Abstract

Keeping in mind the scarcity of available water resources versus its demand in the near future, it has become imperative on the part of water scientists and planners to adopt techniques for quantifying the available water resources for sustainable development and management. As more and more surface water bodies are getting polluted especially in fast developing global economies like India due to the rapid urbanization as well as lack of awareness, attention has been diverted towards the available groundwater resources.

The apparent heterogeneities and complexities present in the hard rock aquifers makes it a challenging research to tackle groundwater problems. The intricacy increases manifold for the management of groundwater when the hard rock aquifers are situated in arid or semi-arid regions. Thus groundwater management becomes utmost important in areas of hard rock aquifers with semi-arid climates as the entire stress is put on the groundwater due to absence of perennial source of surface water. Groundwater has another advantage of its availability almost everywhere as more or less all the geological formations have some space containing groundwater. The demand supply gap has led to the over abstraction of the groundwater and water level depletion in many areas beyond economic exploitation.

Geological formation that can store as well as transmit water to yield sufficient quantities of water to wells and springs are termed as aquifer. Thus the two main properties which can make any geological formation, a potential aquifer, is the presence of porosity and permeability. In alluvial and soft rock formations these properties are quite evenly distributed and the flow mechanisms are simple and have been quite well understood. The characterization of the hard rock aquifers however poses a challenging problem. The heterogeneities associated with the distribution of porosity and permeability makes it extremely difficult to predict the flow path using the conventional methods applicable to homogeneous aquifer. Aquifer parameter estimation using such approach often results in unrealistic values thus over estimating and in some cases even under estimating the aquifer potential.
The availability of water in hard rocks is attributed to the development of secondary porosity. Weathering plays an important role in this. In India so far no serious attempts were made to link the hydrogeological behavior of the aquifer with the weathering process.

The present work has been carried out in the Maheshwaram watershed which is situated about 35 km south of Hyderabad in the Rangareddy district of Andhra Pradesh India. The watershed has an area of 53 km² and is a true representative of an over exploited crystalline-rock watershed in a typical rural Indian setting with semi-arid climatic conditions. The study area is highly over-exploited but free from industrial pollution. Therefore, to tackle the groundwater problems systematically, the research has been focused on fully understanding the aquifer system both in terms of structure and functioning, characterize the flow parameters and prepare as well as analyze the groundwater balance for a long term and sustainable management of groundwater in the study area and approaches developed could be applied to other similar regions. Geologically the watershed comprises of Archean granites which forms a part of the Peninsular Gneissic Complex of the Eastern Dharwar craton. Structural features in the form of Quartz veins and dolerites are often seen cutting across these granites.

Detailed investigations using geological methods of mapping the structures, mineral distribution etc and an exhaustive mapping of weathering profile clubbed with the geophysical investigations available have provided a clear and comprehensive conceptualization of the aquifer system in the study area as well as in such a region. The approach involves mapping of the different layers (result of the weathering processes) of granitic rocks. It has been well established that weathering follows the same pattern in granitic and metamorphic terrains. From top to bottom any hard rock area covered by igneous or metamorphic rocks may be divided into the saprolites, fissured zone and the fresh basement. The fissured zone which lies in between the weathered saprolite and the fresh basement is found to be the most productive zone in such areas. The mapping of this layer has helped in the estimation of the aquifer thickness on a regional scale. Such kind of study will definitely help in determining the maximum resource limit up to which groundwater abstraction can be made and also helping in planning and decision making. Mapping the different zones of weathering will also help in the preparation of the aquifer vulnerability map. Greater thickness of the saprolite and fissured layers generally makes potential aquifer zones
and vice versa. Thus mapping these zones on a regional scale will help in protecting the areas with a thin weathering cover from over exploitation.

Apart from these, the thickness of the different zones are very important for the groundwater flow modelling in hard rock terrains and the aquifer parameter and the height of the different level above the mean sea level are very important for calculating the inflows and out flows across the watershed boundaries during water balance calculations.

Mapping of the weathering profile in the Maheshwaram watershed has also revealed important information which shows that the Maheshwaram weathering profile is a result of a multi-phase weathering process where the earlier profile has been obliterated due to subsequent erosion and a new weathering profile has been superimposed on the existing partially eroded weathering profile.

A major part of the work is devoted on the analysis of various methods both classical and modern available to interpret various types of the hydraulic tests in such an aquifer system. The applicability of different methods has been verified and specific methods of evaluating aquifer parameters in such aquifers are established. A large variety of hydraulic tests have been carried out that includes Specific capacity tests, slug tests, pumping tests of long as well as short durations, injection tests, to determine the hydraulic properties and their distribution as well as variability.

No single universal method exists for the analysis of pumping tests data in fractured rocks. Application of a number of methods depending upon the behaviour of the time drawdown curve during pumping tests helps in getting the realistic values. Depending on the model used for determination, the aquifer geometry can be conceptualized. However, the procedure adopted to have a conceptual geological model is often time taking and the presence of limits or boundary conditions are often not noticeable in the drawdown versus time data.

In the recent times a set of modern interpretation technique has been developed in the oil industry. These techniques are mainly characterized by computerized methods and by a standard methodology which involves two systematic steps. (1) Model identification and (2) Parameter identification. The model identification involves the determination of the conceptual model. This is facilitated by the plot of logarithmic derivative together with the drawdown as a function of time on a logarithmic scale.
These modern techniques have been applied in the present study for the interpretation of long duration pumping tests and have given very realistic values of the aquifer parameter as well as the aquifer geometry.

Groundwater management has been the key issue for most of the problems related to water resources in the semi-arid areas with over exploited aquifers. In spite of several types of artificial recharge structures, the water level decline continues and it has become imperative to consider analyzing the demand of groundwater. This needs to evaluate each and every component of the groundwater and prepare a meaningful groundwater balance.

With the eventual objective of the groundwater management in the area global water balance and budget have been prepared. For this exercise, all the components involved in the water balance belonging to both surface and subsurface were established and defined. All components have been estimated using most of the information available and attempts have been made to avoid ad-hoc assumptions that hitherto used in the existing methodologies of the estimations. For example, the rainfall recharge to aquifer has been estimated using various methods and particularly dividing the water cycle into two different seasons using the monsoon nature of rainfall prevailing in India. This method ensures the removal of uncertainties and errors in the estimation of the Specific yields. The groundwater draft/withdrawal has been estimated by a number of approaches including land-use map obtained from the satellite data as well as the ground information by cent percent well inventories and also the crop requirement information. Evaporation and Irrigation return flows were estimated using latest approaches.

A unique part of this study has been the use of exhaustive piezometric survey for groundwater levels in the aquifer. But since the groundwater levels are time varying, a new methodology was developed to obtain the number and location of optimal piezometric network with the help of Geostatistical techniques. The optimal nature of the network determined from the new approach has been tested not only on the variation of the piezometric levels but also on the value of the Specific yield as well as the groundwater balance. The approach has been tested for a fairly long period of three hydrological cycles.

The development of methods and estimation of various water balance components will be crucial input to the numerical model for the aquifer as a predictive tool and also are used in designing an important tool viz., Decision support Tool.
(DST) that on one hand is useful to the decision makers for planning and on the other hand provide the farmers a detailed knowledge of the system behaviors following their farming practices that helps introducing any change required for sustainable management of the groundwater resources. The entire work has provided sufficient light on the hydrogeological systems and the geological structural control on them that help in conceptualizing the flow regime in such a system in the hard rock terrene. Then estimation of water balance through an optimal piezometric network makes this exercise cost-effective as it has to be carried out at frequent interval of time and at the same time reliable estimates are made using the specific methods developed.