ARTICLE IN PRESS

Geoscience Frontiers xxx (2017) 1–13

HOSTED BY

ELSEVIER

Contents lists available at ScienceDirect

China University of Geosciences (Beijing)

Geoscience Frontiers

journal homepage: www.elsevier.com/locate/gsf

Research paper

Inverse modelling of aquifer parameters in basaltic rock with the help of pumping test method using MODFLOW software

Kanak Moharir [a,*], Chaitanya Pande [a], Sanjay Patil [b]

[a] *Sant Gadge Baba Amravati University, Amravati, India*

[b] *Maharashtra Remote Sensing Application Center, Pune, India*

A R T I C L E I N F O

Article history:
Received 28 May 2016
Received in revised form
6 November 2016
Accepted 29 November 2016
Available online xxx
Handling Editor: M. Yoshida

Keywords:
Pumping test
Hantush method
GPS
MODFLOW
Inverse modelling
Hydraulic parameters

A B S T R A C T

The origin and movement of groundwater are the fundamental questions that address both the temporal and spatial aspects of ground water run and water supply related issues in hydrological systems. As groundwater flows through an aquifer, its composition and temperature may variation dependent on the aquifer condition through which it flows. Thus, hydrologic investigations can also provide useful information about the subsurface geology of a region. But because such studies investigate processes that follow under the Earth's shallow, obtaining the information necessary to answer these questions is not continuously easy. Springs, which discharge groundwater table directly, afford to study subsurface hydrogeological processes.

The present study of estimation of aquifer factors such as transmissivity (T) and storativity (S) are vital for the evaluation of groundwater resources. There are several methods to estimate the accurate aquifer parameters (i.e. hydrograph analysis, pumping test, etc.). In initial days, these parameters are projected either by means of in-situ test or execution test on aquifer well samples carried in the laboratory. The simultaneous information on the hydraulic behavior of the well (borehole) that provides on this method, the reservoir and the reservoir boundaries, are important for efficient aquifer and well data management and analysis. The most common in-situ test is pumping test performed on wells, which involves the measurement of the fall and increase of groundwater level with respect to time. The alteration in groundwater level (drawdown/recovery) is caused due to pumping of water from the well. Theis (1935) was first to propose method to evaluate aquifer parameters from the pumping test on a bore well in a confined aquifer. It is essential to know the transmissivity ($T = Kb$, where b is the aquifer thickness; pumping flow rate, $Q = TW$ (dh/dl) flow through an aquifer) and storativity (confined aquifer: $S = bS_s$, unconfined: $S = S_y$), for the characterization of the aquifer parameters in an unknown area so as to predict the rate of drawdown of the groundwater table/potentiometric surface throughout the pumping test of an aquifer. The determination of aquifer's parameters is an important basis for groundwater resources evaluation, numerical simulation, development and protection as well as scientific management. For determining aquifer's parameters, pumping test is a main method. A case study shows that these techniques have been fast speed and high correctness. The results of parameter's determination are optimized so that it has important applied value for scientific research and geology engineering preparation.

1. Introduction

Aquifer mapping can be defined as a scientific process, wherein a combination of geologic, geophysical, hydrologic and chemical field and laboratory analyses are applied to characterize the quantity, quality and sustainability of ground water in aquifers. Systematic aquifer mapping is expected to improve our understanding of the geologic framework of aquifers, their hydrologic

* Corresponding author.
E-mail address: Kanak.moharir1@gmail.com (K. Moharir).
Peer-review under responsibility of China University of Geosciences (Beijing).

http://dx.doi.org/10.1016/j.gsf.2016.11.017

characteristics, water levels in the aquifers and how they change over time, and the occurrence of natural and anthropogenic contaminants that affect the portability of ground water. Results of these studies will contribute significantly to resource management tools such as long-term aquifer monitoring networks and conceptual and quantitative regional ground-water-flow models used planners, policy makers and other stakeholders. Aquifer mapping at the appropriate scale can help prepare, implement and monitor the efficacy of various management interventions aimed at long-term sustainability of our precious ground water resources, which, in turn, will help achieve drinking water security, improved irrigation facilities and sustainability in water resources development in the country as a whole.

Pumping test is a very simple technique. A well, which is screened in the aquifer, is pumped and the fall of water level (drawdown) is measured in the pumping well and/or in the nearby observation well at regular interval. As the pumping stops, the water level in the well rises and this rise is also measured at suitable intervals. These measured water levels are used to determine the aquifer characteristics. In Asian and Southeast Asian countries, large diameter wells are abundant and they are often cost-effective means to conduct pumping test as one can use the farmer's pump to perform this test. There are several suggested methods to estimate aquifer parameters through pumping test data, in which, curve matching and numerical methods are widely used. Special emphasis need to be given to pumping tests and data interpretation, which were carried out at various locations in a basaltic terrain. The data are interpreted by using both analytical and numerical methods; and compared with them. The results of analytical methods have shown up to 35% error involved in the calculated drawdown as well as residual drawdown in comparison with the field observations, whereas it is less than 4.5% in the case of numerical method. Hence, the present study shows that the numerical method is found to be more accurate than the analytical curve matching method for estimating the aquifer parameters.

MODFLOW, a three-dimensional finite-difference groundwater flow model by Michael G. McDonald and Arlen W. Harbaugh, is the most widely used groundwater model in the world. Flows from external stress such as flow to wells, areal recharge, evapotranspiration, flow to drains and flow through riverbeds can also be simulated. A large amount of information and a complete description of the flow system are required to make the most efficient use of MODFLOW (Kruseman and de Ridder, 1970; Singh and Gupta, 1986; Karanth, 1987; Raj, 2001).

2. Study area

The present study is based on the hydrogeological data obtained for large-diameter dug wells tapping unconfined aquifers in various parts of Maharashtra and considers the potential of the above five groups as aquifers. The area under study is forming a part of the Akola and Buldhana districts, Maharashtra, India, located close to the western margin of the Deccan traps terrain about 25 km SW of Chikhli Taluka (20°54′59″N and 76°41′23″E). The study area is covered by Survey of India toposheets 55D/7, 55D/9, 55D/11, 55D/13, 55D/14 and 55D/15 on 1:50,000 scale. The east to west monsoon (during middle June to September) contributes more than 70% of the rainfall. Rainwater is the main source for recharging of groundwater. The location map of the study area is shown in Fig. 1.

2.1. Rainfall

The area receives major part of the rainfall (about 45%) during South-West-monsoon period. There are eleven rain gauge stations in the area which have rainfall recorded for more than 50 years. The normal rainfall for Akola and Buldhana districts is 800–1200 mm (source IMD). It is minimum in the northwestern part of the district and increases towards the southeastern parts of the district i.e. toward Washim district. The percentage of probability of receiving normal rainfall over the district has been studied.

2.2. Agriculture

Agriculture plays an important role in the economic development of Akola and Buldhana districts of Maharashtra. Nearly 80% of the total area is arable and most of the total population is engaged in different agricultural activities. The farmers are harvesting two crops in a year. Ground water the most important natural source that is widely used in agricultural production amounts to nearly 80% of the total irrigated area.

3. Methodology

3.1. Test performance

Pumping method is a very modest procedure. An observation well, which is selected in the aquifer system has been pumped and the drop of groundwater level is calculation in the pumping test well or in the close pumped well at continuous interval. As the pumping test stops, the groundwater level in the observation well increases. These reported groundwater levels are used to control the aquifer parameters characteristics (Fig. 2).

3.2. Pre-pumping measurements

Before the commencement of pumping test, it is very essential to make measurements of water levels in the pumping as well as in the observation wells. The measurements are repeated after regular intervals (half an hour). In case appreciable difference is noted, the sufficient time is given to get water level stabilized. In some cases, the measurement of water level prior to the test is carried out for a couple of days. This gives the trend of variation in the water level which can be used for correction of drawdowns obtained during the test.

3.3. Measurements during pumping test

During the pumping test, mainly two measurements are made. These are water level measurements in the wells and abstraction rate from the pumping well. The water level measurements are made in all the wells during pumping test at regular interval. The fall of water level in the initial hours of the test is rapid. Therefore, the water level is measured at short interval during the initial period. As the test continues, the change in water level becomes less and less. Hence at the later stage, the interval of measurement is increased. The most practical time intervals are given in Table 1.

Similarly, the water level measurements are carried out in the wells after the pumping stops. During the recovery period also the water level rises rapidly during the initial hours. Hence the measurements of water level in the initial hours should be carried out at short intervals. The measurement of the water level should be continued till near complete recovery occur.

3.4. Pumping duration

The rate of fall of water level decreases as the pumping continues. After some time, the increase in drawdown is very small. In other words, near steady state condition has been achieved. The

Please cite this article in press as: Moharir, K., et al., Inverse modelling of aquifer parameters in basaltic rock with the help of pumping test method using MODFLOW software, Geoscience Frontiers (2017), http://dx.doi.org/10.1016/j.gsf.2016.11.017