Ground Water Recharge Potential of the Dhanbad District, Jharkhand – A Case Study

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Abstract

With the increase in demand for water for competing uses, it is difficult to meet the entire demand from a single source and it is a challenge to plan and manage the different water resources. Among the two major water resources, surface and ground water, it is the ground water resource, which needs to be managed carefully, especially in drought prone areas. The hydro-geological features such as sub-soil structure, rock formation, lithology and location of water play a crucial role in determining the potential of water storage in groundwater reservoirs. To assess the groundwater potential, a suitable and accurate technique is required for a meaningful and objective analysis. A critical study is carried out on the different methods of estimating the groundwater potential and compared to arrive at the most suitable technique for practical utility. In this work, four methods of estimating groundwater recharge were studied viz., yearly water level fluctuation, ten year average water level fluctuation, fluctuation between the lowest and highest water levels over ten years and fluctuation in monsoon seasons. The results of this study help in accurate prediction of groundwater availability, which in turn may avoid groundwater over exploitation and help restore the aquatic eco-systems. 

Keywords: Drought, lithology, groundwater potential, fluctuation

I. INTRODUCTION

In view of increasing demand of water for various purposes like agricultural, domestic, industrial etc., a greater emphasis is being laid for a planned and optimal utilization of water resources. Due to uneven distribution of rainfall both in time and space, the surface water resources are unevenly distributed. Also, increasing intensities of irrigation from surface water alone may result in alarming rise of water table creating problems of water logging and salinization, affecting crop growth adversely and rendering large areas unproductive. This has resulted in increased emphasis on development of ground water resources. The simultaneous development of ground water especially through dug wells and shallow tube wells will lower water table, provide vertical drainage and thus can prevent water logging and salinization. Areas which are already waterlogged can also be reclaimed. On the other hand continuous increased withdrawals from a ground water reservoir in excess of replenishable recharge may result in regular lowering of water table. In such a situation, a serious problem is created resulting in drying of shallow wells and increase in pumping head for deeper wells and tube wells. This has led to emphasis on Planned and optimal development of water resources.

An appropriate strategy will be to develop water resources with planning based on conjunctive use of surface water and ground water. For this the first task would be to make a realistic assessment of the surface water and ground water resources and then plan their use in such a way that full crop water requirements are met and there is neither water logging nor excessive lowering of ground water table. It is necessary to maintain the ground water reservoir in a state of dynamic equilibrium over a period of time and the water level fluctuations have to be kept within a particular range over the monsoon and non-monsoon seasons. Water balance techniques have been extensively used to make quantitative estimates of water resources and the impact of man's activities on the hydrologic cycle. The study of water balance is defined as the systematic presentation of data on the supply and use of water within a geographic region for a specified period. With water balance approach, it is possible to evaluate quantitatively individual contribution of sources of water in the system, over different time periods, and to establish the degree of variation in water regime due to changes in components of the system. The basic concept of water balance is:

Input to the system - outflow from the system = change in storage of the system (over a period of time)

The general methods of computations of water balance include:
1) identification of significant components,
2) evaluating and quantifying individual components, and
3) Presentation in the form of water balance equation.
II. GROUND WATER BALANCE EQUATION

Considering the various inflow and outflow components, the terms of the ground water balance equation can be written as:

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

where,
- \( R_i \) = recharge from rainfall;
- \( R_c \) = recharge from canal seepage;
- \( R_r \) = recharge from field irrigation;
- \( R_t \) = recharge from tanks;
- \( S_i \) = influent seepage from rivers;
- \( I_g \) = inflow from other basins;
- \( E_t \) = evapotranspiration;
- \( T_p \) = draft from ground water;
- \( S_e \) = effluent seepage to rivers;
- \( O_g \) = outflow to other basins; and
- \( \Delta S \) = change in ground water storage.

This equation considers only one aquifer system and thus does not account for the interflows between the aquifers in a multi-aquifer system. However, if sufficient data related to water table and piezometric head fluctuations and conductivity of intervening layers are available, the additional terms for these interflows can be included in the governing equation. All elements of the water balance equation are computed using independent methods wherever possible. Computations of water balance elements always involve errors, due to shortcomings in the techniques used. The water balance equation therefore usually does not balance, even if all its components are computed by independent methods. The discrepancy of water balance is given as a residual term of the water balance equation and includes the errors in the determination of the components and the values of components which are not taken into account.

The water balance may be computed for any time interval. The complexity of the computation of the water balance tends to increase with increase in area. This is due to a related increase in the technical difficulty of accurately computing the numerous important water balance components.

III. STUDY AREA

Dhanbad district lies in the mid-eastern part of Jharkhand state. Giridih bound it in the north, Bokaro in the west, Purulia district in the south and Jamtara district in the east. It is connected through NH-2 and NH-32 from state capital and different district headquarters of the state. The district has total area of 2074 sq. km.and is located between 23\(^{\circ}\)26'-24\(^{\circ}\)01’ North latitude to 86\(^{\circ}\)10'- 86\(^{\circ}\)48’ East longitude. Area is included in toposheet no 73I/1, 73I/2, 73I/5, 73I/6, 73I/7 73I/9, 73I/10, 73I/13 and 73I/14 of survey of India (1:50000 scale), Fig. 1.

The northern boundary of which is marked by Barakar river and the southern boundary by Damodar river, on which two important reservoirs viz Maithon and Panchet are located respectively. The region lies on the eastern part of Chhotanagpur plateau and has an undulating topography with three distinct geomorphic features from north to south, (a) the hill ranges in north western part, (b) the coal field in southern and eastern part, and (c) the undulating upland and intervening alluvial fill low valleys with isolated bare ridges between them in north. The metamorphic terrain of the region is underlain by a wide range of geological formations ranging in age from Archaean to Recent. The Archeans and Gondwanas constitute the major parts. Thin veneer of Quaternary alluvial deposits occurs in the topographic depressions along the Damodar and Barakar Rivers (Figure 2). The Dhanbad district consist of 8 blocks of Dhanbad district namely Baghmara, Baliapur, Dhanbad, Govindpur, Jharia, Nirsa, Topchanchi & Tundi. The district comprises of 9 blocks, 157 number of panchayats and 1052 no. of villages. The total population of the Dhanbad district as per the 2011 census is 26,82,662. The density of population is 1300 person per sq. Km. The decadal growth of population is 11.91% (2001-11). It covers about 2057.26 sq km areas.
Fig. 1: Location map of Dhanbad District, Jharkhand

Fig. 2: Map showing General Geology of study area (after Krishman, 1982).
IV. DRAINAGE

The drainage system of the district is the part of Damodar sub-basin. All the rivers that originate or flow through the district have an easterly or south easterly course. The Damodar is the most important river with an easterly course for about 125 km. streams as Jamunia, Katri, and Pusai are originating from northern hills of Parasnath and Tundi areas. These are flowing from N – S to NNW – SSE and meeting Damodar river. The Barakar river is the most important tributary of the Damodar and their confluence marks the eastern border of the district. It recieves from the west its only tributary, the Khudia, which takes its rise in the extreme west of the district between the parasnath and Tundi ranges, Fig. 3.

Fig. 3: Drainage Map of dhanbad district

V. RESULTS AND DISCUSSION

A. Drinking water quality assessment:

Four classes viz., excellent, good, moderate and poor have been categorized in the study area (Table 1). Drinking Water quality has been assessed in terms of their chemical characteristics into five classes. The southern part of the study area falls under the excellent class of water quality and spreads about 19.93%. About 54.44% of the study area comes under good class of quality whereas nearly 23.33% area in the western side of the district is found under the class of moderate quality. Less than 3% of the area is represented by poor quality where the concentration of fluoride and iron are found to be on the higher side of the tolerance on limit.

Table – 1

<table>
<thead>
<tr>
<th>Drinking Water Quality Category</th>
<th>Area (in Sqm) (Sq.Km.)</th>
<th>% Contribution Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>410.00</td>
<td>19.93</td>
</tr>
<tr>
<td>Good</td>
<td>1120.00</td>
<td>54.44</td>
</tr>
<tr>
<td>Moderate</td>
<td>480.00</td>
<td>23.33</td>
</tr>
<tr>
<td>Poor</td>
<td>47.26</td>
<td>2.30</td>
</tr>
<tr>
<td>Total</td>
<td>2057.26</td>
<td>100.00</td>
</tr>
</tbody>
</table>
VI. STUDY PERIOD

In areas where most of the rainfall occurs in a part of a year, it is desirable to conduct water balance study on part year basis, that is, for monsoon period and non-monsoon period. Generally, the periods for study in such situations will be from the time of maximum water table elevation to the time of minimum water table elevation as the non-monsoon period and from the time of minimum water table to the time of maximum water table elevation as monsoon period. For northern India, the water year can be taken as November 1 to October 31 next year. The monsoon and non-monsoon periods can be taken as June to October and November to May next year respectively. It is desirable to use the data of a number of years preferably covering one cycle of a dry and a wet year.

A. Climate Of Dhanbad

The climate of Dhanbad district is very pleasant especially in the cold weather months November to February during, which the temperature varies from lowest minimum of 47°F to the highest maximum of 94°F. After February the climate becomes warmer and warmer until the rains break in the middle of June. The temperature during these four months March to June varies from the lowest minimum of 56°F to the highest maximum of 114°F. During the remaining months, July to October, which includes the rainy season, the temperature range is from the lowest minimum 59°F to 97°F.

The average annual rainfall of the area is 55", most of which is precipitated during the rainy season – middle of June to middle of October. The rainfall around Parasnath hills is reported to be more than the average.

B. Hydrogeology

Groundwater occurs in the area under unconfined condition in the weathered zones at shallow depths in most of the litho units in the Achaean and almost all the litho units in the Gondwanas. Groundwater occurs under confined to semi-confined condition where the fractures are deep seated and are unconnected with the top weathered zone.

1) Aquifer Geometry

The aquifer geometry for shallow and deeper aquifer has been established through hydro geological studies, exploration, the surface and subsurface geophysical studies in the district covering all geological formations. The aquifer can be divided into two zones – shallow and deeper aquifer.

2) Shallow Aquifer

The shallow aquifers are being tapped through dug wells, dug cum bore wells or shallow bore wells drilled to the depth of 60 m. The weathered mantle and shallow fractures constitute the shallow aquifers. The thickness of weathered mantle varies from 5 to 25 mbgl. The well inventory data suggest that the maximum depth of dug well in granite gneiss and Gondwana is 17 m and 25 m respectively. Exploration in granite gneiss indicates that shallow fractures are less productive. Many dug wells and hand pumps get dried up during summer.

C. Deeper Aquifers

1) Depths—to-water levels and groundwater conditions:

Groundwater conditions in various litho units are usually described under two broad heads viz.

1) The porous formations and

2) The fissured formations

2) The porous Formations

The main members of the porous formations are the Newer and Older alluvium of the Recent and sub-recent age. Recent alluvium is found in very thin veneers in topographic depressions along the Damodar River. Insignificant occurrences may also be noticed along Barakar River and in some major tributaries of these two. They cannot however, be considered as potential aquifers.

3) The Fissured Formations

Achaean meta-sedimentsaries, the granites, intrusive metabasics and the Lower Gondwana sedimentary constitute the productive aquifer. The first three come under consolidated Formation and the last one under semi consolidated Formation.

VII. WATER TABLE BEHAVIOUR IN THE AREA

Total 300 dug wells were selected as observation points in all the 09 blocks (Baghmara – 30 ; Bialiapur – 40 ; Dhanbad – 40, Govindpur – 30 ; Jharia – 40 ; Nirsa – 40, Topchanchi – 30 & Tundi including E Tundi - 50) of the Dhanbad district. Then further their clustering was done and out of 300 locations, 30 representatives monitored stations consisting of 4, 3, 3, 4, 3, 4 & 6 number of wells respectively were selected for measuring the water levels in these wells during pre and post monsoon seasons. The fluctuation of ground water level is given in Table 1.

Water table in these monitored varies between 5.05–9.40 m in pre-monsoon and 2.70 - 4.28 m during post-monsoon. The average water table during pre-monsoon is 6.93 m and while in post-monsoon season, the average water table is measured as 3.42 m... The average water table fluctuation was noted as 3.51 m.
VIII. GROUND WATER RECHARGE POTENTIAL

Rainfall is the principal recharge source to groundwater. The area experience an average annual rainfall of about 1368 mm in the year 2012 and the highest annual rainfall was recorded as 2061 mm in 2006. The highest rainfall recorded within 24 hours was 35.0 mm. Besides rainfall, the mine water discharge from the local mining areas and existing water bodies including water logged in abundant mine quarries are also contributed to the ground water recharge as return flow.

A. Pre-monsoon Depth To Water Level

Pre-monsoon depths to water level for Baghmara (5.60 – 9.30 m) ; Baliapur (7.20 – 8.34 m) ; Dhanbad (5.05 – 7.50 m) ; Govindpur (5.60 – 9.30 m) ; Jharia (7.20 – 8.34 m) ; Nirsa (6.76 – 9.40 m) ; Topchanchi (7.82 – 9.18 m) and Tundi & E Tundi (5.00 – 6.32 m)

B. Post-Monsoon Depth To Water Level

During this period depths to water level for Baghmara (3.23 – 4.25 m) ; Baliapur (3.25 – 3.40 m) ; Dhanbad (2.90 – 3.40 m) ; Govindpur (3.23 – 4.25 m) ; Jharia (3.23 – 4.25 m) ; Nirsa (3.47 – 4.18 m) ; Topchanchi (3.48 – 4.28 m) and Tundi & E Tundi (2.70 – 3.62 m).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Baghmara</td>
<td>5.60 – 9.30 m</td>
<td>3.23 – 4.25 m</td>
<td>2.30 – 5.05 m</td>
</tr>
<tr>
<td>2</td>
<td>Baliapur</td>
<td>7.20 – 8.34 m</td>
<td>3.25 – 3.40 m</td>
<td>3.35 – 4.94 m</td>
</tr>
<tr>
<td>3</td>
<td>Dhanbad</td>
<td>5.05 – 7.50 m</td>
<td>2.90 – 4.30 m</td>
<td>3.15 – 4.30 m</td>
</tr>
<tr>
<td>4</td>
<td>Govindpur</td>
<td>5.60 – 9.30 m</td>
<td>3.23 – 4.25 m</td>
<td>3.30 – 5.05 m</td>
</tr>
<tr>
<td>5</td>
<td>Jharia</td>
<td>7.20 – 8.34 m</td>
<td>3.25 – 4.30 m</td>
<td>3.83 – 4.94 m</td>
</tr>
<tr>
<td>6</td>
<td>Nirsa</td>
<td>6.76 – 9.40 m</td>
<td>3.47 – 4.18 m</td>
<td>3.29 – 5.22 m</td>
</tr>
<tr>
<td>7</td>
<td>Topchanchi</td>
<td>7.82 – 9.18 m</td>
<td>3.48 – 4.28 m</td>
<td>4.10 – 4.90 m</td>
</tr>
<tr>
<td>8</td>
<td>Tundi &amp; E Tundi</td>
<td>5.00 – 6.32 m</td>
<td>2.70 – 3.62 m</td>
<td>2.10 – 3.12 m</td>
</tr>
</tbody>
</table>

IX. GROUND WATER LEVEL FLUCTUATION

The seasonal ground water fluctuation map for dug well data is prepared based on the inventory wells of pre and post monsoon data. The map depicts that maximum (about 70 percent) area falls under 2-4m range while 30 percent area comes under 4-6m.

<table>
<thead>
<tr>
<th>Sites</th>
<th>Well No.</th>
<th>Pre-monsoon (m)</th>
<th>Post-monsoon (m)</th>
<th>Fluctuation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baghmara</td>
<td>W-1</td>
<td>6.38</td>
<td>3.20</td>
<td>3.18</td>
</tr>
<tr>
<td></td>
<td>W-2</td>
<td>7.05</td>
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<td></td>
<td>W-3</td>
<td>6.60</td>
<td>3.10</td>
<td>3.50</td>
</tr>
<tr>
<td></td>
<td>W-4</td>
<td>5.90</td>
<td>3.20</td>
<td>2.70</td>
</tr>
<tr>
<td>Baliapur</td>
<td>W-5</td>
<td>6.10</td>
<td>3.30</td>
<td>2.80</td>
</tr>
<tr>
<td></td>
<td>W-6</td>
<td>5.70</td>
<td>3.10</td>
<td>2.60</td>
</tr>
<tr>
<td></td>
<td>W-7</td>
<td>6.10</td>
<td>3.30</td>
<td>2.80</td>
</tr>
<tr>
<td>Dhanbad</td>
<td>W-8</td>
<td>7.50</td>
<td>3.20</td>
<td>4.30</td>
</tr>
<tr>
<td></td>
<td>W-9</td>
<td>5.05</td>
<td>2.90</td>
<td>2.15</td>
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<tr>
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<td>W-10</td>
<td>7.30</td>
<td>3.40</td>
<td>3.90</td>
</tr>
<tr>
<td>Govindpur</td>
<td>W-11</td>
<td>5.60</td>
<td>3.30</td>
<td>2.30</td>
</tr>
<tr>
<td></td>
<td>W-12</td>
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<td>3.23</td>
<td>3.87</td>
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<td></td>
<td>W-13</td>
<td>8.10</td>
<td>3.60</td>
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<td>W-14</td>
<td>9.30</td>
<td>4.25</td>
<td>5.05</td>
</tr>
<tr>
<td>Jharia</td>
<td>W-15</td>
<td>7.20</td>
<td>3.28</td>
<td>3.92</td>
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<tr>
<td></td>
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<td>W-17</td>
<td>7.08</td>
<td>3.25</td>
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<td>Nirsa</td>
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<td>6.76</td>
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<td>Topchanchi</td>
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<td>7.82</td>
<td>3.48</td>
<td>4.34</td>
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<tr>
<td></td>
<td>W-23</td>
<td>8.34</td>
<td>4.24</td>
<td>4.10</td>
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<tr>
<td></td>
<td>W-24</td>
<td>9.18</td>
<td>4.28</td>
<td>4.90</td>
</tr>
<tr>
<td>Tundi</td>
<td>W-25</td>
<td>6.22</td>
<td>3.62</td>
<td>2.60</td>
</tr>
</tbody>
</table>
In the study area, groundwater is withdrawn usually by means of open dug wells and small diameter hand operated tube wells for domestic and irrigation purposes. The tube wells are most often deeper (19m–58m) than the dug wells and tap the aquifer below the weathered mantle. As the area is being located in the hot-tropical belt, the temperature regime is very high, the daily maximum reaches to over 44°C. Due to excessive heat, the loss of moisture through evaporation is considerably high (60-65%). During the wet monsoon seasons, the net evaporation is less than the precipitation, resulting in surplus water which loss through either surface runoff or being part of the subsurface storage. The surface runoff and subsurface storage of water depends upon various factors including the amount of rainfall, topography of the area, land use pattern, soil type, slope, physiographic, drainage pattern and hydro geomorphology of the catchment/sub-catchment. The study area is having gentle slope towards south and south east. Water received on the slopes, gets collected in low-lying area and is thus ultimately absorbed in the top soil cover and become part of the ground water flow according to the slope to form seasonal streams/nallas.

In the mining area, the water levels are bound to be affected and disturbed. The famous Jharia coal field area is highly disturbed and the permeability’s of individual geological units are spatially variable and depend on lithology, fracturing and attenuation with depth. The porous and more open-jointed sandstone members tend to form aquifers, the shaly members are aquitards, which may be leaky but are poorly permeable and form the poor permeable barriers to the vertical groundwater movement. The ground water recharge potential in the area was estimated by using rainfall-infiltration and water table fluctuation methods. As reported in the GEC Report 1997 [4], for semi-consolidated sandstones and weathered and fractured hard rock terrains, a rainfall infiltration factor of 10-15 % of normal rainfall and for sandy areas infiltration factor of 20-25% may be undertaken for calculation of recharge potential. Here, we have considered an average 15% rainfall infiltration factor for calculating annual recharge potential of the area. The total annual ground water replenishable recharge (TARR) estimated for the areas are 358.782 million m$^3$ by rainfall infiltration factor. Following the GEC Report-1997 [5] prepared by CGWB, irrigation annual draft was estimated as 25.856 million m$^3$. For calculating the domestic water consumption, population of 26,82,662 at the consumption rate of 70 liter per day per person was considered. The water withdrawal for domestic uses was estimated as 68.542 million m$^3$. The consumption by cattle population was projected as 10% of domestic consumption, amounting 6.854 million m$^3$. The total mine discharge into the area through different active and abundant opencast and underground mines was estimated as 80.3 million m$^3$. Of this about 20% (i.e. 16.06 million m$^3$) is estimated as return flow to the ground water system. Thus the net mine water discharge in the area was projected as 64.24 million m$^3$. The net ground water recharge and draft were estimated as 358.782 million m$^3$ and 25.927 million m$^3$ respectively. Thus the balance available groundwater resource projected as 165.492 million m$^3$.

### X. GROUNDWATER STAGE DEVELOPMENT

Except, for coal mining and some coal based industries, no major industrial development activity is located in the area. As per GEC-1997 [5], the total annual replenishable groundwater resource in the area is assessed as 74.119 million m$^3$ and total withdrawal from the area as 25.927 million m$^3$ and the calculated stage of ground water development as 45.79% and it falls within the category “white”. Summary of the water potential estimation is given in Table 2.

#### A. Total annual replenishable recharge (TARR) in million m$^3$/year

1) **By Rainfall Infiltration Factor Method**

\[
\text{TARR} = \text{Area} \times \text{AVERAGE RAINFOLL} \times \text{Infiltration Factor}
\]

- Total geographical area = 2057 km$^2$
- Average rain fall of the area = 1368 mm
- Infiltration factor = 15%

\[
\text{TARR} = 2057 \text{km}^2 \times 1.368 \text{m} \times 15\% = 422.096 \text{million m}^3
\]

Natural discharges & other losses (15% of Recharge) = (-) 63.314 million m$^3$

\[
\text{Net Annual Groundwater Recharge (TARR)} = 422.096 \text{m}^3 - 63.314 \text{m}^3 = 358.782 \text{m}^3
\]

2) **By Ground Water Table Fluctuation Method**

\[
\text{Total annual replenishable recharge (TAAR)} = \text{Area} \times \text{Average water table fluctuation} \times \text{Specific Yield}
\]

- Total Area = 2057 km$^2$
- Average water table fluctuation = 3.72 m
- Specific Yield = 0.04

\[
\text{TAAR} = 2057 \text{km}^2 \times 3.72 \text{m} \times 0.04 = 305.744 \text{million m}^3
\]

The table below shows the average water table fluctuation in different parts of the area:

<table>
<thead>
<tr>
<th>Location</th>
<th>Max.</th>
<th>Min.</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-26</td>
<td>5.00</td>
<td>2.90</td>
<td>2.10</td>
</tr>
<tr>
<td>W-27</td>
<td>5.40</td>
<td>3.10</td>
<td>2.30</td>
</tr>
<tr>
<td>W-28</td>
<td>5.20</td>
<td>2.90</td>
<td>2.30</td>
</tr>
<tr>
<td>W-29</td>
<td>5.74</td>
<td>2.70</td>
<td>3.04</td>
</tr>
<tr>
<td>W-30</td>
<td>6.32</td>
<td>3.20</td>
<td>3.12</td>
</tr>
</tbody>
</table>

#### Table 2: Groundwater Recharge Potential of the Dhanbad District, Jharkhand – A Case Study

**Ground Water Recharge Potential of the Dhanbad District, Jharkhand – A Case Study**

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Specific Yield \( = \frac{P \times Rg}{HW \times (P - Rs)} \)

Where P is the annual rainfall, Rg is the annual groundwater runoff, Rs is the annual surface runoff and Hw is the water table fluctuation.

\[
= 1368 \times 205.2/3510 \times (1368 - 300.960) \\
= 280713.6 / 3510 \times 1067.04 = 0.075
\]

Table – 4

<table>
<thead>
<tr>
<th>Parameters</th>
<th>% of Rainfall</th>
<th>Values in Million m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Areas</td>
<td>2057 km²</td>
<td></td>
</tr>
<tr>
<td>Total Rainfall</td>
<td>1368 mm</td>
<td>100%</td>
</tr>
<tr>
<td>Evapo-transpiration</td>
<td>861.840mm</td>
<td>63%</td>
</tr>
<tr>
<td>Total Runoff</td>
<td>300.960 mm</td>
<td>22%</td>
</tr>
<tr>
<td>Ground Water Recharge</td>
<td>205.200 mm</td>
<td>15%</td>
</tr>
</tbody>
</table>

Total annual replenishable recharge (TAAR) by ground water fluctuation method

\[
= 2057 \text{ km}^2 \times 3.51 \times 0.100 = 541.505 \text{ million m}^3
\]

B. Annual Ground Water Withdrawal

1) Annual Water Withdrawal for Irrigation Uses

1) Net irrigation draft derived from the total irrigation land of 531.43 km²

\[= \frac{32.320 \text{ million m}^3}{358.782} \]

2) Return flow from irrigation to ground water (-20%)

\[= - 6.464 \text{ million m}^3\]

3) Net irrigation use (i-ii)

\[= 25.856 \text{ million m}^3\]

2) Domestic Withdrawal

1) Annual domestic consumption

\[= \text{Population x 70 Liter x 365 days} \]

\[= 26,82,662 \times 70 \text{ liters x 365 days} = 68.542 \text{ million m}^3\]

2) For cattle population (10% of the domestic uses) = 6.854 million m³

Total domestic water withdrawal (i+ii) = 75.396 million m³

C. Estimated Annual Draft Through Mine Discharge

There are number of coal mines owned by BCCL, Tata Steel & SAIL in the studied area. The estimated mine water discharge from this area is estimated to be 80.3 million m³

20% return flow of the mine water discharges in the area = 16.06 million m³

Net annual mine water discharges (i-ii) = 64.24 million m³

Net Annual Groundwater Draft (A+B+C)

\[= 25.856 + 75.396 + 64.240 = 165.492 \text{ million m}^3\]

Net Annual Ground Water Availability (I-II)

\[= (358.782 – 165.492) \]

\[= 193.29 \text{ million m}^3\]

Summary of Water Potential Estimation

<table>
<thead>
<tr>
<th>a) Range of water table (m bgl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Monsoon (April, 2012)</td>
</tr>
<tr>
<td>Post-Monsoon (October, 2012)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) Total annual replenishable recharge (TARR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>By rainfall infiltration factor method (million m³/year)</td>
</tr>
<tr>
<td>By groundwater table fluctuation method (million m³/year)</td>
</tr>
</tbody>
</table>

| c) Annual draft excluding estimated draft through mine discharge (million m³/year) | 101.252 |
| d) Estimated draft through mine discharge (million m³/year) | 64.24 |
| e) Net annual ground water availability (million m³/year) | 193.29 |

| f) Stage of ground water development in % | 45.79 % |

XI. DRINKING WATER QUALITY OF THE STUDY AREA

The water samples from the area were collected and analyzed as per IS: 10500 standards.

Discussion of ground water analysis is as discussed below:

A. Chemical Quality

1) pH:

It is the measure of acidity or alkalinity of ground water. pH of shallow aquifers varies between 7.10 to 8.66

2) Electrical Conductivity:

It is the measure of conductivity of the water. It varies between 570 to 1900 micro-mhos/cm. at 25°C for shallow aquifers
3) **Total Hardness as CaCO₃:**
Total hardness as CaCO₃ value varies between 175 to 720 mg/l in general for shallow aquifers.

4) **Bicarbonates:**
Bicarbonate values vary between 98 to 390 mg/l for shallow aquifers.

5) **Chlorides:**
Chlorides are important ions of ground water. Its concentration varies between 49.6 mg/l to 249 mg/l.

6) **Calcium:**
Calcium is a major cation found in ground water. Its concentration varies between 24 mg/l to 160 mg/l, which is within permissible limit.

7) **Magnesium:**
In ground water of Dhanbad and parts of Bokaro district concentration of magnesium varies between 17 to 86 mg/l, which is within permissible limit.

8) **Sodium:**
Concentration of Na varies between 33 mg/l to 111 mg/l in general

9) **Potassium:**
Potassium concentration is between 1.2 to 17.5 mg/l.

In general all the measured values are found well within the threshold limit as specified in test parameters of drinking water [6], [7]. However, the sodium absorption ration and the Coliform Org. count are more than the threshold values which make these water less suitable for the irrigation purpose & domestic water supply directly. The overall category of the water belongs to Class B, i.e. more suitable for all beneficial uses except domestic water supply. But with proper treatment, this can also be used for domestic water supply.

**XII. CONCLUSIONS**

Assessing the potential zone of groundwater recharge is extremely important for the protection of water quality and the management of groundwater systems [8], [9]. Various techniques are available to assess recharge-potential, and their capability in estimating recharge is also variable. It is difficult to determine the properties of large aquifers, such as transmissivities, storage coefficients and similar parameters, in sufficient resolution [10]. Modelling large aquifers seems an almost hopeless task. But the essential information for water availability is the information on fluxes in and out of the storage. In this paper, total annual replenish able recharge (TARR) in million m³/year has been calculated by rainfall infiltration factor method by ground water table fluctuation method whereas for the annual ground water withdrawal 3 major sub units such as (i) Annual water withdrawal for irrigation uses (ii) Domestic withdrawal & (iii) Estimated annual draft through mine discharge have been taken into account and on the basis of these results, Net Annual Ground Water Availability has been estimated as million 193. 29 m³ which seems to be quite high and is sufficient to meet the requirement of the people.

In general all the measured values are found well within the threshold limit of drinking water. However, the sodium absorption ration and the Coliform Org. count [11] are more than the optimum values which make these water less suitable for the irrigation & domestic water supply directly [12], [13]. The overall category of the water belongs to Class B, i.e. more suitable for all beneficial uses except domestic water supply [14], [15].

**REFERENCES**


