CHAPTER 6

AQUIFER CHARACTERISTICS
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Development of groundwater resources is necessary to meet out its increasing demand. Even in areas where abundant surface water is available, groundwater plays an increasingly vital role in supplementing surface water. It is a well-known fact that groundwater forms a component of hydrologic cycle in nature, and it is the major source of water supply for irrigation purpose. The recharge of groundwater varies, depending upon annual precipitation, lithology of the area, aquifer characteristics and management.

The reliable and representative values of hydraulic characteristics of aquifer are obtained through pumping test. It is a controlled field experiment, which is reliable and estimates the parameters in situ conditions without disturbing the aquifer material, boundary conditions created at a controlled well & hydraulic boundaries in the aquifer systems. The analysis of pumping test gives an idea about the suitability of aquifer, as potential source. It is the main tool in evaluation of aquifer parameters leading to groundwater resources evaluation for planned development. The usefulness of aquifer as potential source of water depends largely on two inherent properties, viz. its ability to store water and transmit it.

6.1 REVIEW OF METHOD: An aquifer test consists of pumping one well at a certain rate during certain time interval and recording the draw down both in that well and other nearby observation wells. The data thus obtained are synthesized by various analytical and graphical methods for estimating the aquifer parameters.

During pumping test data analysis, few assumptions are common for all methods.

1. The aquifer has seemingly infinite aerial extent.
2. The aquifer is homogenous, isotropic and uniform in thickness over the area influenced by pumping test.
3. Prior to pumping, the piezometric phreatic surface is nearly horizontal over the area influenced by the pumping test.

4. The aquifer is pumped at a constant discharge rate, and.

5. The pumped well penetrates the entire aquifer and then receives water from the entire aquifer thus gives constant horizontal flow.

During pumping test, two types of tests are generally carried out. Steady state test in which after a long enough pumping, the drawdown becomes reasonably constant. Theim's equation is applicable for this state, which gives transmissivity of the aquifer. However, in non steady state test a well is pumped at a constant rate and the drawdown is recorded at various times intervals. The data so recorded are utilized in determination of both transmissivity (T) & storativity (S).

For pumping test, tube wells, dug wells and pump sets available with farmers were selected irrespective of whether observation wells are available or not (Fig.6.1). And all the observations were carried out on the same well normally no observation wells would be available, if available they actually becomes recharge boundaries rather than observation wells. To avoid the situation-pumping test on tube wells has been carried out.


In present study area i.e. Sonbarsa river basin, by evaluation of various methods, Cooper-Jacob’s (1946) time-drawdown method was found to be more suitable (Table-6.1). The time-drawdown curve obtained by this method following the non-equilibrium equation, were used for determining the values of T and S. While specific capacities of open wells were determined using Slichter’s formula (1906).

6.2 AQUIFER PARAMETER EVALUATION (EVALUATION OF TRANSMISSIVITY AND STORATIVITY): Under the investigated area, seven suitable sites for pumping test, representing the different lithology or combination of it were selected. To evaluate the transmissivity and storativity of aquifers, Cooper-Jacob’s (1946) non-equilibrium method is employed. In this method, drawdown ($) versus time since pumping started (t) is plotted on semi-log paper. The resultant straight-line plot, follows the Theis equation for which conditions such as confined nature of aquifer, full penetration, negligible storage are prerequisite. The drawdown difference ($x \Delta$) as per log cycle of time is determined (Fig.6.2 a and Fig.6.2 b). The transmissivity is calculated by equation :

\[
T = \frac{2.303Q}{4 \pi \Delta x}
\]

where \(Q\) = discharge (lpm), \(\Delta x\) = drawdown difference per log cycle of time

The storativity is determined using the following equation.

\[
S = \frac{2.25 T b_0}{r^2}
\]

\(T\) = transmissivity (lpm/m)
\(b_0\) = time intercepts on the zero draw down axis.
\(r\) = radius of well in metre
To determine the value of $t_0$, the line is extended to zero drawdown it
gives $t_0$. The discharge is calculated by collecting discharge in known
volume of container and required time to fill it.

The result obtained by testing with available pumps in the well, have
their own limitations. This factor has been taken into account while analysing
the pump test data. It is also important to note that the area has no availability
of observation wells within the reasonable distance from the pumped wells
and, hence, in most cases observations had to be carried out in pumped wells
only.

6.2.1 Transmissivity (T): In the study area transmissivity was calculated, for
the bore wells located at Karela, Singapur, Tilaibhatt, Dumardih villages in
Chandi limestone area. Remaining test wells are located at Garaghat
Salehbhari, Jogidalli in sandstone/shale terrain. The results are appended in
Table No. 6.2. The transmissivity for limestone ranges from 53 to
115 lpm/m whereas, in case of sandstone/shale area it varies from 73
110 lpm/m. Such a wide variation in the values of $T$ might be attributed to
the heterogeneous and non-uniform nature of the aquifer. Higher values for
limestone lithology may be due to their fractured nature, presence of solution
channels and joints in deep bore wells. The low values may be due to
occurrences of shaly intercalations in the aquifer.

6.2.2 Storage Coefficient (S): The values of S determined for limestone
area range from $10^{-9}$ to $10^{-1}$ while in sandstone, sandstone/shale
$10^{-4}$
to $10^{5}$. The storage coefficient for unconfined aquifer is from 0.05 to 0.3 and
for confined aquifer 0.0005 to 0.005 (Raghunath 1990). The S values in shaly
area fall between $10^{-4}$ to $10^{-5}$ which is indicative of their confined nature
of the aquifer.
Fig. 6.2. a. Time-drawdown Graph

Singarpur

\[ S = \frac{225(0.415)}{(1.3)^2} \quad \text{at} \quad t = 23(600) \]
\[ = 2.7 \times 10^3 \]

Karela

\[ S = \frac{225(0.055)}{1.6 \times 10^3} \quad \text{at} \quad t = 23(600) \]
\[ = 2.05 \]

Dumardih

\[ S = \frac{225(0.55)}{2.2 \times 10^2} \quad \text{at} \quad t = 23(570) \]
\[ = 4.7 \times 10^3 \]

Tilabhat

\[ S = \frac{225(0.061)}{2.09 \times 10^3} \quad \text{at} \quad t = 23(570) \]
\[ = 1.9 \times 10^3 \]
FOR $S = 0$, $t_0 = 2\times10^2$

$T = \frac{2.3 \times 10^2}{4\pi \times 5}$

$S = \frac{2.25 T t_0}{r^2}$

$= \frac{2.25(0.110)2\times10^2}{(2.925)^2}$

$= 7.8 \times 10^{-4}$

FOR $S = 0$, $t_0 = 1.3 \times 10^2$

$T = \frac{2.3(400)}{4\pi(1.0)}$

$= 73 \text{ lpm/m}$

$S = \frac{2.25(0.073)3 \times 10^2}{(1.725)^2}$

$= 1.6 \times 10^{-4}$

FOR $S = 0$, $t_0 = 1.4 \times 10^3$

$T = \frac{2.3(300)}{4\pi(0.40)}$

$= 137 \text{ lpm/m}$

$S = \frac{2.25(0.37)4 \times 10^3}{(1.575)^2}$

$= 0.40$

TIME SINCE PUMPING STARTED, $t \text{ min}$

Fig. 6.2. b. Timedrawdown Graph
Table - 6.1: TIME-DRAWDOWN DATA

<table>
<thead>
<tr>
<th>Time since Pumping started (Minutes)</th>
<th>LOCATION</th>
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6.3 SPECIFIC CAPACITY OF DUGWELLS: It depends on the permeability and thickness of aquifer tapped, cross section area of the well and frictional resistance at the entrance to the well. Specific capacity was calculated by Slichter's recovery (1906) formula (Table 6.3):

\[ C = \frac{A \times 2.3 \log_{10} s_1}{T \times s_2} \]

Where \( C \) = The specific capacity of the well in cubic meters per minute for the drawdown of one meter. (m³/min/m)

\( A \) = Cross sectional area of well in sq. meter.

\( T \) = the time in minutes since pumping stopped

\( s_1 \) = The drawdown in meter of water level just before pumping stopped.

\( s_2 \) = The residual drawdown in meter at time \( t \).

The specific capacity for the Sonbarsa river basin area (Table 7.3) ranges from 63.24 lpm/m to 668.3 lpm/m (Table-6.3). The results indicate that the area with limestone lithology shows moderate to fair range of specific capacity suggestive of numerous karstified features and jointed structures. While sandstone/ calcareous shale litho unit area shows 126.5 lpm/m. Low values suggest that the shales or shaly limestone are poor water-bearing formation, which may be attributed to the absence of fracture porosity and joints.
Table - 6.2 : AQUIFER PARAMETERS OF SONBARSARIVER BASIN

<table>
<thead>
<tr>
<th>S No</th>
<th>Village</th>
<th>Measured drawdown S (m)</th>
<th>Transmissivity T (lpm/m²)</th>
<th>Storage Coefficient S (lpm)</th>
<th>Discharge (Q) (lpm)</th>
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<td>1.3x10⁻³</td>
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<td>4.7x10⁻³</td>
<td>570</td>
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<td>Tilaibhat</td>
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<td>1.9x10⁻⁴</td>
<td>570</td>
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<td>137</td>
<td>1.6x10⁻⁵</td>
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Table - 6.3 : SPECIFIC CAPACITY OF DUG WELLS BY SLICHTER'S METHOD

<table>
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<th>S.No</th>
<th>Village</th>
<th>Total S.W.L. depth (M)</th>
<th>Int. Dia. of well (m)</th>
<th>Area of Cross section (sq.m.)</th>
<th>Drawdown Time (hours)</th>
<th>Residual Drawdown (m)</th>
<th>Pumping Time (hours)</th>
<th>Spec. Cap. (m³/min/m)</th>
<th>Spec. Cap. Area (Cap.)</th>
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Table - 6.3 : SPECIFIC CAPACITY OF DUG WELLS BY SLICHTER'S METHOD

<table>
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<th>S.No</th>
<th>Village</th>
<th>Total S.W.L. depth (M)</th>
<th>Int. Dia. of well (m)</th>
<th>Area of Cross section (sq.m.)</th>
<th>Drawdown Time (hours)</th>
<th>Residual Drawdown (m)</th>
<th>Pumping Time (hours)</th>
<th>Spec. Cap. (m³/min/m)</th>
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6.4 YIELD OF DUG WELLS: The critical observation of large number of tube wells/ dug cum bore wells and other exploratory data obtained from different Govt. & semi Govt. organizations reveals that the depth of bore wells ranges from 45 meters to 70 meters. The depth is higher in Chandi limestone area in comparison to calcareous shale/sandstone area. The yield is found to be higher for limestone area 6300 lph (Karela), but it is not true always. These data do not show any particular relationship between the yield and lithology. This is because of the variation in altitudes of different points, their position with respect to water table and variation in hydrogeological character in same lithounit due to extent of karstification, degree of jointing etc. However, limestone area, in general, behave as relatively good aquifer, with good yield. There is no significant relationship obtained between the specific capacity and cross-section area of the well. However, incase of distinctly identified zone, Gunderdehi shale and karstified limestone are giving low and high yield respectively.