GROUNDWATER RESOURCE EVALUATION

The motivating force for the study of hydrogeology is its importance as a resource (Freeze, R.A. and Cherry, 1979). For the gainful exploitation and optimum utilization of any resource it is imperative that it be properly quantified. The unplanned exploitation may cause irreparable damage to the entire system. This holds good all the more in the case of groundwater resources, which is replenishable but not inexhaustible (Karanth, K.R., 1987).

The basic objective of groundwater resource evaluation is to estimate the total quantity of groundwater resources available, and their future supply potential to predict possible conflicts between supply and demand and to provide a scientific data base for rational water resources utilization (Earth Summit, 1992).

Therefore, quantification of groundwater resources of an area or basin becomes an essential prerequisite for its proper management. Moreover, it involves the application of principle of mass-conservation, to account for the quantitative changes occurring in various components of hydrologic cycle as applied to a basin.

A river basin forms a close system of surface and groundwater. Therefore, it is essential that various aspects of water in transit are quantitatively evaluated and definite recommendations in regards to its development be made. Accordingly, estimate of groundwater recharge, draft and balance of groundwater available was considered to be the important and ultimate aspect of groundwater studies in the area of investigation.

The differences between the recharge and the discharge is balanced by the change in groundwater storage. This can be expressed by the water balance
equation sometimes referred to as the equation of hydrologic equilibrium. 

\[ I - O = \pm \Delta S \]

where,

- **I** : Inflow during a given period of time
- **O** : Outflow during a given period of time
- **\( \Delta S \)** : is the change in groundwater resource

When the outflow is much more it creates serious imbalances of hydrological situations. Accordingly, a reappraisal of groundwater resources of the area of investigation is most desired to keep pace with groundwater development.

An attempt has been made to assess the groundwater potential in and around Aligarh city. The area is beset with dual situation of water logging and soil salinization along the Upper Ganga Canal and depleting water table in Aligarh city and adjoining areas, due to the heavy withdrawal much higher to the quantum of the average annual recharge through rainfall. The rate of decline has been estimated as 0.36 m/year (Akram, 1987) in the water level. Under these situations, the precise evaluation of groundwater resource of the area becomes all the more essential to regulate the further withdrawal of groundwater to make the judicious use of the available groundwater resource and to avail the ill effects.

In the present study the work has been carried out to determine various sources of recharge to groundwater bodies and withdrawal of groundwater through various groundwater structures which are as under:

**GROUNDWATER RECHARGE:***

Determination of groundwater recharge forms an important aspect of groundwater resource evaluation. It has been estimated by two methods,
the water balance method (Adhoc norms) and the water level fluctuation method on the basis of the norms laid down by the Groundwater resource Estimation Committee (G.E.C. 1997) of the Government of India. The major sources of recharge in the study area are as under:

1. Recharge through rainfall.
2. Recharge through canal seepage.
3. Recharge through irrigation return flow

**Estimation of Monsoon Recharge:**

Monsoon recharge of the study area has been estimated by using the following conceptual formula (as per G.E.C. 1997).

(a) \[
\text{Monsoon Recharge} = [(\text{Geographical area} \times \text{specific yield} \times \text{water level fluctuation}) + \text{gross groundwater draft during monsoon period} - (\text{Monsoon canal seepage} + \text{monsoon recharge from surface water irrigation} + \text{monsoon recharge from groundwater irrigation})] \\
+ \frac{\text{Normal monsoon rainfall}}{\text{Average monsoon rainfall}} + \text{monsoon recharge from canal seepage}.
\]

The above mentioned components of monsoon recharge have been computed as under

- Geographical Area = 36700 ham
- Water level fluctuation = 1.45 m
Specific yield = 16%
I.M.D. Normal Yearly rainfall = 627.70 mm
I.M.D. Normal monsoon rainfall = 565.1 mm
IMD Normal non-monsoon rainfall = 42.90 mm
The average normal monsoon rainfall of the observation years (1994-1999) = 686.97 mm

In order to estimate the change in groundwater storage, the total area has been multiplied by specific yield and the seasonal water level fluctuation. The specific yield in the area has been taken as 16%. The seasonal water level fluctuation has been worked out, based on the levels recorded during pre and post monsoon periods. In the observation year (1994-99) the water level fluctuation thus computed for the area comes to the order of 1.45 m.

**Estimation of Gross Monsoon Draft:**

As the information on pumping hours of groundwater structures separately for the monsoon period was readily available, it comes to the order of 1642.67 ham.

Monsoon recharge = \[(36700 \times 0.16 \times 1.45) + 1642.67 - (294.05 + 363.97 + 628.06)\] \times \frac{565.1}{686.97 + 363.97 + 294.05}

= \[(8514.4) + 1642.67 - (1286.08)\] \times 0.8167 + 658.02

= 7902.96 ham

Non-Monsoon Recharge

Non Monsoon Recharge estimated for the basin is given below

Geographical Area = 36700 ham
IMD Normal Non monsoon rainfall (RF) = 42.90 mm
Infiltration factor (IF) = 25%
Non-monsoon rainfall recharge  
\( (a) \)

\[
\text{Non-monsoon rainfall recharge} = \frac{\text{Area} \times \text{Infiltration factor} \times \text{RF}}{10^3}
\]

\[
= \frac{36700 \times 0.25 \times 42.90}{10^3}
\]

\[
= 393.608 \text{ ham}
\]

Total Non Monsoon Recharge

\[
= (a + \text{canal seepage} + \text{irrigation return flow} + \text{tank seepage})
\]

\[
= 393.608 + 852.3 + 681.18 + 4.1167
\]

\[
= 1931.20 \text{ ham}
\]

Recharge through irrigation return flow:

For this purpose, the irrigated area and volume of water applied for irrigation are taken into consideration for working out the total volume of water applied, of which 30% is assumed to return to groundwater bodies. Cropwise return seepage in the area has been calculated in the area which is as follows:

**TABLE-7**  
Showing Recharge from surface water irrigation

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Crop type</th>
<th>Area irrigated (ha)</th>
<th>Average wetted depth (m)</th>
<th>Irrigation water applied (ham)</th>
<th>Seepage factor (%)</th>
<th>Seepage Non monsoon (ham)</th>
<th>Seepage Monsoon (ham)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Kharif</td>
<td>2085.0</td>
<td>0.4</td>
<td>834.19</td>
<td>40</td>
<td>-</td>
<td>333.67</td>
</tr>
<tr>
<td>2.</td>
<td>Rabi</td>
<td>3989.0</td>
<td>0.4</td>
<td>1595.6</td>
<td>30</td>
<td>478.68</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>Zaid I</td>
<td>675.0</td>
<td>0.15</td>
<td>101.0</td>
<td>30</td>
<td>-</td>
<td>30.3</td>
</tr>
<tr>
<td>4.</td>
<td>Zaid II</td>
<td>675.0</td>
<td>1.0</td>
<td>675</td>
<td>30</td>
<td>202.5</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>681.18</td>
</tr>
</tbody>
</table>
The total quantum of the irrigation return flow is computed to be 1045.15 ham.

**Quantum of recharge due to canal seepage:**

Estimation of seepage from canal is computed, based on their wetted area, running days and seepage factor (15 ham/day/10^6 sq.m. wetted area).

(a) Recharge through Upper Ganga Canal:

**Monsoon Recharge**

<table>
<thead>
<tr>
<th>Total length</th>
<th>= 16750.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average wetted perimeter</td>
<td>= 15.27 m</td>
</tr>
<tr>
<td>Average running days during monsoon</td>
<td>= 70 days</td>
</tr>
<tr>
<td>Applied seepage factor</td>
<td>= 15 ham/day/10^6 sq.m.</td>
</tr>
</tbody>
</table>

\[
\text{Per day seepage} = \frac{\text{Applied seepage factor} \times (\text{Total length} \times \text{Av. wetted perimeter})}{10^6}
\]

\[
= 15 \times \frac{(16750 \times 15.27)}{10^6}
\]

\[
= 3.8365 \text{ ham}
\]

**Total Monsoon Seepage** = Per day seepage x Average Running days during monsoon

\[
= 3.8365 \times 70 = 268.56 \text{ ham}
\]

**Non-monsoon Recharge**

<table>
<thead>
<tr>
<th>Total length</th>
<th>= 16750.0 m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average wetted perimeter</td>
<td>= 15.27 m</td>
</tr>
<tr>
<td>Non-monsoon running days</td>
<td>= 200</td>
</tr>
<tr>
<td>Applied seepage factor</td>
<td>= 15 ham/day/10^6 sq.m.</td>
</tr>
<tr>
<td>Per day seepage</td>
<td>= 3.8365 ham</td>
</tr>
</tbody>
</table>
\[ \text{Total Non-monsoon seepage} = \text{Per day seepage} \times \text{Av. running days during non-monsoon} \]
\[ = 3.8365 \times 200 \]
\[ = 767.3 \text{ ham} \]

\[ \text{Total Yearly Recharge} = \text{Total Monsoon Seepage} + \text{Total non-monsoon seepage} \]
\[ = 268.56 + 76.73 \]
\[ = 1035.86 \text{ ham} \]

(b) Recharge through Distributaries:

**Monsoon recharge:**

- Applied seepage factor = 15 ham/day/10^6 sq.m.
- Total length = 4775.0 m
- Average wetted perimeter = 9.16 m
- Monsoon running days = 30 days
- Per day seepage = 15 \times (4775 \times 9.16)/10^6
  \[ = 0.6560 \text{ ham}. \]
- Total monsoon seepage = 0.6560 \times 30
  \[ = 19.68 \text{ ham}. \]

**Non-Monsoon Recharge:**

- Applied seepage factor = 15 ham/day/10^6 sq.m.
- Total length = 4775.0 m
- Average wetted perimeter = 9.16
- Running days = 100
- Per day seepage = 0.6560
- Total Non-monsoon seepage = 0.6560 \times 100
  \[ = 65.60 \text{ ham} \]
Total yearly recharge = 65.60 + 19.68
= 85.28 ham

(c) Recharge through Minors

Monsoon recharge:

Applied seepage factor = 15 ham/day/10^6 sq.m
Total length = 5300 m
Average wetted perimeter = 2.44 m
Average days = 30 days
Per day seepage = 0.1938 ham
Total monsoon seepage = 5.81 ham

Non-Monsoon recharge:

Applied seepage factor = 15 ham/day/10^6 sq.m.
Total length = 5300 m
Average wetted perimeter = 2.44 m
Running days = 100 days
Per day seepage = 0.1939 ham
Total Non-monsoon seepage = 19.39 ham

Total yearly recharge = 5.81 + 19.39
= 25.2 ham

Total Monsoon Recharge from canals = 268.56 + 19.68 + 5.81
= 294.05 ham

Total Non-monsoon recharge from canals = 767.3 + 65.60 + 19.39
= 852.3 ham

Recharge from Tanks:

1. Number of tanks = 42
2. Water spread area = 27.32 ha.
3. Seepage factor = 55 m/year
4. Total monsoon recharge (ham) = 5.02 (Retention period 122 days)

**Recharge from subsurface inflow:**

It has been assumed that inflow to the area balances the outflow from the area hence recharge due to subsurface inflow has not been estimated.

Total Annual Recharge available

= Monsoon recharge + Non-monsoon recharge + Recharge from tanks

= (7902.96 + 294.05) + (852.3 + 1931.20) + (5.02)

= 10985.53 ham

The gross groundwater recharge in the entire area is estimated as 10985.53 ham.

Net annual recharge available for development

= 85% of the total annual recharge = 9337.70 ham

**GROUNDWATER DISCHARGE OR DRAFT**

The discharge of groundwater in the area mainly takes place through state tubewells, shallow farmers tubewells, handpumps etc. A large quantity of groundwater joins the bounding rivers. However the discharge or base flow into the rivers/streams is not taken into consideration due to the lack of data and it is assumed that the discharge to rivers/streams and out flow from the area of investigations is equal to the subsurface inflow into the area of study.

The groundwater discharge in the study area has been estimated by multiplying number of each type of groundwater structures with its unit draft worked out by state groundwater department of U.P. A perusal of the (Table 8) shows the discharge in the study area.

Total annual draft = 10229.10 ham

Net annual draft 70% of the gross annual draft
<table>
<thead>
<tr>
<th>Year</th>
<th>1022.9</th>
<th>767.175</th>
<th>2557.28</th>
<th>Total</th>
<th>Let it be 5% of Irrigation</th>
<th>Hand Pump Mark II</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>487.1</td>
<td>121.78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2074.2</td>
<td>974.2</td>
<td>7306.5</td>
<td>2435.5</td>
<td>Total</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000.0</td>
<td>1200.0</td>
<td>300.0</td>
<td>75</td>
<td>16.0</td>
<td>12.0</td>
<td>4.0</td>
</tr>
<tr>
<td>446.3</td>
<td>111.8</td>
<td>3188</td>
<td>1.4</td>
<td>0.35</td>
<td>1.05</td>
<td>0.0</td>
</tr>
<tr>
<td>407.8</td>
<td>3059.1</td>
<td>1854</td>
<td>2.2</td>
<td>1.65</td>
<td>1.55</td>
<td>0.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Annual</td>
<td>Monsoon season</td>
<td>Non-Monsoon</td>
<td>Annual</td>
<td>Monsoon season</td>
<td>Non-Monsoon</td>
<td>Monsoon season</td>
</tr>
<tr>
<td></td>
<td>Estimated Groundwater for monsoon season</td>
<td>Non-monsoon season</td>
<td>Estimated Groundwater for monsoon season</td>
<td>Non-monsoon season</td>
<td>Monsoon season</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Natural use currently in irrigation of wells</td>
<td>Estimated Groundwater draft</td>
<td>Natural use currently in irrigation of wells</td>
<td>Estimated Groundwater draft</td>
<td>Natural use currently in irrigation of wells</td>
<td></td>
</tr>
</tbody>
</table>

Table 8. Unit groundwater draft per well for different type of wells and current Groundwater Draft in the GWA unit for different uses.
Net annual draft = 7160.37 ham

Utilizable groundwater resource potential
= Net recharge - Net draft
= 9337.70 - 7160.37 ham
= 2177.33 ham

The above evaluation of groundwater resource shows that there is large scope for further development of groundwater through deep tubewells to ensure the continued availability of water supplies to Aligarh city which is very well indicated in the table 9.

**Stages of groundwater development:**

\[
\text{Stage of groundwater development} = \frac{\text{Net groundwater draft}}{\text{Net groundwater recharge}} \times 100
\]

\[
= \frac{7160.37}{9337.70} \times 100
\]

\[
= 76.68
\]

In order to determine the stage of groundwater development in the study area. The National Bank for Agricultural and Rural Development (NABARD's) norms have been taken into account which are as follows.

**TABLE-10**

<table>
<thead>
<tr>
<th>Stage of Development</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 65%</td>
<td>White or safe</td>
</tr>
<tr>
<td>65-85%</td>
<td>Grey or semi critical</td>
</tr>
<tr>
<td>&gt; 85%</td>
<td>Dark or critical</td>
</tr>
<tr>
<td>76.68</td>
<td>2177.33</td>
</tr>
<tr>
<td>-------</td>
<td>--------</td>
</tr>
</tbody>
</table>

Table 6. Estimation of groundwater balance available and stage of groundwater development.
In the area of investigation 76.68% of the dynamic groundwater resource has been developed. Hence it falls under the Grey or semi critical category.

The study shows that there is a balance of 2177.33 ham water resource which is left for further development in the study area through various shallow and deep tubewells. However, the declining trend of the groundwater level in Aligarh city needs to be arrested through a recharge canal, in which at every 100m length of canal, a 10 m deep and 1.0 m dia open wells be constructed in the bed of the recharge canal itself, in order to recharge the top aquifer system which will lead to control the declining trend of groundwater levels. Moreover, it is suggested further that in the area away from the recharge canal, shallow recharge tubewells be constructed at intervals to recharge the depleting top aquifers. Thus an approximate balance between recharge and discharge will be maintained in the city. Moreover, some more tanks be constructed and various existing tanks be cleaned and further deepened to contain the storm flow and to recharge the groundwater bodies. Besides, roof-top rainwater harvesting be practiced so that the water collects be first passed through a sand filter and finally through a pipe into the top aquifer. These suggested measures if brought into practice will go a long way in gradually containing the declining trend of the groundwater levels in Aligarh city positively.