsoon Extraction	Number	8	0
18	Total Sub Unit Monsoon Change in GW Storage	Number	8	0
19	Total Sub Unit Monsoon RF Recharge WTFM	Number	8	0
20	Ground Water year	Number	4	0
21	Monsoon Rainfall m	Number	7	3
22	Corresponding Monsoon RF Recharge WTFM THam	Number	7	3
23	Deviation Monsoon RF with Normal	Number	5	2
24	Normal RF RechargeY=mX	Number	7	3
25	Average Normal RF RechargeY=mX	Number	7	3
26	Rainfall Square	Number	7	3
27	Product of Rainfall and Recharge	Number	7	3
28	Sum Rainfall	Number	7	3
29	Sum Recharge	Number	7	3

S.No	Parameter	Type	Size	Decimals
30	Sum Rainfall Square	Number	7	3
31	Sum Product	Number	7	3
32	Number of Data Points	Number	2	0
33	Slope	Number	7	3
34	Intercept	Number	7	3
35	Normal RF RechargeY=mX+C	Number	7	3
36	Percent Difference	Number	6	2
37	Normalised RF Recharge	Number	7	0
38	Final RF Recharge Monsoon	Number	7	0
39	Final RF Recharge Monsoon m	Number	7	3
40	Final RF Recharge Non Monsoon	Number	7	0
41	Final RF Recharge Non-Monsoon m	Number	7	3
42	Final RF Recharge Annual	Number	7	0
43	Final RF Recharge Annual m	Number	7	3

Table 19.1 Rainfall During Monsoon Season of the Current Ground Water Assessment Year in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Rain gauges applicable for command area	
	Name	Rainfall during monsoon season of current ground water assessment year as recorded in the rain gauge
(1)	(2)	(3)
1		
2		
3		
Monsoon season rainfall in mm during current ground water assessment year in command area (average of rainfall recorded at all rain gauges considered)		

Table 19.2 Water Table Fluctuation During Monsoon Season of Current Ground Water Assessment Year in Command Area

Name of Ground Water Assessment Unit	:
Principal Aquifer	:
Major Aquifer	:
Index Number of Ground Water Assessment Unit	:
Ground Water Assessment Year	:

S.No	Observation wells in the command area		
	Name	Depth to water table below ground level in meters in the observation wells as recorded in current ground water assessment year	
		Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)
1			
2			
3			
Average of water levels recorded at all wells considered		y1=	y2=

a) Water table fluctuation in meters during monsoon season of the current ground water assessment year in command area [y_1 - y_2] =

Table 19.3 Specific Yield in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for command area)	Quantity
(1)	(2)	(3)
1	Major Aquifer	
2	Are results of specific yield available from pump tests (Yes / No)	
3	If (2) is 'Yes', a) Specific yield from pump tests as a fraction b) Is the value in '3a' less than the minimum or greater than the maximum as specified in Annexure V (Yes / No)	
4	Specific Yield in Command Area as a Fraction	

Table 19.4 Ground Water Balance Computations During Monsoon Season of Current Ground Water Assessment Year In Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for command area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Recharge from 'Other Sources' in hectare meters during monsoon season [From Table 9.1]	
3	Resultant Flows in hectare meters during monsoon season [From Table 17.1]	
4	Gross ground water extraction for 'All Uses' during monsoon season in hectare meters [From Table 3.13]	
5	Water table fluctuation in meters during monsoon season [From Table 19.2]	
6	Specific yield as a fraction [From Table 19.3]	
7	Change in ground water storage in hectare meters during monsoon season [(1) * (5) * (6)]	
8	Rainfall recharge in hectare meters during monsoon season in command area by ground water balance approach [(7) + (4) - (3) - (2)]	
9	Rainfall in mm during monsoon season in command area for which the rainfall recharge in (8) above corresponds to [From Table 19.1]	

Table 19.5 Ground Water Balance Computations During Monsoon Season of the Past Ground Water Assessment Years in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Index Number of Ground Water Assessment Unit :

Ground Water Assessment Year :
Major Aquifer :

S.No	Year	Ground Water fluctuation in meters	Specific Yield as Fraction	Area of the sub unit in hectares	Change in Storage in hectare meters	Recharge due to other sources in hectare meters	Resultant flows in hectare meters	Gross ground Water extraction for all uses In hectare meters	Rainfall Recharge in hectare meters	Rainfall in mm during monsoon season
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1										
2										
3										

Note: All the above data to be extracted from Table 19.15 for the respective ground water assessment years.

Table 19.6 Complete Set of Data on Monsoon Season Rainfall And Corresponding Rainfall Recharge in Command Area as obtained by Ground Water Balance Approach

Name of Ground Water Assessment Unit	:	
Principal Aquifer	:	
Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:	
Ground Water Assessment Year	:	

S.No	Ground water year	Monsoon season rainfall in millimeters	Rainfall recharge during monsoon season in hectare meters
	[From Table 19.5]		
(1)	(2)	(3)	(4)
1			
2			
3			

Note : The last pair of data on monsoon season rainfall and its corresponding rainfall recharge as given above is for the current ground water assessment year

Table 19.7 Valid Set of Data on Monsoon Season Rainfall and Corresponding Rainfall Recharge in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Command Area in mm, 'NMR' =
[From Table 18.2]

S.No	Ground water year	Monsoon season rainfall in millimeters	Rainfall recharge during monsoon season in hectare meters	Deviation of monsoon season rainfall from normal monsoon season rainfall value as a percentage
	[From Table 19.6]			$\frac{(3) - NMR}{NMR} \times 100$
(1)	(2)	(3)	(4)	(5)
1				
2				
3				

Note : Only those ground water years in Table 19.6 are considered for which rainfall recharge values during monsoon season are neither negative nor nearly zero

Table 19.8 Rainfall Recharge During Monsoon Season in Command Area by Water Table Fluctuation Method (Using Normalisation Procedure No.1)

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Command Area in mm, 'NMR' =
[From Table 18.2]

S.No	Rainfall during monsoon season in mm	Corresponding rainfall recharge in hectare meters	Recharge corresponding to normal monsoon season rainfall in hectare meters
	[From Table 19.7]		$\frac{NMR \times (3)}{(2)}$
(1)	(2)	(3)	(4)
1			
2			
3			
Rainfall recharge during monsoon season in hectare meters in command area by 'Water Table Fluctuation Method' [Average of recharge values in Col. (4)]			

Note : This normalisation procedure assumes that the relation between recharge, 'y' and rainfall, 'x' is of the form, y = a * x where 'a' is a constant.

Table 19.9 Rainfall Recharge During Monsoon Season in Command Area by Water Table Fluctuation Method (Using Normalisation Procedure No.2 which Employs Linear Regression Analysis)

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Command Area in meters, 'NMR' =
[From Table 18.2]

S.No	Rainfall during monsoon season in meters x(i)	Corresponding rainfall recharge in thousand hectare meters y(i)	$(x(i))^2$	x(i) * y(i)
	[From Table 19.7]			
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered , 'N' =

A) Regression Constants 'a' and 'b' in y = a * x + b

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2}$$

$$b = \frac{S_2 - aS_1}{N}$$

B) Rainfall recharge during monsoon season in hectare meters =
in command area by 'Water Table Fluctuation Method'
[(a * 'NMR' + b) * 1000]

Table 19.10 Rainfall Recharge During Monsoon Season in Command Area After Comparing Results From Water Table Fluctuation Method and Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in command area)	Quantity
1	Is the water table fluctuation method used for computing rainfall recharge during monsoon season (Yes/No)	
2	If response to (1) is 'NO' * Rainfall recharge during monsoon season in hectare meters in command area (Same as by rainfall infiltration factor method) [From Table 18.4]	
3	If response to (1) is 'YES' * Rainfall recharge during monsoon season in hectare meters in command area a) By Water Table Fluctuation Method [From Table 19.8 or 19.9] b) By Rainfall Infiltration Factor Method [From Table 18.4] * Difference between (3a) and (3b) expressed as a percentage of (3b), 'PD' $\frac{(3a)-(3b)}{(3b)}\times 100$ * Rainfall recharge during monsoon season in hectare meters in command area [= (3a) if 'PD' is between - 20 and + 20% = 0.8 * (3b) if 'PD' is less than - 20% = 1.2 * (3b) if 'PD' is greater than + 20%]	

Table 19.11 Summary of Recharge from Rainfall in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in command area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Is recharge from rainfall during monsoon season computed by 'Water Table Fluctuation Method' (Yes / No)	
3	Recharge from rainfall during monsoon season (By water table fluctuation method if (2) is 'Yes', or by rainfall infiltration method if (2) is 'No')	
	a) in hectare meters [From Table 19.10]	
	b) per unit area in mm [((3a) / (1))*1000]	
4	Recharge from rainfall during non - monsoon season (By rainfall infiltration factor method)	
	a) in hectare meters [From Table 18.4]	
	b) per unit area in mm [((4a) / (1))*1000]	
5	Annual recharge from rainfall in command area	
	a) in hectare meters [(3a) + (4a)]	
	b) per unit area in mm [(3b) + (4b)]	

Table 19.12 Rainfall During Monsoon Season of the Current Ground Water Assessment Year in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Rain gauges applicable for non-command area	
	Name	Rainfall during monsoon season of current ground water assessment year as recorded in the rain gauge
(1)	(2)	(3)
1		
2		
3		
Monsoon season rainfall in mm during current ground water assessment year in non-command area (average of rainfall recorded at all rain gauges considered)		

Table 19.13 Water Table Fluctuation During Monsoon Season of Current Ground Water Assessment Year in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Observation wells in the non-command area		
	Name	Depth to water table below ground level in meters in the observation well as recorded in current ground water assessment year	
		Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)
1			
2			
3			
Average of water levels recorded at all the wells considered		y1=	y2=

a) Water table fluctuation in meters during monsoon season of the current ground water assessment year in non-command area [y_1 - y_2] =

Table 19.14 Specific Yield in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for non-command area)	Quantity
(1)	(2)	(3)
1	Major Aquifer	
2	Are results of specific yield available from pump tests (Yes / No)	
3	If (2) is 'Yes', a) Specific yield from pump tests as a fraction b) Is the value in '3a' less than the minimum or greater than the maximum as specified in Annexure V (Yes / No)	
4	Specific Yield in Non-Command Area as a Fraction	

Table 19.15 Ground Water Balance Computations During Monsoon Season of Current Ground Water Assessment Year In Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for non-command area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Recharge from 'Other Sources' in hectare meters during monsoon season [From Table 9.2]	
3	Resultant Flows in hectare meters during monsoon season [From Table 17.2]	
4	Gross ground water extraction for 'All Uses' during monsoon season in hectare meters [From Table 3.26]	
5	Water table fluctuation in meters during monsoon season [From Table 19.13]	
6	Specific yield as a fraction [From Table 19.14]	
7	Change in ground water storage in hectare meters during monsoon season [(1) * (5) * (6)]	
8	Rainfall recharge in hectare meters during monsoon season in non-command area by ground water balance approach [(7) + (4) - (3) - (2)]	
9	Rainfall in mm during monsoon season in non- command area for which the rainfall recharge in (8) above corresponds to [From Table 19.12]	

Table 19.16 Ground Water Balance Computations During Monsoon Season of the Past Ground Water Assessment Years in Non-Command Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S.No	Year	Ground Water fluctuation in meters	Specific Yield as Fraction	Area of the sub unit in hectares	Change in Storage in hectare meters	Recharge due to other sources in hectare meters	Resultant flows in hectare meters	Gross ground Water extraction for all uses In hectare meters	Rainfall Recharge in hectare meters	Rainfall in mm during monsoon season
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1										
2										
3										

Note: All the above data to be extracted from Table 19.15 for the respective ground water assessment years.

Table 19.17 Complete Set of Data on Monsoon Season Rainfall and Corresponding Rainfall Recharge in Non-Command Area as obtained by Ground Water Balance Approach

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Ground water year	Monsoon season rainfall in millimeters	Rainfall recharge during monsoon season in hectare meters
	[From Table 19.16]		
(1)	(2)	(3)	(4)
1			
2			
3			

Note : The last pair of data on monsoon season rainfall and its corresponding rainfall recharge as given above is for the current ground water assessment year

Table 19.18 Valid Set of Data on Monsoon Season Rainfall and Corresponding Rainfall Recharge in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Non-Command Area in mm, 'NMR' =
[From Table 18.6]

S.No	Ground water year	Monsoon season rainfall in millimeters	Rainfall recharge during monsoon season in hectare meters	Deviation of monsoon season rainfall from normal monsoon season rainfall value as a percentage
	[From Table 19.17]			$\frac{(3) - NMR}{NMR} \times 100$
(1)	(2)	(3)	(4)	(5)
1				
2				
3				

Note : Only those ground water years in Table 19.17 are considered for which rainfall recharge values during monsoon season are neither negative nor nearly zero

Table 19.19 Rainfall Recharge During Monsoon Season in Non-Command Area by Water Table Fluctuation Method (Using Normalisation Procedure No.1)

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Non-Command Area in mm, 'NMR' =
[From Table 18.6]

S.No	Rainfall during monsoon season in mm	Corresponding rainfall recharge in hectare meters	Recharge corresponding to normal monsoon season rainfall in hectare meters
	[From Table 19.18]		$\frac{NMR \times (3)}{(2)}$
(1)	(2)	(3)	(4)
1			
2			
3			
Rainfall recharge during monsoon season in hectare meters in command area by 'Water Table Fluctuation Method' [Average of recharge values in Col. (4)]			

Note : This normalisation procedure assumes that the relation between recharge, 'y' and rainfall, 'x' is of the form, y = a * x where 'a' is a constant.

Table 19.20 Rainfall Recharge During Monsoon Season in Non-Command Area by Water Table Fluctuation Method (Using Normalisation Procedure No.2 which Employs Linear Regression Analysis)

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Non-Command Area in meters, 'NMR' =
[From Table 18.6]

S.No	Rainfall during monsoon season in meters x(i)	Corresponding rainfall recharge in thousand hectare meters y(i)	$(x(i))^2$	x(i) * y(i)
	[From Table 19.18]			
(1)	(2)	(3)	(4)	(5)
1 2 3				
N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered , 'N' =

A) Regression Constants 'a' and 'b' in y = a * x + b

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2}$$

$$b = \frac{S_2 - aS_1}{N}$$

B) Rainfall recharge during monsoon season in hectare meters =
in non-command area by 'Water Table Fluctuation Method'
[(a * 'NMR' + b) * 1000]

Table 19.21 Rainfall Recharge During Monsoon Season in Non-Command Area after Comparing Results from Water Table Fluctuation Method and Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in non-command area)	Quantity
1	Is the water table fluctuation method used for computing rainfall recharge during monsoon season (Yes/No)	
2	If response to (1) is 'NO' * Rainfall recharge during monsoon season in hectare meters in non-command area (Same as by rainfall infiltration factor method) [From Table 18.8]	
3	If response to (1) is 'YES' * Rainfall recharge during monsoon season in hectare meters in non-command area a) By Water Table Fluctuation Method [From Table 19.19 or 19.20] b) By Rainfall Infiltration Factor Method [From Table 18.8] * Difference between (3a) and (3b) expressed as a percentage of (3b), 'PD' $\frac{(3a)-(3b)}{(3b)} \times 100$ * Rainfall recharge during monsoon season in hectare meters in non-command area [= (3a) if 'PD' is between - 20 and + 20% = 0.8 * (3b) if 'PD' is less than - 20% = 1.2 * (3b) if 'PD' is greater than + 20%]	

Table 19.22 Summary of Recharge from Rainfall in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in non-command area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Is recharge from rainfall during monsoon season computed by 'Water Table Fluctuation Method' (Yes / No)	
3	Recharge from rainfall during monsoon season (By water table fluctuation method if (2) is 'Yes', or by rainfall infiltration method if (2) is 'No')	
	a) in hectare meters [From Table 19.21]	
	b) per unit area in mm [(3a) / (1)]	
4	Recharge from rainfall during non - monsoon season (By rainfall infiltration factor method)	
	a) in hectare meters [From Table 18.8]	
	b) per unit area in mm [((4a) / (1))*1000]	
5	Annual recharge from rainfall in non-command area	
	a) in hectare meters [((3a) + (4a))*1000]	
	b) per unit area in mm [(3b) + (4b)]	

Table 19.23 Rainfall During Monsoon Season of the Current Ground Water Assessment Year in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Rain gauges applicable for poor ground water quality area	
	Name	Rainfall during monsoon season of current ground water assessment year as recorded in the rain gauge
(1)	(2)	(3)
1		
2		
3		
Monsoon season rainfall in mm during current ground water assessment year in poor ground water quality area (average of rainfall recorded at all the rain gauges considered)		

Table 19.24 Water Table Fluctuation During Monsoon Season of Current Ground Water Assessment Year in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Observation wells in the poor ground water quality area		
	Name	Depth to water table below ground level in meters in the observation wells as recorded in current ground water assessment year	
		Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)
1			
2			
3			
Average of water levels recorded at all wells considered		y1=	y2=

a) Water table fluctuation in meters during monsoon season of the current ground water assessment year in poor ground water quality area =
[y_1 - y_2]

Table 19.25 Specific Yield in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for poor ground water quality area)	Quantity
(1)	(2)	(3)
1	Major Aquifer	
2	Are results of specific yield available from pump tests (Yes / No)	
3	If (2) is 'Yes', a) Specific yield from pump tests as a fraction b) Is the value in '3a' less than the minimum or greater than the maximum as specified in Annexure V (Yes / No)	
4	Specific Yield in poor ground water quality Area as a Fraction	

Table 19.26 Ground Water Balance Computations During Monsoon Season of Current Ground Water Assessment Year in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for poor ground water quality area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Recharge from 'Other Sources' in hectare meters during monsoon season [From Table 9.3]	
3	Resultant Flows in hectare meters during monsoon season [From Table 17.3]	
4	Gross ground water extraction for 'All Uses' during monsoon season in hectare meters [From Table 3.39]	
5	Water table fluctuation in meters during monsoon season [From Table 19.24]	
6	Specific yield as a fraction [From Table 19.25]	
7	Change in ground water storage in hectare meters during monsoon season [(1) * (5) * (6)]	
8	Rainfall recharge in hectare meters during monsoon season in poor ground water quality area by ground water balance approach [(7) + (4) - (3) - (2)]	
9	Rainfall in mm during monsoon season in poor ground water quality area for which the rainfall recharge in (8) above corresponds to [From Table 19.23]	

Table 19.27 Ground Water Balance Computations During Monsoon Season of the Past Ground Water Assessment Years in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S.No	Year	Ground Water fluctuation in meters	Specific Yield as Fraction	Area of the sub unit in hectares	Change in Storage in hectare meters	Recharge due to other sources in hectare meters	Resultant flows in hectare meters	Gross ground Water extraction for all uses In hectare meters	Rainfall Recharge in hectare meters	Rainfall in mm during monsoon season
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1										
2										
3										

Note: All the above data to be extracted from Table 19.26 for the respective ground water assessment years.

Table 19.28 Complete Set of Data on Monsoon Season Rainfall And Corresponding Rainfall Recharge in Poor Ground Water Quality Area As obtained by Ground Water Balance Approach

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Ground water year	Monsoon season rainfall in millimeters	Rainfall recharge during monsoon season in hectare meters
	[From Table 19.27]		
(1)	(2)	(3)	(4)
1			
2			
3			

Note : The last pair of data on monsoon season rainfall and its corresponding rainfall recharge as given above is for the current ground water assessment year

Table 19.29 Valid Set of Data on Monsoon Season Rainfall And Corresponding Rainfall Recharge in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Poor Ground Water Quality Area in mm, 'NMR' =
[From Table 18.10]

S.No	Ground water year	Monsoon season rainfall in millimeters	Rainfall recharge during monsoon season in hectare meters	Deviation of monsoon season rainfall from normal monsoon season rainfall value as a percentage
	[From Table 19.28]			$\frac{(3) - NMR}{NMR} \times 100$
(1)	(2)	(3)	(4)	(5)
1				
2				
3				

Note : Only those ground water years in Table 19.28 are considered for which rainfall recharge values during monsoon season are neither negative nor nearly zero

Table 19.30 Rainfall Recharge During Monsoon Season in Poor Ground Water Quality Area By Water Table Fluctuation Method (Using Normalisation Procedure No.1)

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Poor Ground Water Quality Area in mm, 'NMR' =
[From Table 18.10]

S.No	Rainfall during monsoon season in mm	Corresponding rainfall recharge in hectare meters	Recharge corresponding to normal monsoon season rainfall in hectare meters $\frac{NMR \times (3)}{(2)}$
	[From Table 19.29]		
(1)	(2)	(3)	(4)
1			
2			
3			
Rainfall recharge during monsoon season in hectare meters in poor ground water quality area by 'Water Table Fluctuation Method' [Average of recharge values in Col. (4)]			

Note : This normalisation procedure assumes that the relation between recharge, 'y' and rainfall, 'x' is of the form, y = a * x where 'a' is a constant.

Table 19.31 Rainfall Recharge During Monsoon Season in Poor Ground Water Quality Area by Water Table Fluctuation Method (Using Normalisation Procedure No.2 which Employs Linear Regression Analysis)

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Normal Monsoon Season Rainfall in Poor Ground Water Quality Area in meters, 'NMR' =
[From Table 18.10]

S.No	Rainfall during monsoon season in meters x(i)	Corresponding rainfall recharge in thousand hectare meters y(i)	$(x(i))^2$	x(i) * y(i)
	[From Table 19.29]			
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered , 'N' =

A) Regression Constants 'a' and 'b' in y = a * x + b

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2}$$

$$b = \frac{S_2 - aS_1}{N}$$

B) Rainfall recharge during monsoon season in hectare meters =
in poor ground water quality area by 'Water Table Fluctuation Method'
[(a * 'NMR' + b) * 1000]

Table 19.32 Rainfall Recharge During Monsoon Season in Poor Ground Water Quality Area after Comparing Results from Water Table Fluctuation Method and Rainfall Infiltration Factor Method

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in poor ground water quality area)	Quantity
1	Is the water table fluctuation method used for computing rainfall recharge during monsoon season (Yes/No)	
2	If response to (1) is 'NO' * Rainfall recharge during monsoon season in hectare meters in poor ground water quality area (Same as by rainfall infiltration factor method) [From Table 18.12]	
3	If response to (1) is 'YES' * Rainfall recharge during monsoon season in hectare meters in poor ground water quality area a) By Water Table Fluctuation Method [From Table 19.30 or 19.31] b) By Rainfall Infiltration Factor Method [From Table 18.12] * Difference between (3a) and (3b) expressed as a percentage of (3b), 'PD' $\frac{(3a)-(3b)}{(3b)} \times 100$ * Rainfall recharge during monsoon season in hectare meters in poor ground water quality area [= (3a) if 'PD' is between - 20 and + 20% = 0.8 * (3b) if 'PD' is less than - 20% = 1.2 * (3b) if 'PD' is greater than + 20%]	

Table 19.33 Summary of Recharge from Rainfall in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in poor ground water quality area)	Quantity
(1)	(2)	(3)
1	Area in hectares [From Table 2.1]	
2	Is recharge from rainfall during monsoon season computed by 'Water Table Fluctuation Method' (Yes / No)	
3	Recharge from rainfall during monsoon season (By water table fluctuation method if (2) is 'Yes', or by rainfall infiltration method if (2) is 'No')	
	a) in hectare meters [From Table 19.32]	
	b) per unit area in mm [((3a) / (1))*1000]	
4	Recharge from rainfall during non - monsoon season (By rainfall infiltration factor method)	
	a) in hectare meters [From Table 18.12]	
	b) per unit area in mm [((4a) / (1))*1000]	
5	Annual recharge from rainfall in poor ground water quality area	
	a) in hectare meters [(3a) + (4a)]	
	b) per unit area in mm [(3b) + (4b)]	

20

ANNUAL EXTRACTABLE GROUND WATER RESOURCE

20.1 GENERAL

The computation of annual extractable ground water resource in a given sub-unit comprises of the following steps to be carried out :

a) Obtaining the total annual ground water resource as the sum of recharge from rainfall and recharge from 'Other Sources' and the accumulations during both monsoon and non-monsoon seasons.
b) Estimating a value for the Ecological flow of the streams.
c) Obtaining the annual extractable ground water resource by subtracting 'b' from 'a'.

20.2 ASSUMPTIONS

The estimation of annual extractable ground water resource is based on the following assumptions :

a) The ecological flows in the streams are essential for maintaining the eco system. If estimated by any accepted methods the same may be used in the computations for assessing the annual extractable ground water resource.
b) Even though in some assessment units there may much base flow because of the less extraction of ground water. Normally the ecological flows will be less than this base flow. In these situations using base flow as ecological flow may result in considering less resources for the future developmental activities.
c) The base flow is already subtracted as outflow from the system while computing Annual Ground Water Resource and whenever the base flow is less than the Environmental Flow, the difference should be subtracted from Total Annual Ground Water Resource to compute Annual Extractable Ground Water Resource.
d) If the Environmental flow is less than base flow, then the difference to be added to the Total Annual Ground Water Resource to compute Annual Extractable Ground Water Resource.
e) If the estimated base flow is equal to the Environmental Flow, then Annual Extractable Ground Water Resource is equal to the Total Annual Ground Water Resource.

f) If the ecological flows are not assessed in an accepted method, then 5 or 10% of total annual ground water resource may be taken as the quantum of ecological flow.
g) The ecological flows are assigned as 5 percent of the total annual ground water resource if water table fluctuation method has been employed to compute rainfall recharge during monsoon season.
h) The ecological flows are assigned as 10 percent of the total annual ground water resource if rainfall infiltration factor method alone has been employed to compute rainfall recharge during monsoon season also.

20.3 FORMATS SUGGESTED FOR THE COMPUTATION

20.3.1 Command Area

The computations for obtaining the Annual Extractable ground Water Resource in the command area are presented in Table 20.1 .

20.3.2 Non-Command Area

The computations for obtaining the Annual Extractable ground Water Resource in the non-command area are presented in Table 20.2 .

20.3.3 Poor Ground Water Quality Area

The computations for obtaining the Annual Extractable ground Water Resource in the poor ground water quality area are presented in Table 20.3 .

20.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Annual Extractable Ground Water Resource.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Total Sub Unit Monsoon Recharge Other Sources	Number	8	0
3	Total Sub Unit Non-Monsoon Recharge Other Sources	Number	8	0
4	Total Sub Unit Annual Recharge Other Sources	Number	8	0
5	Total Sub Unit Resultant Inflows During Monsoon Season	Number	8	0
6	Total Sub Unit Resultant Inflows During Non-Monsoon Season	Number	8	0
7	Final RF Recharge Monsoon	Number	7	0
8	Final RF Recharge Non Monsoon	Number	7	0
9	Final RF Recharge Annual	Number	7	0
10	Total Annual Ground Water resource	Number	8	0
11	Base Flow	Number	8	0
12	Environmental Flow	Number	8	0
13	Annual Extractable Ground Water Resource	Number	8	0
14	Area	Number	7	0
15	Annual Extractable Ground Water Resource m	Number	7	3

Table 20.1 Annual Extractable Ground Water Resource in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in command area)	Quantity
1	Rainfall recharge in hectare meters a) During monsoon season [From Table 19.11] b) During non - monsoon season [From Table 19.11] c) Annual [(1a) + (1b)]	
2	Recharge from 'Other Sources' in hectare meters a) During monsoon season [From Table 9.1] b) During non - monsoon season [From Table 9.1] c) Annual [(1a) + (1b)]	
3	Resultant Flows into the Sub Unit in hectare meters a) During monsoon season [From Table 17.1] b) During non - monsoon season [From Table 17.1] c) Annual [(1a) + (1b)]	
4	Total annual ground water resource in hectare meters [(1c) + (2c) + (3c)]	
5	Annual Base flow Estimated [From Table 11.11]	
6	Are Environmental Flows Assessed (Yes/No)	
7	If response to (5) is Yes Assessed Environmental Flows	
8	If response to (5) is No Is rainfall recharge during monsoon season computed by 'Water Table Fluctuation Method' (Yes/No)	
9	Environmental Flows in hectare meters [0.05 * (3) if response to (6) is 'No' and (8) is Ýes and, 0.10 * (3) if response to (6) is 'No' and (8) is 'No]	
10	Annual Extractable Ground Water Resource in command area in hectare meters If response to (6) is Yes [(3) +(5)- (7)] If response to (6) is No [(3) +(5) - (9)]	
11	Area in hectares of command area [From Table 2.1]	
12	Annual Extractable Ground Water Resource in command area per unit area in millimeters [((10) / (11)) * 1000]	

Table 20.2 Annual Extractable Ground Water Resource in Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in non-command area)	Quantity
1	Rainfall recharge in hectare meters a) During monsoon season [From Table 19.22] b) During non - monsoon season [From Table 19.22] c) Annual [(1a) + (1b)]	
2	Recharge from 'Other Sources' in hectare meters a) During monsoon season [From Table 9.2] b) During non - monsoon season [From Table 9.2] c) Annual [(1a) + (1b)]	
3	Resultant Flows into the Sub Unit in hectare meters a) During monsoon season [From Table 17.2] b) During non - monsoon season [From Table 17.2] c) Annual [(1a) + (1b)]	
4	Total annual ground water resource in hectare meters [(1c) + (2c) + (3c)]	
5	Annual Base flow Estimated [From Table 11.11]	
6	Are Environmental Flows Assessed (Yes/No)	
7	If response to (5) is Yes Assessed Environmental Flows	
8	If response to (5) is No Is rainfall recharge during monsoon season computed by 'Water Table Fluctuation Method' (Yes/No)	
9	Environmental Flows in hectare meters [0.05 * (3) if response to (6) is 'No' and (8) is Ýes and, 0.10 * (3) if response to (6) is 'No' and (8) is 'No]	
10	Annual Extractable Ground Water Resource in Non-command area in hectare meters If response to (6) is Yes [(3) +(5)- (7)] If response to (6) is No [(3) +(5) - (9)]	
11	Area in hectares of non-command area [From Table 2.1]	
12	Annual Extractable Ground Water Resource in Non-command area per unit area in millimeters [((10) / (11)) * 1000]	

Table 20.3 Annual Extractable Ground Water Resource in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item (in poor ground water quality area)	Quantity
1	Rainfall recharge in hectare meters a) During monsoon season [From Table 19.22] b) During non - monsoon season [From Table 19.22] c) Annual [(1a) + (1b)]	
2	Recharge from 'Other Sources' in hectare meters a) During monsoon season [From Table 9.2] b) During non - monsoon season [From Table 9.2] c) Annual [(1a) + (1b)]	
3	Resultant Flows into the Sub Unit in hectare meters a) During monsoon season [From Table 17.2] b) During non - monsoon season [From Table 17.2] c) Annual [(1a) + (1b)]	
4	Total annual ground water resource in hectare meters [(1c) + (2c) + (3c)]	
5	Annual Base flow Estimated [From Table 11.11]	
6	Are Environmental Flows Assessed (Yes/No)	
7	If response to (5) is Yes Assessed Environmental Flows	
8	If response to (5) is No Is rainfall recharge during monsoon season computed by 'Water Table Fluctuation Method' (Yes/No)	
9	Environmental Flows in hectare meters [0.05 * (3) if response to (6) is 'No' and (8) is Ýes and, 0.10 * (3) if response to (6) is 'No' and (8) is 'No]	
10	Annual Extractable Ground Water Resource in Poor ground water quality area in hectare meters If response to (6) is Yes [(3) +(5)- (7)] If response to (6) is No [(3) +(5) - (9)]	
11	Area in hectares of Poor ground water quality area [From Table 2.1]	
12	Annual Extractable Ground Water Resource in Poor ground water quality area per unit area in millimeters [((10) / (11)) * 1000]	

21

STAGE OF GROUND WATER EXTRACTION

21.1 GENERAL

The current annual gross ground water extraction for 'All Uses' in the sub-units of the assessment unit have been presented in Chapter 3. The annual extractable ground water resource in these sub-units have been presented in Chapter 20. These results are made use of to obtain the stage of ground water extraction in these sub-units. The stage of ground water extraction in a given sub-unit is defined as the current annual gross ground water extraction for 'All Uses' in that sub-unit expressed as a percentage of the annual extractable ground water resource in that sub-unit.

21.2 COMPUTATIONAL PROCEDURE

Let the annual extractable ground water resource in a given sub-unit in hectare meters be 'B' and the current annual gross ground water extraction for 'All Uses' in that sub-unit be 'C'. The stage of ground water extraction in that sub-unit, 'A' as a percentage can be then obtained as,

$$A = (C / B) * 100$$

21.3 FORMATS SUGGESTED FOR THE COMPUTATION

The computations for obtaining the stage of ground water extraction in the sub units are presented in Table 21.1.

21.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the stage of ground water extraction.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Annual Extractable Ground Water Resource	Number	8	0
3	Total Sub Unit All Uses Annual Extraction	Number	8	0
4	Stage of Ground Water Extraction	Number	6	2

Table 21.1 Stage of Ground Water Extraction in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description	Command Area	Non - Command Area	Poor Ground Water Quality Area	Total Assessment Unit
(1)	(2)	(3)	(4)	(5)	(7)
1	Annual Extractable Ground Water Resource in hectare meters [From Table 20.1 / 20.2/20.3]				
2	Current annual gross ground water extraction for all uses in hectare meters [From Table 3.13 / 3.26/3.39]				
3	Stage of Ground Water Extraction as a percentage [(2) / (1) * 100]				

22

CATEGORIZATION OF ASSESSMENT SUB UNITS

22.1 GENERAL

The sub-units of ground water assessment units are to be categorized as one of the following four categories for the purpose of establishing the scope for future ground water development in them.

- **a) Safe**
- **b) Semi-critical**
- **c) Critical**
- **d) Over Exploited**

The above categorization is arrived at by considering the stage of ground water extraction as presented earlier in Chapter 21.

22.2 CRITERIA FOR CATEGORIZATION

22.2.1 Safe

A sub-unit is categorized as 'Safe' with potential for future ground water development if the stage of ground water extraction is less than or equal to 70% .

22.2.2 Semi-critical

A sub-unit is categorized as 'Semi-critical' with caution to be exercised for future ground water development if the stage of ground water extraction is greater than 70% but less than or equal to 90 %.

In case a sub-unit gets categorized as 'Semi-critical', it is necessary to increase the density of observation wells in that sub-unit so that the rainfall recharge during monsoon season by the water table fluctuation method can be estimated with greater accuracy.

22.2.3 Critical

A sub-unit is categorized as 'Critical' with only very marginal scope for future ground water development if the stage of ground water extraction is more than 90%, and less than or equal 100%.

In case a sub-unit gets characterised as 'Critical', it is necessary to adopt the following measures in that sub-unit :

i) Increase the density of observation wells for reasons mentioned earlier.

ii) Implement water conservation measures, artificial recharge etc., in a concerted manner so as to ensure more ground water recharge and a sustainable ground water development .
iii) Carry out micro level studies so that the ground water assessment made for the sub-unit can be reassessed more accurately..

22.2.4 Over Exploited

A sub-unit is categorized as 'Over Exploited' with practically no scope for any future ground water development if the stage of ground water extraction is more than 100%.
The three measures of increasing the density of observation wells, implementing water conservation schemes/ artificial recharge programs, and carrying out micro level studies as described earlier in Section 22.2.3 for 'Critical areas' also apply for all sub-units which are categorized as 'Over Exploited'.

22.3 FORMATS SUGGESTED FOR THE COMPUTATION

The categorization of the sub units in each ground water assessment unit is presented in Table 22.1.

22.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Categorization.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Stage of Ground Water Extraction	Number	6	2
3	Quantity Category	Text	20	

Table 22.1 Categorisation of Sub Units of the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

Sl. No.	Description of item	Command area	Non - command area	Poor Ground Water Quality Area	Total Assessment Unit
(1)	(2)	(3)	(4)	(5)	(6)
1	Stage of ground water extraction as a percentage [From Table 21.1]				
2	Categorisation of the sub-unit (Safe / Semi-critical / Critical / Over Exploited)				

23

VALIDATION OF STAGE OF GROUND WATER EXTRACTION

23.1 GENERAL

The water table trend has to be computed in each groundwater assessment sub unit for the both the pre monsoon measurement and post monsoon measurement.

The above information are made use of, along with results of the stage of ground water extraction as presented earlier in Chapter 21, to check the validity of the exercise. The estimation of the trend of water table during a given season and for a given sub-unit comprises of the following steps :

a. The depth to water table below ground level as recorded in a number of observations wells within the sub-unit are made use of to obtain the depth to water table information applicable for the sub-unit as a whole.
b. The results from 'a' above are used in a scheme of linear regression analysis to establish the trend of water table.
c. Based on the criteria set, the validation of the stage of ground water extraction is assessed.

23.2 ASSUMPTIONS

The estimation of the trend of water table is based on the following assumptions:

a) The variation of depth to water table below ground level over successive ground water years is linear. Let x be successive years, and y be the depth to water table below ground level in metres. The relation between x and y is,

$$\mathbf{y = ax + b}$$

where 'a' and 'b' are the regression constants

b) The value of 'a' obtained by linear regression analysis multiplied by 100 gives the trend of depth to water table below ground level in cm per year. Let this be designated as 'Z'. The water table shows a falling trend if 'Z' is positive and rising trend if 'Z' is negative. The absolute value of 'Z' gives the rise or fall of water table in cm per year.

c) As discussed in 'a' above, the water table shows a neither rising nor falling trend only if 'Z' is equal to zero. However, from a practical point of view it is necessary to adopt a range of values for 'Z' within which the water table can be considered to show a neither rising nor falling trend. With this consideration in mind, the water table trend is assumed to be rising or falling or neither rising nor falling based on the critical value decided by the state government for this purpose.

d) When the stage of ground water extraction is less than 70%, there should not be declining trends in both the seasons. There can be one declining trend in any of the seasons.

e) Similarly when the stage of ground water extraction is more than 100%, there should not be rising trends in both the seasons. There can be one rising trend in any of the seasons.

23.3 COMPUTATIONAL PROCEDURE

23.3.1 Water Table Information

Unprocessed data on depth to water table below ground level during pre-monsoon and post-monsoon measurements for at least five years prior to the ground water assessment year is required to calculate the ground water level trends of the assessment sub unit. If there are more than one well any of the averaging techniques to be used to compute a single value for each season for each year representing the entire area of assessment sub unit.

23.3.2 Water Table Trend during Any Season

The depth to water table below ground water level applicable for the sub unit during any season for at least previous five years are used in the linear regression analysis for estimating the water table trend during that particular season for that sub unit.

The application of linear regression analysis requires a set of ordered pairs of data on x (i) and y(i) for i = 1 to N, where ‘N’ refers to the number of pairs of data, x(i) refers to the year and y(i) refers to the depth to water table below ground level during any season. The value of x(i) for i = 1 is 1, and this corresponds to the earliest ground water year for which water table data is available. If water table data is available for the next ground water year, the value of x(i) for i = 2 is 2. However, if water table data is available only after a gap of one ground water year, the value of x(i) for i = 2 is 3. A similar procedure is followed and the complete set of ordered pairs of data on x(i) and y(i) are obtained and an equation is fit for the relation.

23.4 FORMATS SUGGESTED FOR THE COMPUTATION

23.4.1 Command Area

Location details and availability of water table data of all observation wells in the command area of the ground water assessment unit are presented in Table 23.1. These data are made use of to compute the depth to water table below ground level as applicable to the command area as a whole for the previous ground water years mentioned above. The computations are presented in Table 23.2. The complete set of information on depth to water table below ground level during pre-monsoon and post-monsoon

intervals of a number of successive ground water years as applicable for the command area as a whole is presented in Table 23.3.
The use of linear regression analysis for obtaining the water table trend in the command area during the pre-monsoon period is presented in Table 23.4. The computations of estimating the ground water level trend during post monsoon season are presented in Table 23.5. The validity of the stage of ground water extraction for all sub units is presented in Table 23.16.

23.4.2 Non -Command Area

The computational scheme for the non-command area is identical to what has been described earlier in Section 24.4.1 for the command area. The computations are presented in Tables 23.6 to 23.10. The validity of the stage of ground water extraction for all sub units is presented in Table 23.16.

23.4.3 Poor Ground Water Quality Area

The computational scheme for the poor ground water quality area is identical to what has been described earlier in Section 24.4.1 for the command area. The computations are presented in Tables 23.11 to 23.15. The validity of the stage of ground water extraction for all sub units is presented in Table 23.16.

23.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the validation.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Name of Observation Well	Text	50	
3	Latitude	Text	10	
4	Longitude	Text	10	
5	No of Years Data Available	Number	3	0
6	Start Year	Number	4	0
7	End Year	Number	4	0
8	Year	Number	4	0
9	Pre-Monsoon Water Level	Number	6	2
10	Post-Monsoon Water Level	Number	6	2
11	Year X	Number	2	0
12	WL	Number	6	2
13	Year X Square	Number	4	0
14	Product of Year X and WL	Number	7	3
15	Sum Year X	Number	7	3
16	Sum WL	Number	7	3
17	Sum Year X Square	Number	7	3
18	Sum Product	Number	7	3
19	Number of Data Points	Number	2	0
20	Slope	Number	7	3
21	Trend	Text	20	
22	Stage of Ground Water extraction	Number	6	2
23	Validity	Text	10	

Table 23.1 Location Details and Availability of Water Table Data of All Observation Wells in the Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S.No	Observation wells in the command area					
	Location details			Ground water years for which water table data are available		
	Name of observation well	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 23.2 Water Table Information for Command Area For Previous Years

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S.No	Name of Observation Well	Depth to water table below ground level in meters below ground level during									
		Year 1		Year 2		Year 3		Year 4		Assessment Year	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											
For command area as a whole (average of all wells considered)											

Table 23.3 Water Table Information for Command Area During A Number of Ground Water Years Till the Current Ground Water Assessment Year

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Ground water year	Depth to water table below ground level in metres applicable for command area **[From Table 23.2]**	
		Pre-Monsoon	Post-Monsoon
(1)	(2)	(3)	(4)
1			
2			
3			

Table 23.4 Water Table Trend During Pre - monsoon Season in Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Critical Value of Water Level Trend (z) :

S. No.	Ground water year	Year x (i)	Depth to water table below ground level in meters during pre - monsoon season, y (i) [From Table 23.3]	$(x\,(i))^2$	x (i) * y (i)
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered, 'N' =

a) Trend of depth to water table below ground level during pre - monsoon season in command area in centimeters per year =

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2}$$

b) Water table trend during pre - monsoon season in command area =
(Rising / Falling / Neither Rising nor Falling)

Table 23.5 Water Table Trend During Post - monsoon Season in Command Area

Name of Ground Water Assessment Unit	:	
Principal Aquifer	:	
Major Aquifer	:	
Index Number of Ground Water Assessment Unit	:	
Ground Water Assessment Year	:	
Critical Value of Water Level Trend (z)	:	

S. No.	Ground water year	Year x (i)	Depth to water table below ground level in meters during Post - monsoon season, y (i) [From Table 23.3]	$(x(i))^2$	x (i) * y (i)
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered, 'N' =

a) Trend of depth to water table below ground level during post - monsoon season in command area in centimeters per year =

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2}$$

b) Water table trend during post - monsoon season in command area =
(Rising / Falling / Neither Rising nor Falling)

Table 23.6 Location Details and Availability of Water Table Data of All Observation Wells in the Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S.No	Observation wells in the non-command area					
	Location details			Ground water years for which water table data are available		
	Name of observation well	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 23.7 Water Table Information for Non-Command Area For Previous Years

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S.No	Name of Observation Well	Depth to water table below ground level in meters below ground level during									
		Year 1		Year 2		Year 3		Year 4		Assessment Year	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											
For non-command area as a whole (average of all wells considered)											

Table 23.8 Water Table Information for Non-Command Area During A Number of Ground Water Years Till the Current Ground Water Assessment Year

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Ground water year	Depth to water table below ground level in metres applicable for non-command area **[From Table 23.7]**	
		Pre-Monsoon	Post-Monsoon
(1)	(2)	(3)	(4)
1			
2			
3			

Table 23.9 Water Table Trend During Pre - monsoon Season In Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Critical Value of Water Level Trend (z) :

S. No. (i)	Ground water year	Year x (i)	Depth to water table below ground level in meters during pre - monsoon season, y (i) [From Table 23.8]	$(x(i))^2$	x (i) * y (i)
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered, 'N' =

a) Trend of depth to water table below ground level during pre - monsoon season in non-command area in centimeters per year =

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2}$$

b) Water table trend during pre - monsoon season in non-command area =
(Rising / Falling / Neither Rising nor Falling)

Table 23.10 Water Table Trend During Post - monsoon Season In Non-Command Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Critical Value of Water Level Trend (z) :

S. No. (i)	Ground water year	Year x (i)	Depth to water table below ground level in meters during Post - monsoon season, y (i) [From Table 23.8]	$(x(i))^2$	x (i) * y (i)
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered, 'N' =

a) Trend of depth to water table below ground level during post - monsoon season in non-command area in centimeters per year =

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2}$$

b) Water table trend during post - monsoon season in non-command area =
(Rising / Falling / Neither Rising nor Falling)

Table 23.11 Location Details and Availability of Water Table Data of All Observation Wells in the Poor Ground Water Quality Area

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S.No	Observation wells in the poor ground water quality area					
	Location details			Ground water years for which water table data are available		
	Name of observation well	Latitude	Longitude	Number of ground water years	Earliest ground water year	Latest ground water year
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						

Table 23.12 Water Table Information for Poor Ground Water Quality Area For Previous Years

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S.No	Name of Observation Well	Depth to water table below ground level in meters below ground level during									
		Year 1		Year 2		Year 3		Year 4		Assessment Year	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											
For poor ground water quality area as a whole (average of all wells considered)											

Table 23.13 Water Table Information for Poor Ground Water Quality Area During A Number of Ground Water Years Till the Current Ground Water Assessment Year

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Ground water year	Depth to water table below ground level in metres applicable for poor ground water quality area **[From Table 23.12]**	
		Pre-Monsoon	Post-Monsoon
(1)	(2)	(3)	(4)
1			
2			
3			

Table 23.14 Water Table Trend During Pre - monsoon Season In Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Critical Value of Water Level Trend(z) :

S. No.	Ground water year	Year x (i)	Depth to water table below ground level in meters during pre - monsoon season, y (i) [From Table 23.13]	$(x(i))^2$	x (i) * y (i)
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered, 'N' =

a) Trend of depth to water table below ground level during pre - monsoon season in poor ground water quality area in centimeters per year =

$$a = \frac{NS_4 - S_1 S_2}{NS_3 - S_1^2}$$

b) Water table trend during pre - monsoon season in poor ground water quality area = (Rising / Falling / Neither Rising nor Falling)

Table 23.15 Water Table Trend During Post - monsoon Season In Poor Ground Water Quality Area

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
Critical Value of Water Level Trend (z) :

S. No.	Ground water year	Year x (i)	Depth to water table below ground level in meters during Post - monsoon season, y (i) [From Table 23.13]	$(x (i))^2$	x (i) * y (i)
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
	N=	S_1=	S_2=	S_3=	S_4=

Number of pairs of data considered, 'N' =

a) Trend of depth to water table below ground level during post - monsoon season in poor ground water quality area in centimeters per year =

$$a = \frac{NS_4 - S_1S_2}{NS_3 - S_1^2}$$

b) Water table trend during post - monsoon season in poor ground water quality area (Rising / Falling / Neither Rising nor Falling) =

Table 23.16 Validity of Stage of Ground Water Extraction in the Sub Units of the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Command area	Non - command area	Poor Ground Water Quality Area
(1)	(2)	(3)	(4)	(5)
1	Stage of ground water extraction as a percentage [From Table 21.1]			
2	Ground Water Level Trend During pre-monsoon Season in centimeters [From Table 23.4/23.9/23.14]			
3	Ground Water Level Trend During post-monsoon Season in centimeters [From Table 23.5/23.10/23.15]			
4	Validity of the Stage of Ground Water Extraction (Valid/ Invalid)			

24

GROUND WATER QUALITY TAG

24.1 GENERAL

Quality assessment of ground water is equally important as the quantity assessment. But with the existing network of quality monitoring, it is not possible to categorize the area. There are so many problems in respect to type of attributes also. Some of the attributes are point data which can be considered as varying linearly between two points. Hence it was decided to add a quality tag to the assessment sub unit. The major sources of quality concern are salinity, fluoride and arsenic. It can vary depending on the area also. If the particular parameter is influencing an area in mappable units then the parameter should be tagged to the assessment sub unit.

24.2 ASSUMPTIONS

Even some of the parameters are point sources if it occurs in two nearby areas, it is assumed that the area intervening these two sample sites is affected by that parameter. If those patches of contamination or quality deterioration is mappable in 1:2,50,000 scale as of now may be considered for tagging. Quality tag should be as follows:This sub unit has F, As, salinity contamination in Mappable units. Otherwise the quality tag will be Fresh.

24.3 FORMATS SUGGESTED FOR THE COMPUTATION

The data pertains to quality tagging in all sub units are presented in Table 24.1 ..

24.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Quality tagging.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Quality Hazard	Text	10	
3	Area in hectares	Number	6	**2**

Table 24.1   Quality Tagging in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Command Area	Non-Command Area	Poor Ground Water Quality Area
1	Area of the sub unit			
2	Area effected by Salinity in mappable patches in 1:250,000			
3	Area effected by Fluoride in mappable patches in 1:250,000			
4	Area effected by Arsenic in mappable patches in 1:250,000			
5	Other Hazardous parameters present in the sub unit in mappable areas in 1:250,000			
	Parameter1:________			
	Parameter2:________			
	Parameter3:________			
	Parameter4:________			
	Parameter5:________			
6	Quality tag For the sub unit			

25

ALLOCATION OF GROUND WATER RESOURCES FOR DOMESTIC UTILIZATION

25.1 GENERAL

Among various demands for water, the 'National Water Policy' assigns the highest priority to domestic water supply. There is therefore, a need to provide a certain allocation of ground water for domestic water supply so that, the demands for the domestic purposes are ensured before planning any future ground water development to meet the demands of other purposes like irrigation and industrial purpose .

Unlike irrigation water requirement which primarily depends on the availability of irrigable land, the requirement for domestic water supply depends on the population. It is also preferable that, a projected population say as on 2025, and not the current population is considered, while arriving at the annual allocation for domestic water supply.

The following factors are important for arriving at an estimate for the annual allocation of ground water to meet domestic water requirements.

a) extent of dependency on ground water
b) per capita per day requirement of water
c) criteria for population projection

The above factors are likely to vary considerably from State to State, and even within a State. In other words, the estimation of allocation for domestic water supply is highly location specific. Consequently, each State/ Union Territory is given a freedom to arrive at the estimate of the annual allocation on the basis of any procedure most suitable to them. The only requirement is that, the annual allocation of ground water for domestic water supply should be arrived at for the all the sub-units in each ground water assessment unit with as much reliability as possible. The dependency on ground water in a poor ground water quality area may be zero.

The report on "Ground Water Estimation Methodology-2015" however, suggests a procedure which can be made use for estimating the annual allocation of ground water for domestic water supply. This procedure which is described in the next section can be adopted if it is found suitable and if a better procedure is not available.

25.2 ASSUMPTIONS

The Allocation for future domestic needs may be obtained by the following formula

$$Y = 22 * N * L_g$$

where,

Y is allocation for domestic water supply per unit area in mm/ year

N is projected population density in thousands per sq.km.

This formula assumes that the percapita requirement for domestic needs is 60liters/day.

25.3 COMPUTATIONAL PROCEDURE

The report on "Ground water Estimation Methodology - 2015" recommends that the allocation for domestic water supply per unit area can be arrived at using the following equation in which it is assumed that, the requirement for domestic water supply is 60 lpcd (litres per capita per day).

$Y = 22 * N * L_g$

where,

Y is allocation for domestic water supply per unit area in mm/ year

N is projected population density in thousands per sq.km.

25.4 FORMATS SUGGESTED FOR THE COMPUTATION

The computations as recommended by GEC 2015 for all the sub units is presented in Table 25.1. More generalized method when the percapita requirement and load on ground water are known separately is presented in Table 25.2 .

25.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Allocation.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Population	Number	7	0
3	Year of Census	Number	4	0
4	Growth Rate	Number	5	2
5	Projected Population	Number	7	0
6	Dependency on GW	Number	3	2
7	Percapita requirement	Number	3	0
8	Annual Allocation	Number	8	0
9	Area	Number	7	0
10	Annual Allocation m	Number	7	3

Table 25.1 Annual Ground Water Allocation for Domestic Water Supply
(By the method suggested by 'Ground Water Estimation Methodology - 2015')

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Command area	Non-command area	Poor Ground Water Quality Area
(1)	(2)	(3)	(4)	(5)
1	Projected population density as on 2025 in thousands per sq. km.			
2	Extent of dependency on ground water to meet domestic water supply as a fraction (less than or equal to 1)			
3	Annual allocation of ground water for domestic water supply per unit area in millimeters [22 * (1) * (2)]			
4	Area in hectares [From Table 2.1]			
5	Annual allocation of ground water for domestic water supply in hectare meters [((3) * (4)) / 1000]			

Note : The per capita per day requirement for domestic water supply is assumed as 60 lpcd

Table 25.2 Annual Ground Water Allocation for Domestic Water Supply (By a Generalized method)

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Command area	Non-command area	Poor Ground Water Quality Area
(1)	(2)	(3)	(4)	(5)
1	Projected population density as on 2025 in thousands per sq. km.			
2	Domestic water requirement in litres per capita per day, lpcd			
3	Extent of dependency on ground water to meet domestic water supply as a fraction (less than or equal to 1)			
4	Annual allocation of ground water for domestic water supply per unit area in millimetres $\left[\frac{(1)\times(2)\times 365\times(3)}{1000}\right]$			
5	Area in hectares [From Table 2.1]			
6	Annual allocation of ground water for domestic water requirement in hectare meters [((4) * (5)) / 1000]			

26

NET GROUND WATER AVAILABILITY FOR FUTURE USE

26.1 GENERAL

Annual extractable ground water resource in the three sub-units of command, non-command and poor ground water quality area have been presented in Chapter 20. The current annual gross ground water extraction for 'Irrigation' and 'Industrial' uses in the command area, non-command area and poor ground water quality areas have been presented in Chapter 3. The annual allocations for 'Domestic Water Supply' as on 2025 in the command, non-command and poor ground water quality areas have been presented in Chapter 25. These results are used in computing the net annual ground water availability for future use in each of the ground water assessment sub unit.

26.2 COMPUTATIONAL PROCEDURE

Let the annual extractable ground water resource in hectare meters in a given sub-unit be 'B'. Let the current annual gross ground water extraction for 'Irrigation' in hectare meters in that sub-unit be 'C' and the current annual gross ground water extraction for 'Industrial use' in hectare meters in that sub-unit be, 'D'. Let the annual allocation for 'Domestic Water Supply' as on 2025 in hectare meters in that sub-unit be, 'E'. The net annual ground water availability for 'Future Use' in that sub-unit, 'A' in hectare meters can be then computed as:

$$A = B - (C + D + E)$$

26.3 FORMATS SUGGESTED FOR THE COMPUTATION

The net annual ground water availability for 'Future Use' in the sub-units within a ground water assessment unit as computed above are presented in Table 26.1.

26.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the net ground water availability for future use.

S.No	Parameter	Type	Size	Decimals
1	Assessment Sub Unit	Text	20	
2	Area	Number	7	0
3	Annual Extractable Ground Water Resource	Number	8	0
4	Total Sub Unit Irrigation Annual Extraction	Number	7	0
5	Total Sub Unit Industrial Annual Extraction	Number	7	0
5	Annual Allocation for Domestic needs	Number	8	0
6	Net Ground Water Availability For Future Use	Number	8	0
7	Net Ground Water Availability For Future Use m	Number	7	3

Table 26.1 Net Annual Ground Water Availability for Future Use in the Sub-Units

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Command area	Non - command area	Poor Ground Water Quality Area
1	Area in hectares [From Table 2.1]			
2	Annual Extractable Ground Water Resource in hectare meters [From Table 20.1/20.2/20.3]			
3	Current annual gross ground water extraction for Irrigation in hectare meters [From Table 3.13 / 3.26/3.39]			
4	Current annual gross ground water extraction for Industrial use in hectare meters [From Table 3.13 / 3.26/3.39]			
5	Annual allocation of ground water for domestic water supply as on 2025 in hectare meters [From Table 25.1/25.2]			
6	Net annual ground water availability for 'Future Use' in hectare meters [(2) - ((3) + (4) + (5))]			
7	Net annual ground water availability for 'Future Use' per unit area in millimeters [((6) / (1)) * 1000]			

27

ADDITIONAL POTENTIAL RESOURCES UNDER SPECIFIC CONDITIONS

27.1 GENERAL

In addition to the ground water assessment components covered in the earlier chapters, it is necessary to compute the following three components in respect of each ground water assessment unit where there is a potential of ground water development. These are termed as Additional Potential Ground Water Resources. In any ground water assessment unit there can be some area which is influenced by number of springs. Even though this is a part of dynamic resource which is replenishable in nature, it is considered as potential resource because of the paucity of data in a national perspective, the other two potential resources are the ground water available in areas which are under waterlogged or shallow water table conditions and area under flood prone conditions.

Spring discharge constitutes an additional source of ground water in hilly areas which emerges at the places where ground water level cuts the surface topography. The spring discharge is equal to the ground water recharge minus the outflow through evaporation, transpiration and vertical & lateral sub-surface flow. Thus, Spring Discharge is a form of 'Annual Extractable Ground Water Resource'. It is a renewable resource. Spring discharge measurement is to be carried out by volumetric measurement of discharge of the springs. Spring discharges multiplied with time in days of each season will give the quantum of spring resources available during that season.

In the water logged & shallow water table conditions and flood prone conditions, the rejected discharge will be considerable, and the water table fluctuation will also be subdued. The computation of rainfall recharge considering the water table fluctuation data is therefore likely to lead to an underestimation of the recharge in all such areas of the ground water assessment unit. It is also always desirable that, the ground water table in such areas should be lowered down to an acceptable optimum level before the commencement of the monsoon so as to provide additional scope for recharge from rainfall during the monsoon season. The additional potential resource is considered as the ground water resource available above 5m below the ground surface in the water logging and shallow water table areas. In the flood prone areas, the recharge which is taking place by the inundation of the area. In case of springs, the component of ground water which is available as a free flow due to the springs during the year is considered as potential resource.

27.2 ASSUMPTIONS

27.2.1 Spring Discharges

The assumptions in computing potential resource due to spring discharges are as follows:

a) Spring discharges are assumed to be constant throughout the season.
b) It is also assumed that it exists throughout the season with the same discharge.
c) The spring discharge for any season is the average of the spring discharges monitored during the season.
d) Potential resource due to spring discharges is estimated as the product of the following parameters
   i) Average discharge during the season
   ii) No of days the spring yields during the season

27.2.2 Waterlogged and Shallow Water Table Areas

a) Waterlogged and shallow water table areas are characterised by depth to water table below ground level being less than 5 meters
b) The potential resource in hectare meters can be computed as the product of the following three parameters
   i) Area in hectares
   ii) Specific yield of the aquifer in the zone up to 5 meters below ground level
   iii) Difference between the actual average depth to water table below ground level in meters and the optimum limit of 5 meters mentioned in 'a' above

27.2.3 Flood Prone Area

a) Potential recharge in flood prone area depends on several factors like,
   i) Area inundated
   ii) Retention period of the flood
   iii) Soil strata in the flood prone area
   iv) Silt load in the river which gets deposited in the flood prone area.
b) The collection of data on all these factors is usually very difficult, and hence, potential resource in flood prone area is computed on the same basis adopted for computing recharge from tanks and ponds as described earlier in Chapter 7.
c) The potential resource is calculated as the product of the following three parameters
   i) Area of inundation
   ii) Recharge factor same as considered for Tanks/ponds
   iii) No of days of inundation

27.3 COMPUTATIONAL PROCEDURE

27.3.1 Spring Discharges

The computational procedure for estimating the potential resource due to spring discharges within the ground water assessment unit involves the following steps :

a) The identification of springs in the area which are yielding sufficiently and for sufficient number of days.
b) The discharges of the springs are to be monitored as many number of times as possible so as to assess the resources more accurately.
c) The minimum number of monitoring of springs as suggested by GEC 2015 is four in accordance with the water level monitoring viz. Pre monsoon, mid monsoon, post monsoon, mid non monsoon seasons.
d) The potential resource due to spring discharges (Y) can be computed in hectare meters as

$$Y = \frac{\text{Average Spring Discharge in lpm x60} \times 24 \times \text{No of days}}{1000 \times 10000}$$

27.3.2 Waterlogged and Shallow Water Table Areas

The computational procedure for estimating the potential resource in hectare meters in the waterlogged and shallow water table areas within the ground water assessment unit involves the following steps :

a) The portions of the ground water assessment unit characterised by waterlogged and shallow water table conditions are identified, and the area and the average depth to water table below ground level of those portions are obtained. Let the area in hectares be 'A', and the depth to water table below ground level in meters be 'D'
b) The specific yield , S_y of the aquifer formation in the zone up to 5 meters below ground level is obtained
c) The potential resource in waterlogged and shallow water table areas, 'Y' in hectare meters is finally computed as

$$Y = (5 - D) * A * S_y$$

It also needs to be emphasised that, unlike the 'Annual Extractable Ground Water Resource' as presented earlier in Chapter 20 which is available year after year, the additional potential resource in waterlogged and shallow water table areas is a onetime availability of ground water which ceases as and when the water table is lowered down to the accepted optimum level of 5 meters below ground level.

27.3.3 Flood Prone Area

The computational procedure for estimating the potential resource in hectare meters in the flood prone area involves the following steps :

a. The portion within the ground water assessment unit under flood prone conditions is identified. The area of this inundation in hectares, as well as the number days during a year when water is retained in it are obtained. Let ‘A’ be the area in hectares, and ‘N’ be the number of days water is retained in a year.

b. The annual potential resource ‘Y’, in hectare meters in the flood prone area within the ground water assessment unit is finally computed as,

Y = Recharge Factor For Tanks/Ponds* N * A / 1000.

27.4 FORMATS SUGGESTED FOR THE COMPUTATION

27.4.1 Spring Discharges

The computations for obtaining the average spring discharges for each of the spring are presented in Table 27.1. Computations for obtaining the total spring discharges in the assessment unit during monsoon, non-monsoon seasons and annual are presented in Table 27.2.

27.4.2 Waterlogged and Shallow Water Table Areas

The computations for obtaining the average water level data during pre-monsoon monitoring are presented in Table 27.3. Location details with the Average Pre-Monsoon water levels are presented in Table 27.4. Zonation of shallow water table preferably with 0.5meter contour are presented in the Map 27.1. The computations of Potential Resource due to shallow water table are presented in Table 27.5.

27.4.3 Flood Prone Area

The computations of Potential Resource Due to Flood Prone Areas are presented in Table 27.6.

27.4.4 Total Potential Resources in the Assessment Unit

The computations of Total Potential Resources in the Assessment Unit are presented in Table 27.7.

27.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Potential ground Water Resources.

S.No	Parameter	Type	Size	Decimals
1	Assessment Unit	Text	20	
2	Spring discharge During Monsoon	Number	5	2
3	Spring Discharge During Non-Monsoon	Number	5	2
4	Average Monsoon Days Spring Yields in the unit	Number	3	0
5	Average Non-Monsoon Days Spring Yields in the unit	Number	3	0
6	Annual Spring Discharge in the Unit	Number	5	2
7	No of Such Springs in the Unit	Number	4	0
8	Potential resource Due to Spring Discharges	Number	8	0
9	Water Logged Area	Number	7	0
10	Average Depth to Water level	Number	6	2
11	Specific Yield	Number	5	2
12	Potential Resources Shallow WT	Number	8	0
13	Flood Prone Area	Number	7	0

S.No	Parameter	Type	Size	Decimals
14	No of Days Area is inundated	Number	3	0
15	Potential Resources in Flood Prone Areas	Number	8	0
16	Total Potential Resources	Number	8	0

Table 27.1 Average Spring Discharge of Each Spring during Monsoon and Non-monsoon Seasons

Name of Ground Water Assessment Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Ground Water Assessment Unit :

S. No.	Name of the spring	Year	Spring Discharges during the season in lpm			Average Spring Discharge in lpm	
			Pre-Monsoon	Post-Monsoon	Pre-Monsoon of Next Year	During Monsoon Season $\frac{(4)+(5)}{2}$	During Non-Monsoon Season $\frac{(5)+(6)}{2}$
(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)
1							
2							
3							
		Average Discharge for each spring					

Table 27.2 Spring Discharge during Monsoon and Non-monsoon Seasons

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

S. No.	Name of the spring	Longitude	Latitude	Spring Discharge in lpm		No of days Spring Yields		Total Spring Discharge in hectare meters	
				During Monsoon Season	During Non-Monsoon Season	During Monsoon Season	During Non-Monsoon Season	During Monsoon Season $60*24*(5)*(7)/10^7$	During Non-Monsoon Season $60*24*(6)*(8)/10^7$
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1									
2									
3									
Potential Resource due to Spring Discharges in hectare meters									

Annual Potential Resource due to Spring Discharges:
(Total of Potential Resource due to Spring Discharges During Monsoon and Non-Monsoon Seasons)

Table 27.3 Average Water Level of Each Well during Pre-Monsoon Monitoring in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (For each of the wells in the assessment unit)	Year	Ground Water level During Pre-Monsoon Monitoring in meters below ground level
(1)	(2)	(3)	(4)
1			
2			
3			
Average Ground Water Level For Each Monitoring Station During Pre-Monsoon Monitoring			

Table 27.4 Ground Water Level during Pre-Monsoon in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the observation well (for all the wells in the assessment unit)	Longitude	Latitude	Average Ground Water level during Pre-Monsoon Season in meters below ground level
(1)	(2)	(3)	(4)	(5)
1				
2				
3				

MAP 27.1: Ground Water Level Contour During Pre-Monsoon Monitoring in the Assessment Unit

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Table 27.5 Potential Resources due to Shallow Water Table Zones in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Shallow Water Table Zone No.	Area in hectares	Average Water Level of the Zone in meters below ground level	Specific Yield	Potential Resource due to shallow water table in the zone in hectare meters. $(3)\times(5)\times(5-(4))$
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
Potential Resource due to all the shallow water Table zones in the Assessment Unit in hectare meters					

Table 27.6 Potential Resource due to Flood Prone Areas in the Ground Water Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Quantity
1	Area in hectares	
2	Number of days in a year when water is retained in the flood prone area	
3	Recharge Factor assigned to Tanks/Ponds in the assessment unit in millimeters/day	
4	Potential resource in flood prone area in hectare metres [(1) * (2) * (3) / 1000]	

Table 27.7 Total Potential Resources in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of the component	Potential Resource in Hectare meters
1	Annual Potential Resource due to Spring Discharges [From Table 27.2]	
2	Potential Resource due to Shallow Water Table Areas [From Table 27.5]	
3	Potential Resource due to Flood Prone Areas [From Table 27.6]	
Total Potential Resource in the Assessment Unit		

28

IN-STORAGE GROUND WATER RESOURCES OF UNCONFINED AQUIFER

28.1 GENERAL

The 'Annual Extractable Ground Water Resource' as computed earlier in Chapter 20 is the 'Dynamic' component of the ground water resource which is available in the zone of water table fluctuation. All plans for ground water development are made on the basis of this dynamic component which is available year after year.

The in-storage ground water resource in a ground water assessment unit can be considered to be that which is available below the zone of water table fluctuation upto the bottom of the unconfined aquifer. The in-storage ground water resource, unlike the dynamic ground water resource, is not available year after year. Also, any development of the in-storage ground water resource is synonymous to ground water mining. Consequently, the in-storage ground water resource can be considered for development only during periods of extreme drought condition, and that too probably only to meet drinking water supply. The in-storage ground water resource thus mined, can be expected to be recouped during those forth coming years of excess rainfall.

28.2 ASSUMPTIONS

a) The in-storage resource is below average pre monsoon water level in the assessment area.
b) If aquifer mapping is completed, the bottom of the aquifer is to be considered for the bottom level for computing this resources. If not 100m below ground level for hard rock areas and 300meters below ground level for soft rock areas to be considered as the bottom for computing this resource.
c) In-storage resources can be computed as the product of the following
    i) Thickness of the in-storage zone which is nothing but the difference between bottom of the Unconfined aquifer and average pre monsoon water level.
    ii) Area considered for the in-storage resources
    iii) Specific yield in the zone of in-storage resources

28.3 COMPUTATIONAL PROCEDURE

The computational procedure for estimating the in-storage resource in the unconfined aquifer of the ground water assessment unit involves the following steps :

a) The area of the ground water assessment unit for which the in-storage ground water resource is to be obtained. Let this area in hectares be 'A'
b) The depth below ground level up to which the zone of water table fluctuation occurs is obtained. This can be taken as the average depth below ground level recorded during the pre-monsoon monitoring. Let this depth below ground level in meters be 'Z_1'
c) Bottom of the aquifer if aquifer mapping is completed or 100meters or 300 meters depending on the aquifer lithology. Let this depth below ground level in meters be 'Z_2'.
d) The specific yield of the aquifer formation in the depth horizon between 'Z_1' and 'Z_2' as defined above is obtained. Let this specific yield value as a fraction be 'S_y'
e) The in-storage ground water resource, 'Y' in hectare meters is finally computed as,

$$\mathbf{Y = A * (Z_2 - Z_1) * S_y}$$

28.4 FORMATS SUGGESTED FOR THE COMPUTATION

The computations for obtaining the in-storage ground water resources as described earlier are presented in the Table 28.1.

28.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the In-Storage Ground Water resources of un confined aquifer.

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Static Resources Area	Number	7	0
3	Average Depth of Fluctuation	Number	6	2
4	Bottom of Aquifer	Number	7	2
5	Bottom of Aquifer for Computation	Number	7	2
6	Specific Yield	Number	5	2
7	Total Instorage Resources Unconfined	Number	8	0

Table 28.1 In-storage Ground Water Resources in Each Ground Water Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Quantity for Fresh Ground Water (For Command & Non-Command Sub Units Together)	Quantity for Saline Ground Water (For Poor Ground Water Quality Area)
1	Area considered for In-storage ground water resource estimation in hectares		
2	Depth below ground level up to which the zone of water table fluctuation extends, in meters		
3	Depth below ground level up to which the Unconfined aquifer extends in meters		
4	Specific yield of the depth zone considered for in-storage ground water resources estimation as a fraction		
5	**In-storage Ground Water Resource in the Ground Water Assessment Unit**, in hectare meters [(1) * ((3) - (2)) * (4)]		

29

DYNAMIC GROUND WATER RESOURCES OF CONFINED AQUIFERS IN THE ASSESSMENT UNIT

29.1 GENERAL

Assessment of ground water resources of confined aquifers assumes crucial importance, since over-exploitation of these aquifers may lead to far more detrimental consequences than to those of shallow unconfined aquifers. If the piezometric surface of the confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs which may lead to subsidence of land surface posing serious geotectonical problems.

GEC 2015 recommends the use volumetric approach to assess the ground water resources of the confined aquifers. GEC 2015 also recommends to assess the ground water potential of a confined aquifer as the water available for use without damaging the aquifer. Hence the resources available under pressure are only considered as the ground water potential. As per the recommendations of GEC 2015, If extraction of ground water is being taken place from the confined aquifer, then only there is a need to assess the dynamic resources of the confined aquifer.

29.2 ASSUMPTIONS

a) There exists a confined aquifer in the assessment unit which is completely sealed from the over lying and under lying aquifers.
b) There are sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is done.
c) The Dynamic ground water resources of the confined aquifer can be assessed using volumetric approach as the product of the following:
    i) Area of the confined aquifer
    ii) Storage coefficient
    iii) Fluctuation in the piezometric head between the monitorings of pre-monsoon and post monsoon seasons.

29.3 COMPUTATIONAL PROCEDURE

The computational procedure for estimating the dynamic ground water resources in the confined aquifer in the assessment unit involves the following steps :

a) The area of the confined aquifer for which the dynamic ground water resource is to be obtained. Let this area in hectares be ‘A’
b) The average piezometric head during pre-monsoon season above mean sea level is to be obtained. Let this head above mean sea level in meters be ‘h_{PRE}’
c) The average piezometric head during post-monsoon season above mean sea level is to be obtained. Let this head above mean sea level meters be ‘h_{POST}’
d) The storativity of the aquifer is to be obtained. Let this storativity value as a fraction be ‘S’
e) The Dynamic Ground water resource of the confined aquifer , ‘Y’ in hectare meters is finally computed as,

$$\mathbf{Y = SA\,(h_{POST} - h_{PRE})}$$

29.4 FORMATS SUGGESTED FOR THE COMPUTATION

The computations for obtaining the average piezometric heads for pre-monsoon and post monsoon seasons for all the piezometers tapping the confined aquifer are presented in Table 29.1. The computations for obtaining average heads for both the seasons for the entire assessment unit are presented in Table 29.2. The computations for assessing the dynamic ground water resources of the confined aquifer are presented in Table 29.3.

29.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Dynamic Resources of confined aquifer.

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2
6	Total Dynamic Resource of Confined Aquifer	Number	8	0

Table 29.1 Average Piezometric heads of Each Piezometer Tapping the confined aquifer in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :
:

S. No.	Name of piezometer (For each of the piezometers tapping confined aquifer in the assessment unit)	Year	Piezometric head in meters above mean sea level during	
			Pre-monsoon	Post monsoon
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Average Piezometric Head For Each Piezometer				

Table 29.2 Piezometric heads of all the Piezometers in the Assessment unit Tapping Confined Aquifer

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Piezometers in the Assessment Unit tapping the Confined Aquifer		
	Name	Average Piezometric Head in meters above mean sea level	
		Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)
1			
2			
3			
Average of all piezometers considered			

Table 29.3 Dynamic Ground Water Resources of the Confined Aquifer in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for the confined aquifer)	Quantity
1	Area in hectares	
2	Storativity of the confined Aquifer	
3	Average Piezometric Head During Pre-Monsoon Season [From Table 29.2]	
4	Average Piezometric Head During Post-Monsoon Season [From Table 29.2]	
5	Fluctuation in the Piezometric Head in meters due to monsoon [(4)-(3)]	
6	Dynamic Ground Water Resources of the Confined Aquifer in hectare meters [(1) * (2) * (5)]	
7	Dynamic Ground Water Resources of the Confined Aquifer in millimeters [(6)*100/(1)]	

30

IN-STORAGE GROUND WATER RESOURCES OF CONFINED AQUIFERS IN THE ASSESSMENT UNIT

30.1 GENERAL

The ‘Dynamic Ground Water Resource of the Confined aquifer ’ as computed earlier in Chapter 29 is the ‘Dynamic’ component of the ground water resource of the confined aquifer which is available in the zone of fluctuation in the piezometric surface. All plans for ground water development are made on the basis of this dynamic component which is available year after year.

GEC 2015 recommends to use volumetric approach to assess the ground water resources of the confined aquifers. As per the recommendations of GEC 2015, If any ground water is being extracted from the confined aquifer, then only there is a need to assess the dynamic resources of the confined aquifer. Wherever the dynamic ground water resources of the confined aquifer are assessed, the in-storage ground water potential of a confined aquifer, is the resources between the pre monsoon piezometric head and bottom of the top confining layer. Wherever the aquifer is not being exploited the dynamic ground water resources of the confined aquifer need not be estimated separately. Instead only one component as the in-storage ground water resources of the confined aquifer need to be assessed. This in-storage ground water potential of a confined aquifer can be assessed as the resources available between the post monsoon piezometric head and bottom of the top confining layer.

30.2 ASSUMPTIONS

a) There exists a confined aquifer in the assessment unit which is completely sealed from the over lying and under lying aquifers.
b) There are sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is also to be carried out.
c) If the dynamic ground water resources of the confined aquifer is assessed then the in-storage resources of the confined aquifer can be assessed using volumetric approach as the product of the following:
    i) Area of the confined aquifer

   ii) Storage coefficient
   iii) Difference of the piezometric head during pre-monsoon and altitude of the bottom of top confining layer.

d) If the dynamic ground water resources of the confined aquifer is not assessed then the in-storage resources of the confined aquifer can be assessed using volumetric
e) approach as the product of the following:
   i) Area of the confined aquifer
   ii) Storage coefficient
   iii) Difference of the piezometric head during post-monsoon and altitude of the bottom of top confining layer.
f) The calculated in-storage resource when calculated for the confined aquifers where there is no exploitation, includes small amount of dynamic resource of the confined aquifer also, which replenishes every year. But to make it simpler this was also computed as part of the in-storage resource of the confined aquifer.

30.3 COMPUTATIONAL PROCEDURE

The computational procedure for estimating the in-storage ground water resources of the confined aquifer in the assessment unit involves the following steps :

a) The area of the confined aquifer for which the in-storage ground water resource is to be computed. Let this area in hectares be 'A'
b) The average piezometric head during pre-monsoon season above mean sea level is to be obtained. Let this head above mean sea level in meters be 'h_{PRE}'
c) The average piezometric head during post-monsoon season above mean sea level is to be obtained. Let this head above mean sea level meters be 'h_{POST}'
d) The average altitude of the bottom of top confining layer of the confined aquifer is to be obtained. Let this level in meters above mean sea level is h_0 .
e) The storativity of the aquifer is to be obtained. Let this storativity value as a fraction be 'S'
f) If the Confined Aquifer is being exploited then the In-storage ground water resource of the confined aquifer , 'Y' in hectare meters is finally computed as,

$$\mathbf{Y = SA\ (h_{PRE} - h_0)}$$

g) If the Confined Aquifer is not being exploited then the In-storage ground water resource of the confined aquifer , 'Y' in hectare meters is finally computed as,

$$\mathbf{Y = SA\ (h_{POST} - h_0)}$$

30.4 FORMATS SUGGESTED FOR THE COMPUTATION

The computations for obtaining the in-storage ground water resources of confined aquifer as described earlier in this chapter are presented in Table 30.1.

30.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of In-Storage Resources of the confined aquifer.

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2
6	Bottom of Top Confined Layer	Number	7	2
6	Total In Storage Resource of Confined Aquifer	Number	8	0

Table 30.1 In-storage Ground Water Resources of the Confined Aquifer in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for the confined aquifer)	Quantity
1	Area in hectares	
2	Storativity of the confined Aquifer	
3	Average Piezometric Head During Pre-Monsoon Season [From Table 29.2]	
4	Average Piezometric Head During Post-Monsoon Season [From Table 29.2]	
5	Altitude of the Bottom of Top Confining Layer of the Confined Aquifer in meters above mean sea level	
6	Whether this confined aquifer is being exploited (Yes/No)	
7	In-Storage Ground Water Resource of the Confined Aquifer If Response to (6) is Yes [(1) * (2) * ((3)-(5))] If Response to (6) is No [(1)*(2)*((4)-(5))]	

31

DYNAMIC GROUND WATER RESOURCES OF SEMI-CONFINED AQUIFERS IN THE ASSESSMENT UNIT

31.1 GENERAL

Assessment of ground water resources of semi-confined aquifers are similar to that of confined aquifers. Similar to the case of confined aquifer, if the piezometric surface of the semi-confined aquifer is lowered below the upper confining layer so that desaturation of the aquifer occurs which may lead to subsidence of land surface posing serious geotectonical problems.

GEC 2015 recommends to use volumetric approach to assess the ground water resources of the semi-confined aquifers also. GEC 2015 also recommends to assess the ground water potential of a semi-confined aquifer as the water available for use without damaging the aquifer. Hence the resources available under pressure are only considered as the ground water potential even for the semi-confined aquifer.

As per the recommendations of GEC 2015, if any ground water is being extracted from the semi-confined aquifer, then only there is a need to assess the dynamic resources of the semi-confined aquifer.

31.2 ASSUMPTIONS

a) It is known that the recharge to the semi-confined aquifer is not assessed either in the over lying unconfined aquifer or under lying/overlying semi-confined aquifers.
b) There are sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is to be done.
c) The Dynamic ground water resources of the semi-confined aquifer can be assessed using volumetric approach similar to the assessment of resources in confined aquifer and this can be assessed as the product of the following:
    i) Area of the semi-confined aquifer
    ii) Storage coefficient
    iii) Fluctuation in the piezometric head between the pre-monsoon and post monsoon seasons.

31.3 COMPUTATIONAL PROCEDURE

The computational procedure for estimating the dynamic ground water resources in the semi-confined aquifer in the assessment unit involves the following steps :

a) The area of the semi-confined aquifer for which the dynamic ground water resource is to be computed. Let this area in hectares be ‘A’
b) The average piezometric head during pre-monsoon season above mean sea level is to be obtained. Let this head above mean sea level in meters be ‘h_{PRE}’
c) The average piezometric head during post-monsoon season above mean sea level is to be obtained. Let this head above mean sea level meters be ‘h_{POST}’
d) The storativity of the aquifer is to be obtained. Let this storativity value as a fraction be ‘S’
e) The dynamic ground water resources of the semi-confined aquifer , ‘Y’ in hectare meters is finally computed as,

$$\mathbf{Y = SA\ (h_{POST} - h_{PRE})}$$

31.4 FORMATS SUGGESTED FOR THE COMPUTATION

The computations for obtaining the average piezometric heads for pre-monsoon and post monsoon seasons for all the piezometers tapping the semi-confined aquifer are presented in Table 31.1. The computations for obtaining average heads for both the seasons for the entire assessment unit are presented in Table 31.2. The computations for assessing the dynamic ground water resources of the semi-confined aquifer are presented in Table 31.3.

31.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of Dynamic Resources of semi-confined aquifer.

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Semi-Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2
6	Total Dynamic Resources of Semi-Confined Aquifer	Number	8	0

Table 31.1 Average Piezometric heads of Each Piezometer Tapping the Semi-Confined aquifer in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Name of piezometer (For each of the piezometers tapping semi-confined aquifer in the assessment unit)	Year	Piezometric head in meters above mean sea level during	
			Pre-monsoon	Post monsoon
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Average Piezometric Head For Each Piezometer				

Table 31.2 Piezometric heads of all The Piezometers in the Assessment unit Tapping Semi-Confined Aquifer

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S.No	Piezometers in the Assessment Unit tapping the Semi-Confined Aquifer		
	Name	Average Piezometric Head in meters above mean sea level	
		Pre - monsoon	Post - monsoon
(1)	(2)	(3)	(4)
1			
2			
3			
Average of all piezomters considered			

Table 31.3 Dynamic Ground Water Resources of the Semi-Confined Aquifer in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for the semi-confined aquifer)	Quantity
1	Area in hectares	
2	Storativity of the semi-confined Aquifer	
3	Average Piezometric Head during Pre-Monsoon Season [From Table 31.2]	
4	Average Piezometric Head during Post-Monsoon Season [From Table 31.2]	
5	Fluctuation in the Piezometric Head in meters due to monsoon [(4)-(3)]	
6	Dynamic Ground Water Resources of the Semi-Confined Aquifer in hectare meters [(1) * (2) * (5)]	
7	Dynamic Ground Water Resources of the Semi-Confined Aquifer in millimeters [(6)*100/(1)]	

32

IN-STORAGE GROUND WATER RESOURCES OF SEMI-CONFINED AQUIFERS IN THE ASSESSMENT UNIT

32.1 GENERAL

The 'Dynamic Ground Water Resources of the Semi-Confined aquifer ' as computed earlier in Chapter 31 is the 'Dynamic' component of the ground water resources of the semi-confined aquifer which is available in the zone of fluctuation of the piezometric surface. All plans for ground water development are made on the basis of this dynamic component which is available year after year.

GEC 2015 recommends to use volumetric approach to assess the ground water resources of the semi-confined aquifers. As per the recommendations of GEC 2015, If any ground water is being extracted from the semi-confined aquifer, then only there is a need to assess the dynamic resources of the confined aquifer. Wherever the dynamic ground water resources of the semi-confined aquifer are assessed, the in- storage ground water potential of a semi-confined aquifer, is the resources between the pre monsoon piezometric head and bottom of the top confining layer. Wherever the aquifer is not being exploited the dynamic ground water resources of the semi-confined aquifer need not be estimated separately. Instead only one component as the in-storage ground water resources of the semi-confined aquifer need to be assessed. This in-storage ground water potential of a semi-confined aquifer can be assessed as the resources between the post monsoon piezometric head and bottom of the top confining layer.

32.2 ASSUMPTIONS

a) It is known that the recharge to the semi-confined aquifer is not assessed either in the over lying unconfined aquifer or under lying/overlying semi-confined aquifers.
b) There are sufficient number of observation wells tapping exclusively that particular aquifer and proper monitoring of the piezometric heads is to be done.
c) If the dynamic ground water resources of the semi-confined aquifer is assessed then the in-storage resources of the semi-confined aquifer can be assessed using volumetric approach as the product of the following:

   i) Area of the semi-confined aquifer
   ii) Storage coefficient
   iii) Difference of the piezometric head during pre-monsoon and altitude of the bottom of top confining layer.

d) If the dynamic ground water resources of the semi-confined aquifer is not assessed then the in-storage resources of the semi-confined aquifer can be assessed using volumetric approach as the product of the following:
   i) Area of the confined aquifer
   ii) Storage coefficient
   iii) Difference of the piezometric head during post-monsoon and altitude of the bottom of top confining layer.
e) The calculated in-storage resources of the semi-confined aquifers where there is no exploitation, includes small amount of dynamic resource of the semi-confined aquifer also, which replenishes every year. But to make it simpler this was also computed as part of the in-storage resource of the semi-confined aquifer.

32.3 COMPUTATIONAL PROCEDURE

The computational procedure for estimating the in-storage ground water resources of the semi-confined aquifer in the assessment unit involves the following steps :

a) The area of the semi-confined aquifer for which the in-storage ground water resources is to be computed. Let this area in hectares be ‘A’
b) The average piezometric head during pre-monsoon season above mean sea level is to be obtained. Let this head above mean sea level in meters be ‘h_{PRE}’
c) The average piezometric head during post-monsoon season above mean sea level is to be obtained. Let this head above mean sea level meters be ‘h_{POST}’
d) The average altitude of the bottom of top confining layer of the semi-confined aquifer is to be obtained. Let this level in meters above mean sea level is h_0 .
e) The storativity of the aquifer is to be obtained. Let this storativity value as a fraction be ‘S’
f) If the Semi-Confined Aquifer is being exploited then In-storage ground water resources of the semi-confined aquifer , ‘Y’ in hectare meters is finally computed as,

$$\mathbf{Y = SA\,(h_{PRE} - h_0)}$$

g) If the Semi-Confined Aquifer is not being exploited then In-storage ground water resources of the semi-confined aquifer , ‘Y’ in hectare meters is finally computed as,

$$\mathbf{Y = SA\,(h_{POST} - h_0)}$$

32.4 FORMATS SUGGESTED FOR THE COMPUTATION

The computations for obtaining the in-storage ground water resources of semi-confined aquifer as described earlier in this chapter are presented in Table 32.1.

32.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of In-Storage Resources of semi-confined aquifer.

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Area of the Semi-Confined Aquifer	Number	7	0
3	Storativity	Number	10	8
4	Pre monsoon Piezometric head	Number	7	2
5	Post monsoon Piezometric head	Number	7	2
6	Bottom of Top Confined Layer	Number	7	2
7	Total In Storage Resources of Semi-Confined Aquifer	Number	8	0

Table 32.1 In-storage Ground Water Resources of the Semi-Confined Aquifer in the Assessment Unit

Name of Ground Water Assessment Unit :
Principal Aquifer :
Major Aquifer :
Name of the Confined Aquifer :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of items (for the semi-confined aquifer)	Quantity
1	Area in hectares	
2	Storativity of the semi-confined Aquifer	
3	Average Piezometric Head During Pre-Monsoon Season [From Table 31.2]	
4	Average Piezometric Head During Post-Monsoon Season [From Table 31.2]	
5	Altitude of the Bottom of Top Confining Layer of the Semi-Confined Aquifer in meters above mean sea level	
6	Whether this semi-confined aquifer is being exploited (Yes/No)	
7	In-Storage Ground Water Resource of the Semi-Confined Aquifer If Response to (6) is Yes [(1) * (2) * ((3)-(5))] If Response to (6) is No [(1)*(2)*((4)-(5))]	

33

TOTAL GROUND WATER AVAILABILITY IN THE ASSESSMENT UNIT

33.1 GENERAL

The Total Ground Water Availability in any area is the Sum of Dynamic Ground Water Resources, the in-storage ground water resources of the unconfined aquifer and the dynamic and In-storage resources of the confined aquifers and semi confined aquifers in the area.

The sum of Annual Exploitable Ground Water Resources as computed in Chapter 20 and the In-storage ground water resources of the unconfined aquifer as computed in chapter 28 is the Total Ground Water Availability of the unconfined aquifer.

If the confined aquifer is being exploited, the Total Ground Water Availability of the confined aquifer is the sum of Dynamic Ground Water Resources as computed earlier in chapter 29 and the In-storage ground water resources of that confined aquifer as computed in chapter 30 . If the confined aquifer is not being exploited, the Total Ground Water Availability of the confined aquifer comprises of only one component i.e. the In-storage of that confined aquifer as computed in Chapter 30.

If the semi-confined aquifer is being exploited, the Total Ground Water Availability of the semi-confined aquifer is the sum of Dynamic Ground Water Resources as computed earlier in chapter 31 and the In-storage ground water resources of that semi-confined aquifer as computed in chapter 32 . If the semi-confined aquifer is not being exploited, the Total Ground Water Availability of the semi-confined aquifer comprises of only one component i.e. the In-storage of that semi-confined aquifer as computed in Chapter 32.

33.2 ASSUMPTIONS

a) The total Availability of ground Water in unconfined aquifer is the sum of Annual Extractable Ground Water Resources and the In-storage Ground Water Resources.
b) If aquifer geometry is known the in-storage resources of the unconfined aquifer will be assessed up to the bottom of the aquifer. If the aquifer geometry is not known, the in-storage resources will be assessed up to 100 meters below ground level in hard rock areas and 300meters below ground level in soft rock areas.

33.3 COMPUTATIONAL PROCEDURE

The computational procedure for estimating the total ground water availability in the assessment unit involves the following steps :

a) Total Ground Water Availability of the unconfined aquifer is the sum of Annual Exploitable Ground Water Resources and the In-storage ground water resources of the unconfined aquifer.
b) Total Ground Water Availability of the confined aquifer is the sum of Dynamic Ground Water Resources and the In-storage ground water resources of that confined aquifer if that confined aquifer is being exploited,
c) If the confined aquifer is not being exploited, the Total Ground Water Availability of the confined aquifer comprises of only one component i.e. the In-storage ground water resources of that confined aquifer.
d) Total Ground Water Availability of the semi-confined aquifer is the sum of Dynamic Ground Water Resources and the In-storage ground water resources of that semi-confined aquifer if the semi-confined aquifer is being exploited,
e) If the semi-confined aquifer is not being exploited, the Total Ground Water Availability of the semi-confined aquifer comprises of only one component i.e. the In-storage ground water resources of that semi-confined aquifer.
f) The Total Ground Water Availability in any assessment unit is the Sum of Dynamic Ground Water Resources, the in-storage ground water resources in the unconfined aquifer and the dynamic and In-storage resources of the all confined aquifers and semi confined aquifers existing in the area.

33.4 FORMATS SUGGESTED FOR THE COMPUTATION

The computations for obtaining the total ground water availability of the assessment unit as described earlier in this chapter are presented in Table 33.1.

33.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the estimation of In-Storage Resources of semi-confined aquifer.

S.No	Parameter	Type	Size	Decimals
1	Name of the Assessment Unit	Text	20	
2	Annual Extractable Ground Water Resource	Number	8	0
3	In storage Ground Water Resources of Unconfined Aquifer	Number	8	0
4	Total Ground Water Availability of Unconfined Aquifer	Number	8	0
5	Dynamic Ground Water Resources of Confined Aquifers	Number	8	0
6	In storage Ground Water Resources of Confined Aquifers	Number	8	0
7	Total Ground Water Availability of Confined Aquifers	Number	8	0

S.No	Parameter	Type	Size	Decimals
8	Dynamic Ground Water Resources of Semi-Confined Aquifers	Number	8	0
9	In storage Ground Water Resources of Semi-Confined Aquifers	Number	8	0
10	Total Ground Water Availability of Semi-Confined Aquifers	Number	8	0
11	Total Ground Water Availability of the Assessment Unit	Number	8	0

Table 33.1 Total Ground Water Availability in the Ground Water Assessment Unit

Name of Ground Water Assessment Unit :
Index Number of Ground Water Assessment Unit :
Ground Water Assessment Year :

S. No.	Description of item	Quantity of Fresh Ground Water (Sum of the Resources of Command & Non-Command Sub Units)	Quantity of Saline Ground Water (Resources of Poor Ground Water Quality Sub Unit)
1	Unconfined Aquifer a. Annual Extractable ground Water Resources in hectare meters b. In-storage ground Water Resources c. Total Ground Water Availability [(1a)+(1b)]		
2	Whether Confined Aquifers are being Exploited (yes/no)		
3	Confined Aquifers If response to (2) is Yes a. Dynamic Ground Water resources b. In-Storage ground Water Resources c. Total Ground Water Availability [(3a)+(3b)] If response to (2) is No b. In-Storage ground Water Resources c. Total Ground Water Availability [(3b)]		
4	Whether Semi-Confined Aquifers are being Exploited (yes/no)		
5	Semi-Confined Aquifers If response to (4) is Yes a. Dynamic Ground Water resources b. In-Storage ground Water Resources c. Total Ground Water Availability [(5a)+(5b)] If response to (4) is No b. In-Storage ground Water Resources c. Total Ground Water Availability [(5b)]		
6.	**Total Ground Water Availability in the Ground Water Assessment Unit**, in hectare meters [(1c) + (3c) + (5c)]		

34

SUMMARY REPORT OF THE ASSESSMENT UNIT

34.1 GENERAL

The report on 'Ground Water Estimation Methodology - 2015', requires that a summary report on each ground water assessment unit should be prepared in the form of two concise tables. The first report contains only the dynamic ground water resources which can be used for planning for future ground water management. Whereas the other report should contain the total availability of the ground water resources which indicates if there is any ground water mining taking place in the assessment unit for sensitizing stakeholders about the damage being done to the environment and for planning the remedial measures there upon for rectifying the damage. This table should also be accompanied by graphical plots, one for each sub units, which show the trend of depth to water table below ground level during pre-monsoon and post-monsoon monitorings. The intentions behind this requirement are many. Some of the more important among them are listed below :

a) A comprehensive understanding of the ground water assessment in each ground water assessment unit can be obtained from these concise tables of information
b) The first Report on the dynamic ground water resources can be used for planning for future ground water management.
c) The second report on the total availability of the ground water resources indicates the status of ground water mining taking place in the assessment unit which can be used for sensitizing stakeholders about the damage being done to the environment and for planning the remedial measures there upon for rectifying the damage
d) The relative importance of each ground water assessment component can be better appreciated as a result of which more attention can be focused in the future for refining the methodology for computing those components which are relatively more important
e) A concise table of information will be made available so that the task of refining the norms adopted in ground water assessment as and when it is undertaken can be more efficiently accomplished.

34.2 FORMATS SUGGESTED FOR THE COMPUTATION

The summary report on the dynamic ground water resources assessment for each ground water assessment unit is to be presented in Table 34.1. The summary report on the total ground water availability of each ground water assessment unit is to be presented in Table 34.2. The graphical plots showing the trend of depth to water table below ground level during the pre-monsoon and post-monsoon monitoring in the sub units are to be presented in Map 34.1, 34.2, 34.3, one map for each sub-unit.

34.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Summary report.

S.No	Parameter	Type	Size	Decimals
1	State	Text	50	
2	Assessment Unit	Text	20	
3	Type of Assessment Unit	Text	20	
4	Predominant Rock Terrain	Text	30	
5	Total Area	Number	7	0
6	Poor Ground Water Quality Area	Number	7	0
7	Command Area	Number	7	0
8	Non Command Area	Number	7	0
9	Ground Water Assessment year	Text	9	0
10	Final Monsoon Recharge Other Sources NC	Number	8	0
11	Final Non-Monsoon Recharge Other Sources NC	Number	8	0
12	Base Flow During Monsoon NC	Number	8	0
13	Recharge Due to Streams Monsoon NC	Number	8	0
14	Lateral Flows During Monsoon NC	Number	8	0
15	Vertical Flows During Monsoon NC	Number	8	0
16	Evaporation During Monsoon NC	Number	8	0
17	Transpiration During Monsoon NC	Number	8	0
18	Recharge Due to Streams Non-Monsoon NC	Number	8	0
19	Lateral Flows During Non-Monsoon NC	Number	8	0
20	Vertical Flows During Non-Monsoon NC	Number	8	0
21	Evaporation During Non-Monsoon NC	Number	8	0
22	Transpiration During Non-Monsoon NC	Number	8	0
23	Final RF Recharge Monsoon NC	Number	7	0
24	Final RF Recharge Non-Monsoon NC	Number	7	0
25	Total Annual Ground Water Resources NC	Number	8	0
26	Environmental Flows NC	Number	8	0
27	Annual Extractable Ground Water Resources NC	Number	8	0
28	Total Sub Unit All Uses Annual Extraction NC	Number	8	0
29	Stage of Ground Water Extraction NC	Number	6	2
30	Total Sub Unit Irrigation Annual Extraction NC	Number	8	0
31	Total Sub Unit Industrial Annual Extraction NC	Number	8	0
32	Annual Allocation NC	Number	8	0
33	Net Ground Water Availability For Future Use NC	Number	8	0
34	Final Monsoon Recharge Other Sources C	Number	8	0
35	Final Non-Monsoon Recharge Other Sources C	Number	8	0
36	Recharge Due to Streams Monsoon C	Number	8	0
37	Lateral Flows During Monsoon C	Number	8	0
38	Vertical Flows During Monsoon C	Number	8	0

S.No	Parameter	Type	Size	Decimals
39	Evaporation During Monsoon C	Number	8	0
40	Transpiration During Monsoon C	Number	8	0
41	Recharge Due to Streams Non-Monsoon C	Number	8	0
42	Lateral Flows During Non-Monsoon C	Number	8	0
43	Vertical Flows During Non-Monsoon C	Number	8	0
44	Evaporation During Non-Monsoon C	Number	8	0
45	Transpiration During Non-Monsoon C	Number	8	0
46	Final RF Recharge Monsoon C	Number	8	0
47	Final RF Recharge Non-Monsoon C	Number	8	0
48	Total Annual Ground Water Resources C	Number	8	0
49	Environmental Flows C	Number	8	0
50	Annual Extractable Ground Water Resources C	Number	8	0
51	Total Sub Unit All Uses Annual Extraction C	Number	8	0
52	Stage of Ground Water Extraction C	Number	6	2
53	Total Sub Unit Irrigation Annual Extraction C	Number	8	0
54	Total Sub Unit Industrial Annual Extraction C	Number	8	0
55	Annual Allocation C	Number	8	0
56	Net Ground Water Availability For Future Use C	Number	8	0
57	WTFM Used NC	Logical	1	
58	WTFM Used C	Logical	1	
59	Method For SY Determination NC	Text	20	
60	Method For SY Determination C	Text	20	
61	Declining Pre and Post WL NC	Logical		
62	Category NC	Text	15	
63	Validity NC	Text	10	
64	Declining Pre and Post WL C	Logical		
65	Category C	Text	15	
66	Validity C	Text	10	
67	Final Monsoon Recharge Other Sources PQ	Number	8	0
68	Final Non-Monsoon Recharge Other Sources PQ	Number	8	0
69	Recharge Due to Streams Monsoon PQ	Number	8	0
70	Lateral Flows During Monsoon PQ	Number	8	0
71	Vertical Flows During Monsoon PQ	Number	8	0
72	Evaporation During Monsoon PQ	Number	8	0
73	Transpiration During Monsoon PQ	Number	8	0
74	Recharge Due to Streams Non-Monsoon PQ	Number	8	0
75	Lateral Flows During Non-Monsoon PQ	Number	8	0
76	Vertical Flows During Non-Monsoon PQ	Number	8	0
77	Evaporation During Non-Monsoon PQ	Number	8	0
78	Transpiration During Non-Monsoon PQ	Number	8	0
79	Final RF Recharge Monsoon PQ	Number	7	0
80	Final RF Recharge Non-Monsoon PQ	Number	7	0
81	Total Annual Ground Water Resources PQ	Number	8	0
82	Environmental Flows PQ	Number	8	0
83	Annual Extractable Ground Water Resources PQ	Number	8	0
84	Total Sub Unit Irrigation Annual Extraction PQ	Number	8	0
85	Total Sub Unit Industrial Annual Extraction PQ	Number	8	0
86	Net Ground Water Availability For Future Use PQ	Number	8	0
87	WTFM Used PQ	Logical	1	
88	Method For SY Determination PQ	Text	20	
89	Declining Pre and Post WL PQ	Logical		

S.No	Parameter	Type	Size	Decimals
90	Category PQ	Text	15	
91	Validity PQ	Text	10	
92	Potential Resources Due to Spring Discharges	Number	8	0
93	Potential Resources Due to Shallow WT	Number	8	0
94	Potential Resources Due to Flood Prone Area	Number	8	0
95	Total Potential Resources	Number	8	0

TABLE 34.1 SUMMARY REPORT IN RESPECT OF THE DYNAMIC GROUND WATER RESOURCES OF EACH GROUND WATER ASSESSMENT UNIT

A. Dynamic Ground Water Resources of Unconfined Aquifer:

1. Command and Non - command Areas

S. No.	Description of item	Command area		Non-Command area	
		in hectare metres	in mm	in hectare metres	in mm
1	Recharge from 'Rainfall' during monsoon season [From Table 19.11]				
2	Recharge from 'Other Sources' during monsoon season [From Table 9.1]				
3	Resultant Ground Water Inflow during monsoon season [From Table 17.1]				
4	Recharge from 'Rainfall' during non - monsoon season [From Table 19.11]				
5	Recharge from 'Other Sources' during non - monsoon season [From Table 9.1]				
6	Resultant Ground Water Inflow during non-monsoon season [From Table 17.1]				
7	Annual ground water resources [(1) + (2) + (3) + (4) + (5) + (6)]				
8	Estimated Base Flow Restricted to ecological Flow Or 5-10% of Annual Ground Water Resources [From Table 20.1]				
9	Annual Extractable Ground Water Resource [(7) - (8)]				
10	Current annual gross ground water extraction for 'All Uses' [From Table 3.13]				
11	Current annual gross ground water extraction for 'Domestic Use' [From Table 3.13]				
12	Current annual gross ground water extraction for 'Irrigation Use' [From Table 3.13]				

S. No.	Description of item	Command area		Non-Command area	
		in hectare metres	in mm	in hectare metres	in mm
13	Current annual gross ground water extraction for ‘Industrial use'’ [From Table 3.13]				
14	Annual ground water allocation for domestic water supply as on 2025. [From Table 25.1]				
15	Net annual ground water availability for ‘Future Use’ [(9) - (12) - (13) - (14)]				

S. No.	Description of item	Command area	Non-Command area
16	Stage of ground water Extraction as a percentage [((10) / (9)) * 100]		
17	Quantity Categorisation for future ground water development (Safe / Semi-Critical/ Critical / Over exploited)		
18	Quality Tag [From Table 24.1]		
19	Does the water table during pre and post monsoon seasons show a significant falling trend (Yes / No) [From Table 23.4]		
20	Validation of Assessment Using Ground Water level trends (Valid/ To Be Reassessed) [From Table 23.4]		

2. Poor Ground Water Quality Area

S. No.	Description of item	in hectare metres	in mm
1	Recharge from 'Rainfall' during monsoon season		
2	Recharge from 'Other Sources' during monsoon season		
3	Resultant Ground Water Inflow during monsoon season		
4	Recharge from 'Rainfall' during non - monsoon season		
5	Recharge from 'Other Sources' during non - monsoon season		
6	Resultant Ground Water Inflow during non-monsoon season		
7	Annual ground water resources [(1) + (2) + (3) + (4) + (5) + (6)]		
8	Estimated Base Flow Restricted to ecological Flow Or 5-10% of Annual Ground Water Recharge		
9	Annual Extractable Ground Water Resource [(7) - (8)]		
10	Current annual gross ground water extraction for 'All Uses'		
11	Current annual gross ground water extraction for 'Domestic Use'		
12	Current annual gross ground water extraction for 'Irrigation Use'		
13	Current annual gross ground water extraction for 'Industrial use		
14	Annual ground water allocation for domestic water supply as on 2025.		
15	Net annual ground water availability for 'Future Use' [(9) - (12) - (13) - (14)]		

S. No	Description of item	Poor Ground Water Quality Area
16	Stage of ground water extraction as a percentage [((10) / (9)) * 100]	
17	Quantity Categorisation for future ground water development (Safe / Semi-Critical/ Critical / Over exploited)	
18	Quality Tag	
19	Does the water table during pre and post monsoon seasons show a significant falling trend (Yes / No)	
20	Validation of Assessment Using Ground Water level trends (Valid/ To Be Reassessed)	

3. Potential Resources (If any) in Ground Water Assessment Unit

a.	Potential resource due to Spring discharges in hectare meters	
b.	Potential resource in waterlogged and shallow water table areas in hectare metres [From Table 27.7]	
c.	Potential resource in flood prone area in hectare metres	
d.	Total potential recharge in hectare metres [(a) + (b) + (c)]	

B. Dynamic Ground Water Resources of Confined/ Semi-Confined Aquifers:
(If the aquifer is being exploited)
[From Table 29.3]

S.No	Aquifer Number & Name	Type	Dynamic Ground Water Resources in ham
1			
2			
3			

TABLE 34.2 SUMMARY REPORT IN RESPECT OF THE TOTAL GROUND WATER AVAILABILITY OF EACH GROUND WATER ASSESSMENT UNIT

A. In storage Ground Water Resources of Unconfined Aquifer in Ground Water Assessment Unit

S.No	Component	Fresh Ground Water Resource	Saline Ground Water Resource
a.	In storage / Static ground water resources in hectare metres [From Table 28.1]		

B. In storage Ground Water Resources of Confined/ Semi-Confined Aquifers:

[From Table 30.1]

S.No	Aquifer Number & Name	Type	In storage Ground Water Resources in hectare meters	
			Fresh	Saline
1				
2				
3				
Total In-Storage Ground Water Resources of confined and semi-confined aquifers in the Assessment Unit				

C. Total Extractable Ground Water Resources in the Assessment Unit

[From Table 20.1 & 29.3]

S.No	Aquifer Number & Name	Type	Extractable Ground Water Resources in hectare meters	
			Fresh	Saline
1				
2				
3				
Total Extractable Ground Water Resources in the Assessment Unit				

(Note: For Unconfined Aquifer - it is Annual Extractable Ground Water Resources and for other aquifers it is the dynamic resources computed)

E. Total Ground Water Availability in the Assessment Unit

S.No	Component	Fresh	Saline
1	Total Extractable Ground Water Resources in hectare meters		
2	Total In storage Ground Water Resources in hectare meters		
3	Total Ground Water Availability in hectare meters [(1)+(2)]		

MAP 34.1: Variation of Depth to Water Table Below Ground Level Over Successive Ground Water Years in Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

	Pre - monsoon ground water level trend	Shows a Rise / Fall of [From Table 23.4]	cm per year
——	Post - monsoon ground water level trend	Shows a Rise / Fall of [From Table 23.5]	cm per year

MAP 34.2: Variation of Depth to Water Table Below Ground Level Over Successive Ground Water Years in Non-Command Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Pre - monsoon ground water level trend Shows a Rise / Fall of cm per year
[From Table 23.9]

Post - monsoon ground water level trend Shows a Rise / Fall of cm per year
[From Table 23.10]

MAP 34.3: Variation of Depth to Water Table Below Ground Level Over Successive Ground Water Years in Poor Ground Water Quality Area

Name of Ground Water Assessment Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Ground Water Assessment Unit	:		

Pre - monsoon ground water level trend Shows a Rise / Fall of cm per year
[From Table 23.14]

—— Post - monsoon ground water level trend Shows a Rise / Fall of cm per year
[From Table 23.15]

35

APPORTIONING OF GROUND WATER RESOURCES IN TERMS OF ADMINISTRATIVE UNIT

35.1 GENERAL

Ground water assessment units as adopted by a particular State/Union Territory can be, Block, Taluka, Mandal, Firka or Watershed. Whenever a 'Watershed' has been adopted as the ground water assessment unit, it is also necessary to present the results of ground water assessment in terms of an appropriate administrative development unit like Block, Taluka, Mandal or Firka as the case may be. Each such administrative development unit will have to be sub-divided in to four sub-units namely, 'Hilly Area', 'Command Area', 'Non-command Area' and 'Poor Ground Water Quality Area' following the same guidelines described in Chapter 2. Ground water assessment is not made for the 'Hilly Area'. Ground water assessment results for the other three sub-units which are to be obtained are given below :

a) Annual Extractable ground Water Resources
b) Current annual gross ground water extraction for 'All Uses'
c) Stage of ground water Extraction
d) Categorization as safe, semi-critical, critical or over exploited
e) Current annual gross ground water extraction for 'Irrigation'
f) Annual allocation of ground water for 'Domestic Water Supply'
g) Net annual ground water availability for 'Future Use'
h) Dynamic Resources of Confined Aquifers
i) Dynamic Resources of Semi-Confined Aquifers

35.2 ASSUMPTIONS

The ground water assessment for a given administrative development unit is based on the ground water assessment results obtained for those watersheds which are partly or wholly contained within the administrative development unit under consideration. It is assumed that the resources are equally distributed throughout the assessment unit.

35.3 COMPUTATIONAL PROCEDURE

35.3.1 Annual Extractable Ground Water Resource

The computational scheme for estimating the annual extractable ground water resources in any sub unit of the administrative development unit under consideration comprises of the following steps.

a) All those watersheds which have a portion of this particular sub unit falling within the sub unit of the administrative development unit under consideration are to be identified, and the area of each of those portions are obtained. Let the number of such watersheds be 'N', and let X(i), for i = 1 to N be the area of each of those portions. The sum of X(i) for i = 1 to N will be equal to the area of the sub unit of the administrative development unit.
b) Let Y(i), for i = 1 to N be the annual extractable ground water resource per unit area in the sub unit of each of the N watersheds.
c) The annual extractable ground water resource in the sub unit of the administrative development unit under consideration is obtained as the sum of the product of X(i) and Y(i), for i = 1 to N.

35.3.2 Current Annual Gross Ground Water Extraction For All Uses

The computational procedure for this is similar to what has been described earlier in 35.3.1, except that, Y(i) for i = 1 to N now represent the current annual gross ground water extraction for 'All Uses' per unit area in the sub unit of each of the N watersheds.

35.3.3 Current Annual Gross Ground Water Extraction for Irrigation

The computational procedure for this is similar to what has been described earlier in 35.3.1, except that, Y(i) for i =1 to N now represent the current annual gross ground water extraction for 'Irrigation' per unit area in the command areas of each of the 'N' watersheds.

35.3.4 Allocation for Domestic Water Supply

The computational procedure for this is similar to what has been described earlier in 35.3.1, except that, Y(i) for i = 1 to N now represent the annual allocation of ground water for 'Domestic Water Supply' per unit area in the command areas of each of the 'N' watersheds.

35.4 FORMATS SUGGESTED FOR THE COMPUTATION

Location details of each administrative development unit, its area and area of the sub-units within it are presented in Table 35.1.

35.4.1 Command Area

The computations for estimating the annual extractable annual ground water resources in the command area of a given administrative development unit are to be presented in Table 35.2. The computations for estimating the current annual gross ground water extraction for 'All Uses' in command area of the given administrative development unit are to be presented in Table 35.3. The computations for estimating annual gross ground water extraction for ‘Irrigation use’ in the command area of the given administrative development unit are to be presented in Table 35.4. The computations for estimating annual gross ground water extraction for ‘Industrial use’ in the command area of the given administrative development unit are to be presented in Table 35.5. The computations for estimating annual allocation of ground water for ‘Domestic and Industrial Water Supply’ in the command area of the given administrative development unit are to be presented in Table 35.6. The information related to the dynamic ground water resources of confined aquifers in the command area of the administrative development unit is to be presented in Table 35.7. The information related to the dynamic ground water resources of semi-confined aquifers in the command area of the administrative development unit is to be presented in Table 35.8.

35.4.2 Non-Command Area

The computational procedure for obtaining the components of assessment for the non-command area is identical to that described earlier in Section 35.4.1 for the command area. The necessary computations are to be presented in Tables 35.9 to 35.15.

35.4.3 Poor Ground Water Quality Area

The computational procedure for obtaining the components of assessment for the poor ground water quality area is identical to that described earlier in Section 35.4.1 for the command area. The necessary computations are to be presented in Tables 35.16 to 35.22.

35.4.4 Quality Tag

The quality tag pertains to the administrative development is to be presented in Table 35.23.

35.4.5 Summary Report

The summary report on ground water assessment for each administrative development unit is to be presented. This summary report should contain the following information in addition to the ground water assessment components discussed earlier :

a) Stage of ground water extraction computed as the current annual gross ground water extraction for ‘All Uses’ expressed as a percentage of the Annual Extractable Ground Water Resources.
b) Categorization as safe, semi-critical, critical or over exploited on the basis of the set of criteria discussed earlier in Chapter 22..
c) The net annual ground water availability for ‘Future Use’ computed by subtracting the sum of the current annual gross ground water extraction for ‘Irrigation use’, current annual gross ground water extraction for ‘Industrial use’, and the annual allocation of ground water for ‘Domestic Water Supply’ from the Annual extractable ground water resources .

The summary report as discussed above is to be presented in Table 35.24.

35.5 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Apportioning.

S.No	Parameter	Type	Size	Decimals
1	State	Text	50	
2	Administrative Unit	Text	20	
3	Type of Administrative Unit	Text	20	
4	Toposheet Numbers	Text	50	
5	Starting Latitude	Text	10	
6	Ending Latitude	Text	10	
7	Starting Longitude	Text	10	
8	Ending Longitude	Text	10	
9	Total Area	Number	7	0
10	Hilly Area	Number	7	0
11	Recharge Worthy Area	Number	7	0
12	Poor Ground Water Quality Area	Number	7	0
13	Command Area	Number	7	0
14	Non Command Area	Number	7	0
15	Name of the Assessment Unit	Text	20	
16	Annual Extractable Ground Water Resources NC	Number	8	0
17	Area of Assessment Sub Unit in the Admin Unit NC	Number	7	0
18	Annual Extractable Ground Water Resources in Admin NC	Number	8	0
19	Total Area of Assessment Unit in the Admin Unit NC	Number	7	0
20	Total Annual Extractable Ground Water Resources in Admin NC	Number	8	0
21	Total Annual Extractable Ground Water Resources in Admin NC m	Number	8	3
22	Sub Unit All Uses Annual Extraction NC	Number	8	0
23	Sub Unit All Uses Annual Extraction in Admin NC	Number	8	0
24	Total Sub Unit All Uses Annual Extraction Admin NC	Number	8	0
25	Total Sub Unit All Uses Annual Extraction Admin NC m	Number	8	3
26	Sub Unit Irrigation Annual Extraction NC	Number	8	0
27	Sub Unit Irrigation Annual Extraction in Admin NC	Number	8	0
28	Total Sub Unit Irrigation Annual Extraction Admin NC	Number	8	0
29	Total Sub Unit Irrigation Annual Extraction Admin NC m	Number	8	3
30	Sub Unit Industrial Annual Extraction NC	Number	8	0
31	Sub Unit Industrial Annual Extraction in Admin NC	Number	8	0
32	Total Sub Unit Industrial Annual Extraction Admin NC	Number	8	0
33	Total Sub Unit Industrial Annual Extraction Admin NC m	Number	8	3
34	Sub Unit Allocation NC	Number	8	0
35	Sub Unit Allocation in Admin NC	Number	8	0
36	Total Sub Unit Allocation Admin NC	Number	8	0
37	Total Sub Unit Allocation Admin NC m	Number	8	3
38	Stage of Ground Water Extraction NC	Number	6	2

S.No	Parameter	Type	Size	Decimals
39	Annual Extractable Ground Water Resource C	Number	8	0
40	Area of Assessment Sub Unit in the Admin Unit C	Number	7	0
41	Annual Extractable Ground Water Resource in Admin C	Number	8	0
42	Total Area of Assessment Unit in the Admin Unit C	Number	7	0
43	Total Annual Extractable Ground Water Resource in Admin C	Number	8	0
44	Total Annual Extractable Ground Water Resource in Admin C m	Number	8	3
45	Sub Unit All Uses Annual Extraction C	Number	8	0
46	Sub Unit All Uses Annual Extraction in Admin C	Number	8	0
47	Total Sub Unit All Uses Annual Extraction Admin C	Number	8	0
48	Total Sub Unit All Uses Annual Extraction Admin C m	Number	8	3
49	Sub Unit Irrigation Annual Extraction C	Number	8	0
50	Sub Unit Irrigation Annual Extraction in Admin C	Number	8	0
51	Total Sub Unit Irrigation Annual Extraction Admin C	Number	8	0
52	Total Sub Unit Irrigation Annual Extraction Admin C m	Number	8	3
53	Sub Unit Industrial Annual Extraction C	Number	8	0
54	Sub Unit Industrial Annual Extraction in Admin C	Number	8	0
55	Total Sub Unit Industrial Annual Extraction Admin C	Number	8	0
56	Total Sub Unit Industrial Annual Extraction Admin C m	Number	8	3
57	Sub Unit Allocation C	Number	8	0
58	Sub Unit Allocation in Admin C	Number	8	0
59	Total Sub Unit Allocation Admin C	Number	8	0
60	Total Sub Unit Allocation Admin C m	Number	8	3
61	Stage of Ground Water Extraction C	Number	6	2
62	Annual Extractable Ground Water Resource PQ	Number	8	0
63	Area of Assessment Sub Unit in the Admin Unit PQ	Number	7	0
64	Annual Extractable Ground Water Resource in Admin PQ	Number	8	0
65	Total Area of Assessment Unit in the Admin Unit PQ	Number	7	0
66	Total Annual Extractable Ground Water Resource in Admin PQ	Number	8	0
67	Total Annual Extractable Ground Water Resource in Admin PQ m	Number	8	3
68	Sub Unit All Uses Annual Extraction PQ	Number	8	0
69	Sub Unit All Uses Annual Extraction in Admin PQ	Number	8	0
70	Total Sub Unit All Uses Annual Extraction Admin PQ	Number	8	0
71	Total Sub Unit All Uses Annual Extraction Admin PQ m	Number	8	3
72	Sub Unit Irrigation Annual Extraction PQ	Number	8	0
73	Sub Unit Irrigation Annual Extraction in Admin PQ	Number	8	0
74	Total Sub Unit Irrigation Annual Extraction Admin PQ	Number	8	0

S.No	Parameter	Type	Size	Decimals
75	Total Sub Unit Irrigation Annual Extraction Admin PQ m	Number	8	3
76	Sub Unit Industrial Annual Extraction PQ	Number	8	0
77	Sub Unit Industrial Annual Extraction in Admin PQ	Number	8	0
78	Total Sub Unit Industrial Annual Extraction Admin PQ	Number	8	0
79	Total Sub Unit Industrial Annual Extraction Admin PQ m	Number	8	3
80	Sub Unit Allocation PQ	Number	8	0
81	Sub Unit Allocation in Admin PQ	Number	8	0
82	Total Sub Unit Allocation Admin PQ	Number	8	0
83	Total Sub Unit Allocation Admin PQ m	Number	8	3
84	Stage of Ground Water Extraction PQ	Number	6	2

Table 35.1 Location Details and Area of Each Administrative Development Unit and the Sub - units Within It

(When Ground Water Assessment Unit is a 'Watershed')

Name of Administrative Development Unit :
Index Number of Administrative Development Unit :
Type of Administrative Development Unit :
(Block / Taluka / Mandal /Firka)
Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S. No.	Description of item	Quantity
1	Reference number(s) of Survey of India Toposheet(s) of 1 in 50,000 scale in which the Administrative Development Unit is located	
2	Latitudes within which the Administrative Development Unit is located i) Starting ii) Ending	
3	Longitudes within which the Administrative Development Unit is located i) Starting ii) Ending	
4	Total Area in hectares of the **'Administrative Development Unit'**	
5	Area in hectares of the **'Hilly Area'**	
6	Area in hectares of the portion of the Administrative Development Unit in which ground water recharge is possible [(4) - (5)]	
7	**Poor Ground Water Quality Area'** in hectares	
8	**'Command Area'** in hectares	
9	**'Non - command Area'** in hectares	
10	Quality Hazard (Salinity/ Arsenic/Fluoride/Others)	

Table 35.2 Annual Extractable Ground Water Resources in Command Area

Name of Administrative Development Unit :
Principal Aquifer :
Index Number of Administrative Development Unit :

Ground Water Assessment Year :
Major Aquifer :

S.No	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			Annual Extractable Ground Water Resources contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual Extractable Ground Water Resources per unit area in the command area of the watershed in millimeters	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual Extractable ground water availability in command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.3 Annual Gross Ground Water Extraction for 'All Uses' in Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			Annual gross ground water extraction for 'All Uses' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'All Uses' per unit area in the command area of the watershed in millimeters (From Table 3.13of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'All Uses' in command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.4 Annual Gross Ground Water Extraction for 'Irrigation Use' in Command Area

Name of Administrative Development Unit :
Ground Water Assessment Year :
Principal Aquifer :
Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			Annual gross ground water extraction for 'Irrigation' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'Irrigation' per unit area in the command area of the watershed in millimeters (From Table 3.13 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'Irrigation' in command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.5 Annual Gross Ground Water Extraction for 'Industrial Use' in Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			Annual gross ground water extraction for 'Industrial use' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'Industrial use' per unit area in the command area of the watershed in millimeters (From Table 3.13 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'Industrial use' in command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.6 Annual Ground Water Allocation for Domestic Water Supply in Command Area

Name of Administrative Development Unit :
Principal Aquifer :
Index Number of Administrative Development Unit :

Ground Water Assessment Year :
Major Aquifer :

S.No	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			Annual ground water allocation for domestic water supply contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual ground water allocation for domestic water supply per unit area in the command area of the watershed in millimeters (From Table 25.1/25.2 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual ground water allocation for domestic water supply in command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.7 Dynamic Ground Water Resources of Confined Aquifer in Command Area

Name of Administrative Development Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Administrative Development Unit	:		

S.No	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			Dynamic ground water resources of the confined aquifers contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Dynamic ground water resources of the confined aquifers per unit area in the command area of the watershed in millimeters (From Table 29.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Dynamic ground water resources of the confined aquifers in command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.8 Dynamic Ground Water Resources of Semi-Confined Aquifer in Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their command area contained within the command area of the administrative development unit			Dynamic ground water resources of the semi-confined aquifers contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Dynamic ground water resources of the semi-confined aquifers per unit area in the command area of the watershed in millimeters (From Table 31.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Dynamic ground water resources of the semi-confined aquifers in command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.9 Annual Extractable Ground Water Resources in Non-Command Area

Name of Administrative Development Unit :
Ground Water Assessment Year :
Principal Aquifer :
Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their non-command area contained within the non-command area of the administrative development unit			Annual Extractable Ground Water Resources contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual Extractable Ground Water Resources per unit area in the non-command area of the watershed in millimeters [From Table 20.2]	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual Extractable ground water availability in non-command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.10 Annual Gross Ground Water Extraction for 'All Uses' in Non-Command Area

Name of Administrative Development Unit :
Ground Water Assessment Year :
Principal Aquifer :
Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their non-command area contained within the non-command area of the administrative development unit			Annual gross ground water extraction for 'All Uses' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'All Uses' per unit area in the non-command area of the watershed in millimeters (From Table 3.26 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'All Uses' in non-command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.11 Annual Gross Ground Water Extraction for 'Irrigation Use' in Non-Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their non-command area contained within the non-command area of the administrative development unit			Annual gross ground water extraction for 'Irrigation' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'Irrigation use' per unit area in the non-command area of the watershed in millimeters (From Table 3.26 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'Irrigation' in non-command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.12 Annual Gross Ground Water Extraction for 'Industrial Use' in Non-Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their non-command area contained within the non-command area of the administrative development unit			Annual gross ground water extraction for 'Industrial use' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'Industrial use' per unit area in the non-command area of the watershed in millimeters (From Table 3.26 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'Industrial use' in non-command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.13 Annual Ground Water Allocation for Domestic Water Supply in Non-Command Area

Name of Administrative Development Unit :
Ground Water Assessment Year :
Principal Aquifer :
Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their Non-command area contained within the non-command area of the administrative development unit			Annual ground water allocation for domestic water supply contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual ground water allocation for domestic water supply per unit area in the non-command area of the watershed in millimeters (From Table 25.1/ 25.2 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual ground water allocation for domestic water supply in non-command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.14 Dynamic Ground Water Resources of Confined Aquifer in Non-Command Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their non-command area contained within the non-command area of the administrative development unit			Dynamic ground water resources of the confined aquifers contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Dynamic ground water resources of the confined aquifers per unit area in the non-command area of the watershed in millimeters (From Table 29.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Dynamic ground water resources of the confined aquifers in non-command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.15 Dynamic Ground Water Resources of Semi-Confined Aquifer in Non-Command Area

Name of Administrative Development Unit :

Ground Water Assessment Year :

Principal Aquifer :

Major Aquifer :

Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their non-command area contained within the non-command area of the administrative development unit			Dynamic ground water resources of the semi-confined aquifers contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Dynamic ground water resources of the semi-confined aquifers per unit area in the non-command area of the watershed in millimeters (From Table 31.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Dynamic ground water resources of the semi-confined aquifers in non- command area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.16 Annual Extractable Ground Water Resources in Poor Ground Water Quality Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			Annual Extractable Ground Water Resources contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual Extractable Ground Water Resources per unit area in the poor ground water quality area of the watershed in millimeters [From Table 20.3]	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1 2 3				
Total for all the watersheds considered				

Annual Extractable ground water availability in poor ground water quality area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.17 Annual Gross Ground Water Extraction for 'All Uses' in Poor Ground Water Quality Area

Name of Administrative Development Unit :
Ground Water Assessment Year :
Principal Aquifer :
Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			Annual gross ground water extraction for 'All Uses' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'All Uses' per unit area in the poor ground water quality area of the watershed in millimeters (From Table 3.39 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'All Uses' in poor ground water quality area of the administrative development unit

a) in hectare metres =
[Total in Col. (5)]

b) per unit area in millimetres =
[((a) / (Total in Col. (4))) * 1000]

Table 35.18 Annual Gross Ground Water Extraction for 'Irrigation Use' in Poor Ground Water Quality Area

Name of Administrative Development Unit	:	Ground Water Assessment Year	:
Principal Aquifer	:	Major Aquifer	:
Index Number of Administrative Development Unit	:		

S.No	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			Annual gross ground water extraction for 'Irrigation Use' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'Irrigation Use' per unit area in the poor ground water quality area of the watershed in millimeters (From Table 3.39 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'Irrigation' in poor ground water quality area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.19 Annual Gross Ground Water Extraction for 'Industrial Use' in Poor Ground Water Quality Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			Annual gross ground water extraction for 'Industrial use' contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual gross ground water extraction for 'Industrial use' per unit area in the poor ground water quality area of the watershed in millimeters (From Table 3.39 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual gross ground water extraction for 'Industrial use' in poor ground water quality area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.20 Annual Ground Water Allocation for Domestic Water Supply in Poor Ground Water Quality Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			Annual ground water allocation for domestic water supply contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Annual ground water allocation for domestic water supply per unit area in the poor ground water quality area of the watershed in millimeters (From Table 25.1 /25.2 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all the watersheds considered				

Annual ground water allocation for domestic water supply in poor ground water quality area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.21 Dynamic Ground Water Resources of Confined Aquifer in Poor Ground Water Quality Area

Name of Administrative Development Unit : Ground Water Assessment Year :
Principal Aquifer : Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			Dynamic ground water resources of the confined aquifers contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Dynamic ground water resources of the confined aquifers per unit area in the poor ground water quality area of the watershed in millimeters (From Table 29.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Dynamic ground water resources of the confined aquifers in poor ground water quality area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.22 Dynamic Ground Water Resources of Semi-Confined Aquifer in Poor Ground Water Quality Area

Name of Administrative Development Unit :
Ground Water Assessment Year :
Principal Aquifer :
Major Aquifer :
Index Number of Administrative Development Unit :

S.No	Watersheds which have a portion of their poor ground water quality area contained within the poor ground water quality area of the administrative development unit			Dynamic ground water resources of the semi-confined aquifers contribution from the watershed to the administrative development unit $\frac{(3)\times(4)}{1000}$
	Name of the watershed	Dynamic ground water resources of the semi-confined aquifers per unit area in the poor ground water quality area of the watershed in millimeters (From Table 31.3 of respective watersheds)	Area of the portion of the watershed as defined above in hectares	
(1)	(2)	(3)	(4)	(5)
1				
2				
3				
Total for all watersheds considered				

Dynamic ground water resources of the semi-confined aquifers in poor ground water quality area of the administrative development unit

a) in hectare meters =
[Total in Col. (5)]

b) per unit area in millimeters =
[((a) / (Total in Col. (4))) * 1000]

Table 35.23 Quality Tagging in the Administrative Development Unit

Name of Administrative Development Unit :
Index Number of Administrative Development Unit :
Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S. No.	Description of item	Command Area	Non-Command Area	Poor Ground Water Quality Area
1	Area of the sub unit			
2	Area effected by Salinity in mappable patches in 1:250,000			
3	Area effected by Fluoride in mappable patches in 1:250,000			
4	Area effected by Arsenic in mappable patches in 1:250,000			
5	Other Hazardous parameters present in the sub unit in mappable areas in 1:250,000 Parameter1:________ Parameter2:________ Parameter3:________ Parameter4:________ Parameter5:________			
6	Quality tag For the sub unit			

Table 35.24 Summary Report in Respect of Each Administrative Development Unit
(When Ground Water Assessment Unit is a 'Watershed')

Name of State / Union Territory :
Name of Administrative Development Unit :
Index Number of Administrative Development Unit :
Type Administrative Development Unit :
(Block / Taluka / Mandal/ Firka)
Principal Aquifer :
Major aquifer :
Area in hectares of
- a) Administrative Development Unit :
- b) Command Area :
- c) Non - command Area :
- d) Poor Ground Water Quality Area :

Ground Water Assessment Year :

1. Command and Non - Command Areas

S. No.	Description of item	Command area		Non- Command area	
		in hectare metres	in mm	in hectare metres	in mm
1	Annual Extractable Ground Water Resources				
2	Current annual gross ground water extraction for 'All Uses'				
3	Current annual gross ground water extraction for 'Irrigation Use'				
4	Current annual gross ground water extraction for 'Industrial use''				
5	Annual ground water allocation for domestic water supply as on 2025.				
6	Net annual ground water availability for 'Future Use'				

S. No.	Description of item	Non - command area	Command area
7	Stage of ground water extraction as a percentage [((2) / (1)) * 100]		
8	Quantity Categorisation for future ground water extraction (Safe / Semi-Critical/ Critical / Over exploited)		
9	Quality Tag		

2. Poor Ground Water Quality Area

S. No.	Description of item	in hectare metres	in mm
1	Annual Extractable Ground Water Resources		
2	Current annual gross ground water extraction for ‘All Uses’		
3	Current annual gross ground water extraction for ‘Irrigation Use’		
4	Current annual gross ground water extraction for ‘Industrial use		
5	Annual ground water allocation for domestic water supply as on 2025.		
6	Net annual ground water availability for ‘Future Use’		

S. No	Description of item	Poor Ground Water Quality Area
7	Stage of ground water Extraction as a percentage [((2) / (1)) * 100]	
8	Quantity Categorisation for future ground water extraction (Safe / Semi-Critical/ Critical / Over exploited)	
9	Quality Tag	

36

PRESENTATION OF AQUIFER WISE GROUND WATER RESOURCES

36.1 GENERAL

GEC 2015 recommends to present the estimated ground water resources aquifer wise. The assessment made assessment unit wise is to be consolidated make it aquifer wise resources. This will indicate the overall development of the aqufer. This should contain information about the recharge due to rainfall, recharge due to other sources, resultant flow into the aquifer, ground water extraction for various uses and Allocation for future domestic needs, Stage of ground water extraction and the category of the aquifer and the quality tag. This should be done for all the aquifers available in the area viz. unconfined aquifer, one or more confined aquifers and one or more semi-confined aquifers.

36.2 ASSUMPTIONS

The ground water components can be assessed as the sum of the particular component in all the assessment units which form part of the aquifer.

36.3 FORMATS SUGGESTED FOR THE COMPUTATION

36.3.1 Unconfined Aquifer

The computations for estimating the annual extractable annual ground water resources in the command area of the unconfined aquifer are presented in Table 36.1. The computations for estimating the net annual ground water availability for future use in command area of the unconfined aquifer are presented in Table 36.2. Similarly the computational procedure for obtaining the components of assessment for the non-command area are presented in Tables 36.3 to 36.4 and The computational procedure for obtaining the components of assessment for the poor ground water quality area are presented in Tables 36.5 to 36.6. The information related to the quality tagging of the unconfined aquifer is presented in Table 36.7.Computations for estimating Additional Potential resources and in-storage resources of the unconfined aquifer are presented in the Table 36.8. The summary report is presented in Table 36.9.

36.3.2 Confined Aquifer

The computations for estimating the dynamic ground water resources and in-storage ground water resources of the confined aquifer are presented in Table 36.10.

36.3.3 Semi-Confined Aquifer

The computations for estimating the dynamic ground water resources and in-storage ground water resources of the semi-confined aquifer are presented in Table 36.11.

36.4 STRUCTURE OF DATABASE PROPOSED

The following structure is proposed for the data elements pertain to the Aquifer wise Resources.

S.No	Parameter	Type	Size	Decimals
1	State	Text	50	
2	Aquifer Name	Text	20	
3	Total Area	Number	7	0
4	Poor Ground Water Quality Area	Number	7	0
5	Command Area	Number	7	0
6	Non Command Area	Number	7	0
7	Ground Water Assessment year	Text	9	0
8	Final Monsoon Recharge Other Sources NC	Number	8	0
9	Final Non-Monsoon Recharge Other Sources NC	Number	8	0
10	Base Flow During Monsoon NC	Number	8	0
11	Recharge Due to Streams Monsoon NC	Number	8	0
12	Lateral Flows During Monsoon NC	Number	8	0
13	Vertical Flows During Monsoon NC	Number	8	0
14	Evaporation During Monsoon NC	Number	8	0
15	Transpiration During Monsoon NC	Number	8	0
16	Recharge Due to Streams Non-Monsoon NC	Number	8	0
17	Lateral Flows During Non-Monsoon NC	Number	8	0
18	Vertical Flows During Non-Monsoon NC	Number	8	0
19	Evaporation During Non-Monsoon NC	Number	8	0
20	Transpiration During Non-Monsoon NC	Number	8	0
21	Final RF Recharge Monsoon NC	Number	7	0
22	Final RF Recharge Non-Monsoon NC	Number	7	0
23	Total Annual Ground Water Resources NC	Number	8	0
24	Environmental Flows NC	Number	8	0
25	Annual Extractable Ground Water Resources NC	Number	8	0
26	Total Sub Unit All Uses Annual Extraction NC	Number	8	0
27	Stage of Ground Water Extraction NC	Number	6	2
28	Total Sub Unit Irrigation Annual Extraction NC	Number	8	0
29	Total Sub Unit Industrial Annual Extraction NC	Number	8	0
30	Annual Allocation NC	Number	8	0
31	Net Ground Water Availability For Future Use NC	Number	8	0
32	Final Monsoon Recharge Other Sources C	Number	8	0

S.No	Parameter	Type	Size	Decimals
33	Final Non-Monsoon Recharge Other Sources C	Number	8	0
34	Recharge Due to Streams Monsoon C	Number	8	0
35	Lateral Flows During Monsoon C	Number	8	0
36	Vertical Flows During Monsoon C	Number	8	0
37	Evaporation During Monsoon C	Number	8	0
38	Transpiration During Monsoon C	Number	8	0
39	Recharge Due to Streams Non-Monsoon C	Number	8	0
40	Lateral Flows During Non-Monsoon C	Number	8	0
41	Vertical Flows During Non-Monsoon C	Number	8	0
42	Evaporation During Non-Monsoon C	Number	8	0
43	Transpiration During Non-Monsoon C	Number	8	0
44	Final RF Recharge Monsoon C	Number	8	0
45	Final RF Recharge Non-Monsoon C	Number	8	0
46	Total Annual Ground Water Resources C	Number	8	0
47	Environmental Flows C	Number	8	0
48	Annual Extractable Ground Water Resources C	Number	8	0
49	Total Sub Unit All Uses Annual Extraction C	Number	8	0
50	Stage of Ground Water Extraction C	Number	6	2
51	Total Sub Unit Irrigation Annual Extraction C	Number	8	0
52	Total Sub Unit Industrial Annual Extraction C	Number	8	0
53	Annual Allocation C	Number	8	0
54	Net Ground Water Availability For Future Use C	Number	8	0
55	WTFM Used NC	Logical	1	
56	WTFM Used C	Logical	1	
57	Method For SY Determination NC	Text	20	
58	Method For SY Determination C	Text	20	
59	Category NC	Text	15	
60	Category C	Text	15	
61	Final Monsoon Recharge Other Sources PQ	Number	8	0
62	Final Non-Monsoon Recharge Other Sources PQ	Number	8	0
63	Recharge Due to Streams Monsoon PQ	Number	8	0
64	Lateral Flows During Monsoon PQ	Number	8	0
65	Vertical Flows During Monsoon PQ	Number	8	0
66	Evaporation During Monsoon PQ	Number	8	0
67	Transpiration During Monsoon PQ	Number	8	0
68	Recharge Due to Streams Non-Monsoon PQ	Number	8	0
69	Lateral Flows During Non-Monsoon PQ	Number	8	0
70	Vertical Flows During Non-Monsoon PQ	Number	8	0
71	Evaporation During Non-Monsoon PQ	Number	8	0
72	Transpiration During Non-Monsoon PQ	Number	8	0
73	Final RF Recharge Monsoon PQ	Number	7	0
74	Final RF Recharge Non-Monsoon PQ	Number	7	0
75	Total Annual Ground Water Resources PQ	Number	8	0
76	Environmental Flows PQ	Number	8	0
77	Annual Extractable Ground Water Resources PQ	Number	8	0
78	Total Sub Unit Irrigation Annual Extraction PQ	Number	8	0
79	Total Sub Unit Industrial Annual Extraction PQ	Number	8	0
80	Net Ground Water Availability For Future Use PQ	Number	8	0
81	WTFM Used PQ	Logical	1	
82	Method For SY Determination PQ	Text	20	
83	Category PQ	Text	15	

S.No	Parameter	Type	Size	Decimals
84	Potential Resources Due to Spring Discharges	Number	8	0
85	Potential Resources Due to Shallow WT	Number	8	0
86	Potential Resources Due to Flood Prone Area	Number	8	0
87	Total Potential Resources	Number	8	0

Table 36.1 Annual Extractable Ground Water Resources in Command Area of the Unconfined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Monsoon Season			Non-Monsoon Season			Total Annual Resources in hectare meters (3)+(4)+(5)+(6)+(7)+(8)	Environmental Flow in hectare meters	Annual Extractable Ground Water Resource in hectare meters (9)-(10)
		Recharge Due to rainfall in hectare meters	Recharge Due to other Sources in hectare meters	Resultant Inflows in hectare meters	Recharge Due to rainfall in hectare meters	Recharge Due to other Sources in hectare meters	Resultant Inflows in hectare meters			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1										
2										
3										
Total For the Aquifer										

Table 36.2 Net Annual Ground Water Availability For Future Use in Command Area of the Unconfined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Annual Extractable Ground Water Resources	Ground Water Extraction in hectare meters During Monsoon Season for			Ground Water Extraction in hectare meters During Non-Monsoon Season for			Total Annual Ground Water extraction in hectare meters (4)+(5)+(6)+(7)+(8)+(9)	Allocation for Future Domestic needs in hectare meters	Net annual ground water availability for 'Future Use' in hectare meters (3)-(5)-(6)-(8)-(9)
			Domestic use	Irrigation Use	Industrial Use	Domestic use	Irrigation Use	Industrial Use			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											
Total For the Aquifer											

Table 36.3 Annual Extractable Ground Water Resources in Non-Command Area of the Unconfined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Monsoon Season			Non-Monsoon Season			Total Annual Resources in hectare meters (3)+(4)+(5)+(6)+(7)+(8)	Environmental Flow in hectare meters	Annual Extractable Ground Water Resource in hectare meters (9)-(10)
		Recharge Due to rainfall in hectare meters	Recharge Due to other Sources in hectare meters	Resultant Inflows in hectare meters	Recharge Due to rainfall in hectare meters	Recharge Due to other Sources in hectare meters	Resultant Inflows in hectare meters			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1										
2										
3										
Total For the Aquifer										

Table 36.4 Net Annual Ground Water Availability For Future Use in Non-Command Area of the Unconfined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Annual Extractable Ground Water Resources	Ground Water Extraction in hectare meters During Monsoon Season for			Ground Water Extraction in hectare meters During Non-Monsoon Season for			Total Annual Ground Water extraction in hectare meters (4)+(5)+(6)+(7)+(8)+(9)	Allocation for Future Domestic needs in hectare meters	Net annual ground water availability for 'Future Use' in hectare meters (3)-(5)-(6)-(8)-(9)
			Domestic use	Irrigation Use	Industrial Use	Domestic use	Irrigation Use	Industrial Use			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											
Total For the Aquifer											

Table 36.5 Annual Extractable Ground Water Resources in Poor Ground Water Quality Area of the Unconfined Aquifer

Principal Aquifer :

Major Aquifer :

Ground Water Assessment Year :

S.No	Assessment Unit Name	Monsoon Season			Non-Monsoon Season			Total Annual Resources in hectare meters (3)+(4)+(5)+(6)+(7)+(8)	Environmental Flow in hectare meters	Annual Extractable Ground Water Resource in hectare meters (9)-(10)
		Recharge Due to rainfall in hectare meters	Recharge Due to other Sources in hectare meters	Resultant Inflows in hectare meters	Recharge Due to rainfall in hectare meters	Recharge Due to other Sources in hectare meters	Resultant Inflows in hectare meters			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1										
2										
3										
Total For the Aquifer										

Table 36.6 Net Annual Ground Water Availability For Future Use in Poor Ground Water Quality Area of the Unconfined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Annual Extractable Ground Water Resources	Ground Water Extraction in hectare meters During Monsoon Season for			Ground Water Extraction in hectare meters During Non-Monsoon Season for			Total Annual Ground Water extraction in hectare meters (4)+(5)+(6)+(7)+(8)+(9)	Allocation for Future Domestic needs in hectare meters	Net annual ground water availability for 'Future Use' in hectare meters (3)-(5)-(6)-(8)-(9)
			Domestic use	Irrigation Use	Industrial Use	Domestic use	Irrigation Use	Industrial Use			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
1											
2											
3											
Total For the Aquifer											

Table 36.7 Quality Tagging of the Unconfined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S. No.	Description of item	Command Area	Non-Command Area	Poor Ground Water Quality Area
1	Area of the sub unit			
2	Area effected by Salinity in mappable patches in 1:250,000			
3	Area effected by Fluoride in mappable patches in 1:250,000			
4	Area effected by Arsenic in mappable patches in 1:250,000			
5	Other Hazardous parameters present in the sub unit in mappable areas in 1:250,000 Parameter1:________ Parameter2:________ Parameter3:________ Parameter4:________ Parameter5:________			
6	Quality tag For the sub unit			

Table 36.8 Additional Potential Resource in the Unconfined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Potential Resource due to Spring Discharges in hectare meters	Potential Resource Due to Shallow Water table Areas in hectare meters	Potential Resource due to Flood Prone Areas in hectare meters	Total Potential Resources in hectare meters [(3)+(4)+(5)]	In-storage Resources in hectare meters
(1)	(2)	(3)	(4)	(5)	(6)	(7)
1						
2						
3						
Total For the Aquifer						

Table 36.9 Summary Report in Respect of Unconfined Aquifer

S. No.	Description of item	Command area	Non-Command area	Total Fresh Resource (3)+(4)	Poor Ground Water quality Area
(1)	(2)	(3)	(4)	(5)	(6)
1	Recharge from 'Rainfall' during monsoon season				
2	Recharge from 'Other Sources' during monsoon season				
3	Resultant Ground Water Inflow during monsoon season				
4	Recharge from 'Rainfall' during non - monsoon season				
5	Recharge from 'Other Sources' during non - monsoon season				
6	Resultant Ground Water Inflow during non-monsoon season				
7	Annual ground water recharge [(1) + (2) + (3) + (4) + (5) + (6)]				
8	Estimated Base Flow Restricted to ecological Flow Or 5-10% of Annual Ground Water Recharge				
9	Annual Extractable Ground Water Resource [(7) - (8)]				
10	Current annual gross ground water extraction for 'Domestic Use'				
11	Current annual gross ground water extraction for 'Irrigation'				
12	Current annual gross ground water extraction for 'Industrial use''				
13	Current annual gross ground water extraction for 'All Uses'				
14	Annual ground water allocation for domestic water supply as on 2025.				
15	Net annual ground water availability for 'Future Use' [(9) - (12) - (13) - (14)]				

S. No.	Description of item	Command area	Non-Command area	Total Fresh Resource (3)+(4)	Poor Ground Water quality Area
(1)	(2)	(3)	(4)	(5)	(6)
16	Stage of ground water Extraction as a percentage [((10) / (9)) * 100]				
17	Quantity Categorisation for future ground water development (Safe / Semi-Critical/ Critical / Over exploited)				
18	Quality Tag (if any)				

2. Potential Resources (If any) and In-Storage Resources of the Un-Confined Aquifer

a.	Potential resource due to Spring Discharge in hectare meters	
b.	Potential resource in waterlogged and shallow water table areas in hectare metres	
c.	Potential resource in flood prone area in hectare metres	
d.	Total potential recharge in hectare metres [(a) + (b) + (c)]	
e.	In-Storage Ground Water resources in hectare meters	

Table 36.10 Ground Water Resources of Confined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Fresh Ground Water Resources		Saline ground Water Resources	
		Dynamic Ground Water Resources	In-Storage ground Water Resources	Dynamic Ground Water Resources	In-Storage ground Water Resources
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
Total For the Aquifer					

Table 36.11 Ground Water Resources of Semi-Confined Aquifer

Principal Aquifer :
Major Aquifer :
Ground Water Assessment Year :

S.No	Assessment Unit Name	Fresh Ground Water Resources		Saline ground Water Resources	
		Dynamic Ground Water Resources	In-Storage ground Water Resources	Dynamic Ground Water Resources	In-Storage ground Water Resources
(1)	(2)	(3)	(4)	(5)	(6)
1					
2					
3					
Total For the Aquifer					

ANNEXURES

I. Norms Recommended for the Canal Seepage Factor

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	3.50	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

II. Norms Recommended for the Recharge Due To Irrigation

DTW m bgl	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

For surface water, the recharge is to be estimated based on water released at the outlet. For ground water, the recharge is to be estimated based on gross draft. Where continuous supply is used instead of rotational supply, an additional recharge of 5% of application may be used. Where specific results are available from case studies is some states, the adhoc norms are to be replaced by norms evolved from these results.

III. Other Norms

1. Norm Recommended for the Recharge Due To Tanks & Ponds

As the data on the field studies for computing recharge from Tanks & Ponds are very limited, it is recommended to follow the same norm as followed in GEC 1997 in future assessments also. Hence the norm recommended by GEC-2015 for Seepage from Tanks & Ponds is 1.4 mm / day.

2. Norm Recommended for the Recharge Due To Water Conservation Structures

As per the studies carried out by various Non-Government Organizations, GEC-2015 recommends the Norm for the seepage from Water Conservation Structures as 40% of gross storage during a year which means 20% during monsoon season and 20% during non-monsoon Season.

3. Norm for Percapita Requirement

GEC 2015 recommends a norm of 60lpcd for computing the Allocation for future domestic needs. But the committee suggests to use the actual requirement if known.

4. Norm for Environmental Flow

GEC 2015 suggests to carry out studies for estimating the Environmental Flow. But in the absence of the same it recommends to use the norms as recommended by GEC 1997 may be followed. If water table fluctuation method is used for estimating rainfall recharge, 5% of the Annual Ground Water Recharge may be considered as Environmental Flow and if rainfall infiltration method is used for estimating rainfall recharge then 10% of the Annual Ground Water Recharge may be considered as Environmental flow.

IV. Norms Recommended for the Rainfall Infiltration Factor

Sl.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

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
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	Quarternary	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

Sl.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
49	Khondalite	KH01	Khondalites, Granulites - Weathered, Jointed	Azoic	7	5	9
50	Khondalite	KH01	Khondalites, Granulites - Mssive, 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
53	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Weathered, Jointed	Azoic to Proterozoic	7	5	9
54	Gneiss	GN01	Undifferentiated metasedimentaries/ Undifferentiated metamorphic - Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
55	Gneiss	GN02	Gneiss -Weathered, Jointed	Azoic to Proterozoic	11	10	12
56	Gneiss	GN02	Gneiss-Massive, Poorly Fractured	Azoic to Proterozoic	2	1	3
57	Gneiss	GN03	Migmatitic Gneiss - Weathered, Jointed	Azoic	7	5	9
58	Gneiss	GN03	Migmatitic Gneiss - Massive, Poorly Fractured	Azoic	2	1	3
59	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
60	Intrusive	IN01	Basic Rocks (Dolerite, Anorthosite etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3
61	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Weathered, Jointed	Proterozoic to Cenozoic	7	6	8
62	Intrusive	IN02	Ulrta Basics (Epidiorite, Granophyre etc.) - Massive, Poorly Fractured	Proterozoic to Cenozoic	2	1	3

V. Norms Recommended for the Specific Yield

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

S.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
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

S.No	Principal Aquifer	Major Aquifers		Age	Recommended (%)	Minimum (%)	Maximum (%)
		Code	Name				
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 - Mssive, 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