*Chapter – 3*

# HYDROGEOLOGY

## 3.1 GENERAL

Hydrological cycle is the water transfer cycle, which occurs continuously in nature, the three important phases of the hydrologic cycle: (1) Evaporation and Evapotranspiration (2) Precipitation and (3) Runoff. The topography and landforms have strong influence on well yield, especially of shallow wells, as they influence the thickness of weathered zone..

Targetting of groundwater has remained an enigma owing to the heterogeneity of the geological condition (Adayalkar 1974, Todd 1980, Karanth 1987, Adil Elkrai. et.al, 2004). Groundwater is the water occupying all the voids within a geologic stratum, i.e., saturated zone. Groundwater is the water held in the rocks underground by certain forces, replenished by nature according to the climate and local geology and consequently variables in both amount and quantity. The occurrence and movement of groundwater in an area is governed by several factors such as, lithology, geological structures, and depth of weathering.

The Hydrogeology of the study area has revealed that the river Tambraparani, is the perennial river flow in SW and NE directions in the hilly area presenting an angular drainage pattern. Tamiraparani River (Plate 3.1) originating from Papanasam flows thorough the Study area. The tributaries of Tamiraparani river are Chittar, Manimuthar and Pachiayar. The Chittar River

(Plate 3.2) originates near Courtallam and flows from northwest to east. Both the rivers merge at eastern portion, i.e. Seevalaperi, where the main city of Tirunelveli and palayamkottai falls.

A major role in evaluating the hydrological parameters, which in turn helps to understand the groundwater situation (Krishnamurthy and Srinivas 1995). As stated earlier, the groundwater targeting is very complex in hard rock aquifer systems because of the heterogeneity of the aquifer systems. In fact the groundwater mobility and stability greatly varies in hard rock's because of the variance in the rock types, the nature and degree of folding, the morphology and density of the fracture systems, the geomorphic etc. In hard rock areas, such various geologically related groundwater controlling parameters occur in different permutations & combinations and accordingly possess greatly varying groundwater holding and conducting capabilities.

Hence, one has to mandatorily analyse all the parameters to understand and bring out precise models for the successful targeting of groundwater in hard rock aquifer systems. So, for the same, in the present study, various types of thematic data bases were generated on multivariate aquifer parameters and various geological parameters. Subsequent to the generation of such spatial data bases in GIS environment, spatial modelling was carried out by overlaying the various thematic maps of the different aquifer parameters over the thematic/GIS maps on different geological parameters one after the other, so as to understand the actual control of the groundwater systems.

### 3.2 WATER LEVEL

Monitoring of the groundwater levels is an important component in hydrogeological studies. The water level fluctuation reflects the change of groundwater storage and recharge condition in a particular basin. For this purpose, the water levels from 24 open dug wells (Figure 3.1 & Table 3.1) spread over the entire study area were measured during Pre and Post monsoon periods from 2007 to 2012. The water levels from observation wells were collected from 2007 to 2012.

The study of the water level fluctuation in an area helps to assess the gravity of situation in times of drought and also take appropriate remedial measures. The groundwater level in the study area to reaches the lowest level during hottest summer period, after which it starts rising to reach the highest peak at the end of monsoon.

The rise and fall depend on the amount, duration and intensity of precipitation, depth of weathering, specific yield of the formation and the general slope of the terrain towards the drainage channel and various other factors. A general overview of the water level fluctuation suggests in the study area that the water level tends to rise during the months of December to January (Post monsoon) to reach their highest peak and starts descending from May to June (Pre monsoon).

The depth to water level in the study area varied from 2.49 (Kuppakurichi) to 14.79 m bgl (Navaneethakrishnapuram) during pre- monsoon while it varied from 0.97 (Kuppakurichi) to 12.33 m.bgl (Navaneethakrishnapuram) during post monsoon.

### 3.2.1 Pre-monsoon Water Level

Depth to water table from ground level was measured with the help of measuring tape and altitude measured with the help of GPS. The pre-monsoon water level data were collected during the month of May from 24 wells for the period of 2007 to 2012. The water level data were entered as point data and water table contour map was prepared with the help of Arc Map GIS software. The change in the pre monsoon water levels from year to year is observed. The Table.3.2 illustrated the pre monsoon average water level for the period of 2007 to 2012. Figure 3.2 shows represent the average pre monsoon water level contour map of the study area.

### 3.2.2 Post-monsoon Water Level

The post-monsoon water levels from 2007 to 2012 were collected from 24 open wells during the month of January. Post-monsoon water table contour was generated with the help of Arc Map GIS software. The change in post-monsoon water levels observed from one year to another year. The table.3.2 illustrated the post monsoon average water level for the period of 2007 to 2012. Figure 3.3 represent the average post monsoon water level contour map of the study area.

### 3.2.3 Average Water Level

The average water levels from 2007 to 2012 were collected from 24 open wells during the month of January to December. Average water table contour was generated with the help of Arc Map GIS software. The table.3.2 illustrated average water level for the period of 2007 to 2012. Figure 3.4 represent the average water level contour map of the study area.

### 3.2.4 Water Level Fluctuation

Water level fluctuation (Davis, S. N., and Dewiest, J. M., 1966) in the area studied in details by measuring the difference of water level between the post and pre monsoon water level. The measured water level changes are plotted and water level fluctuation map was generated. Based on water level fluctuation the area divided into four major categories as high, medium, low and very low water level fluctuation zones. The water level fluctuation is low and very low in South due to the perennial river Tamiraparani is running in the Southern side. The water level fluctuation is moderate and high in North due to the seasonal or drought river Chittar is running in northern side of the study area. . Figure 3.5 represent the Fluctuation water level contour map of the study area and the maps shows the fluctuation increasing towards the Northern side of the study area.

## 3.3 RAINFALL

The study area receives the rain under the influence of both southwest and northeast monsoons. The northeast monsoon chiefly contributes to the rainfall in the study area. The study area has a monsoonic climate as it lies within the tropical monsoon zone. Based on the hydrometeorological feature of the study area, year is divided into two periods. (i.e.) Monsoon period spanning from June to December and Non-monsoon period spanning from January to May. The monsoon period is further sub-divided into South West monsoon period spanning from June to September (4 Months) and North East monsoon period spanning from October to December (3 months).

Similarly, the non-monsoon period is further sub-divided into Winter period spanning January and February (2 months) and Summer period spanning from March to May (3 months). As the monsoon period brings heavy rainfall it improves the recharging of ground water and storage of surface water. Hence, the monsoon period is hydrologically significant for water resources analysis. But in the case of Non-monsoon, it is insignificant. The Table 3.3 represents the Actual and Normal Rainfall data of Tirunelveli District for the period from 2005 to 2014 and Table 3.4 represents the Season wise Average Rainfall (10 years). The Graph 3.1 represents the graphical representation of Normal and Average Rain fall data for the Period from 2005 to 2014.

A general over-all view of rainfall data indications that the precipitation varies from 768 mm to 1343 mm. Most of the rainfall occurs only during Northeast Monsoon Season. As per meteorological standards, deviation of rainfall +20% or more is excess, -19% and +19% is normal, -20% to -59% is deficient and less than -60% is scanty. Between the periods considered 2005 to 2014, Excess rainfall i.e. morethan >+20% recorded in the year 2006, 2008 and 2014. Normal rainfall i.e. between < -19% to >+19% recorded in Maximum of 5 Years.( 2005, 2007, 2009 - 2011 & 2013). Deficient rainfall i.e. between < -20% to >-59% recorded in Maximum of 3 Years.( 2006, 2008, 2012). Scanty rainfall i.e. less than -60% deficit rainfall was not recorded in past 10 years.

## 3.4 PUMPING TEST

Pumping test will also give information about hydrogeological properties of the well site such as the type of aquifer and its areal extent, thickness, water table gradient and recharge boundaries. When water is pumping out from a well, the water level in the well will drop and when pumping stops, the water level in the well will eventually return to its original position.

During a pumping test, water is pumped out from a well at a specific rate, and measurements are taken to determine how fast and how far the water level in the well drops (time - drawdown data). Measurements are also taken to determine how fast the water level in the well returns to normal level (time-recovery data) once pumping has stopped.

### 3.4.1 Pumping test Data Collection

Water shortage and scarcity, both for domestic and irrigational uses have emerged as a major issue in the public debate. Detailed assessments in study area require special emphasis over the hard rock aquifers in many areas. Whenever a geologist is working on a hydrogeological project, it becomes inevitable for him to have knowledge about hydrologic characters of the aquifer concerned. Pumping test has proved to be the most versatile means of achieving this objective. In the current study, on the basis of a 24 dug-well pump tests conducted in the hard rock areas in the study area, the aquifer parameters have been evaluated, making use of suitable flow- equations. An attempt has also been made to assess the performance of the dug wells with the help of computed specific capacity indices.

### 3.4.2 Selection of Pump Wells

No particular systematic method has been used to choose the wells for the pump tests since they are not uniformly distributed. In short, the availability of energized dug wells with a satisfactory hydraulic response was the most important criterion for well selection. Both circular and rectangular wells are common in the study area. Equivalent radius of a circular well with the same cross – sectional area as the rectangular well under test has been used during substitution in the formulae adopted for the determination of aquifer parameters.

### 3.4.3 Empirical Measurements

The measurements to be taken during an actual pumping test fall in to two groups. (1) Measurements of the water level and (2) Measurements of the discharge / recharge rate. Ideally, a pumping test should not be started before the already existing water level changes in the aquifer are known, including both long term regional trends and short term variations. Hence for some days prior to the actual pumping test, the water level in the well should be measured twice a day. The most important part of a pumping test is the measurement of the depth to water in the well both during pumping and recovery phases. The difference between the static water level and the pumping water level can give the drawdown (S) and the difference between maximum drawdown and the recovery water level can give the recovered drawdown (S'). The difference between maximum drawdown and recovered drawdown will be the residual drawdown (S''). Immediately after starting of pump or its stoppage, the water levels fall or rise very rapidly and hence the water level measurements should also be very rapid during this period.

Kruseman and De Ridder, N.A., (1970) proposed a range of time intervals for measurements in the pumping wells of small diameter. Since the wells under the present investigation are of large diameter, the water level change is so imperceptible during such small time intervals as proposed by them that a time interval ranging between 3 and 30 minutes during both pumping and recovery phases has been followed, depending upon the aquifer response. It may also be added here that a satisfactorily long duration pumping could not always be achieved due either to the limited saturated thickness of the aquifer or the reluctance of the farmers to oblige our request.

Among the arrangements to be made for an aquifer test is the control of the discharge rate. In order to avoid complications in computation, the discharge rate should preferably be kept constant throughout the test. But in the existing field conditions this was not possible. Repeated measurements of discharge using the container method were done during the entire phase of pumping and average taken for computational purposes. Recovery rate has been computed by multiplying the drawdown (S') with the cross – sectional area of the well. About twenty four large diameter wells have been selected and their locations are shown in Figure 3.6 and Table 3.5

### 3.4.4 Evaluation of Aquifer Parametes

Numerous techniques are available for analyzing the pumping test data of wells. The classical methods (Papadopulos et al. 1967; Raju et al. 1967; Cooper et al. 1946; Narasimhan, 1968; Adyalkar et al. 1972; Sammel, 1974; Zhdankus, 1974; Streltsova, 1974;, Neuman, 1975; Boulton et al. 1976; Walton, 1979; Rushton et al. 1983) are mostly graphical in nature and there is a room for error in individual judgment. Many computer methods have been proposed and successfully utilized during the last few decades, for analyzing the pumping test data (Walton, 1970; Saleem, 1970; Rayner, 1980; McElwee, 1980; Dumple et al. 1983; Bradbury et al. 1985; Butt et al.1985; Mukhopadhyay, 1985 and Balasubramanian, 1986). Digital numerical procedures have been applied in this study for the determination of aquifer transmissivity (T) and storage coefficient (S). A composite computer programme has been used to analyze the pumping and recovery test data and to give a variety of information regarding the aquifers. Standard conversion factors have been incorporated in the program in order to get all the results in metric units. The computer programme has been used to analyze the pump tested data of the study area.

**3.4.4.1 Aquifer Transmissivity**

It is generally agreed that the analysis of data from single well tests can estimate transmissivity with confidence, and at a worst case in dual porosity and heterogeneous environments, transmissivity may be overestimated by a factor of 2. However, evaluating transmissivity has little immediate benefit to those responsible for making decisions about whether a borehole is successful or not. The knowledge has to be applied and translated into an estimate of how productive a borehole will be and whether it will sustain a hand pump. Theis et.al. (1954) suggested procedures for estimating transmissivity from specific capacity

(Q/s) data by means of the Theis' et al. (1963) described a method for estimating the transmissivity (T) of an aquifer from the specific capacity of wells. This is based on the Jacob's equation.

$$T = \frac{Q}{4 \pi s} \times 1n \left[ \frac{2.25\, Tt}{r_w^2\, S} \right]$$

Where, T = transmissivity in $m^2$ / day

S = storage coefficient (dimensionless)

Q = discharge rate $m^3$ / day

s = drawdown in mts

t = period of pumping in days, and

$r_w$ = radius of the well in mts

As T appears on both sides of the equation, this cannot be solved directly. Approximations in the determinations of T values have been done using simple iterative procedures. Appropriate S values have to be given for this method. Table 3.6 represents the Transmissivity values of the study area.

The transmissivity concept can be used for all types of aquifers depending on the saturated thickness. The maximum value of T observed through the sensitivity analysis is the minimum of 63 $m^2$/d and maximum is 280 $m^2$/d. The average being 130 $m^2$/d. Overall T values with less than 300 $m^2$/d. Hard rock areas are having more than 100 $m^2$/d are treated as good transmissivity values.

The transmissivity of charnockites may be considered superior to the gneisses in hard rock aquifers. The aquifer transmissivity map of the study area is shown in Figure 3.7.

### 3.4.4.2 Storage Co-efficient

According to Theis (1935), the residual drawdown (s') during the recovery period is

$$S' = Q / 4\pi\ T\ (\ \ln\ (\ 4Tt / r2wS\ ) - \ln\ (4Tt'' / r2wS''))$$

Where, s' = Residual drawdown in metres,

$r_w$ = Effective radius of the pumping well in metres,

s" = Coefficient of storage during recovery (dimensionless),

s = Coefficient of storage during pumping (dimensionless),

t = Time since pumping started in days,

t'' = Time since pumping stopped in days,

T = Transmissivity in $M^2$ /day, and

Q = rate of recharge in $M^3$/day.

When s and s" are constant, and equal and $u = r_w^2\ S/4Tt$ is sufficiently small, and thus,

$$S'' = (\ 2.30\ Q / 4\pi\ a\ )\ \log t / t''$$

The plots of s" v/s, t/t" on semi logarithmic paper fall on a straight line whose slope is equal to 2.30 Q/4πT, and hence the residual drawdown per log cycle of t/t" can be calculated numerically and substituted for evaluating T. The results of the Storage Co-efficient of the study area are given in the Table 3.6 and its ranging between 0.11m/d – 1.36 m/d. The Storage Co-efficient map of the study area is shown in Figure 3.8.

#### 3.4.4.3 Specific Capacity

The specific capacity of a well is the ratio of discharge to the drawdown (Summers, 1972). It is not a constant because the drawdown varies with a number of factors, including length of time since pumping begin, rate of pumping, well construction, boundary condition within the aquifer and the influence of nearby pumping wells. It is a measure of the effectiveness of the well (Todd, 1959). Slichter (1906) gave the formula of computing the specific capacity as;

$$C = 2.303 * (A/t) * \log (s/s')$$

Where, C = Specific capacity of the well in lpm/mdd,

A = Area of the cross section of the well in M2

T = Time since pumping stopped in minutes

S = Drawdown in meters just before pumping stopped, and

S' = Residual drawdown in M at any time (t) after pumping stopped

This formula is valid for the wells penetrating the poorly permeable formations where the recovery is slow and may not hold good for such aquifers where the inflow is equal to or more than outflow. This does not take into account the duration of pumping prior to the shutdown of the pump. The results of Specific Capacity of the study area are given in Table 3.6 and its ranging between 50 – 836 lpm/mdd. The Specific Capacity map of the study area is shown in Figure 3.9.