GROUNDWATER LEVEL FLUCTUATIONS

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Introduction

Groundwater, the largest freshwater storage i.e. 98% of earth's fresh water, is a part of the water cycle and exists underneath the earth's surface almost everywhere (Krishan and Rao, 2017). On a global scale, half of the population depends on groundwater for their drinking needs in urban and rural areas (UNWWDR, 2015). Gleeson et al. (2016) reported that approximately 22.6 million cubic km of groundwater exists in the upper 2 km of the continental crust and 0.1-5.0 million cubic km is the volume of the dynamic groundwater (<50 years of age). Romuld (2016) discussed the research by Dr Oliver Warr et al who discovered 2 billion year old water in the Precambrian rocks of Ontario, at a depth of 3 km below the earth surface. Groundwater is under stress due to ever increasing demands of water in agricultural, industrial and domestic sectors. Most of the aquifers are in critical condition, therefore, identification of variability in the groundwater resource, appropriate data interpretation and management measures to safe guard from depleting groundwater resource for safe and sustainable groundwater use is the urgent need of the hour.

Groundwater availability, monitoring and observations

The groundwater availability is the physically available groundwater in a particular region which relates to how easily the groundwater can be tapped. While rainfall and the interacting surface water sources recharge the groundwater; draught and groundwater pumping cause groundwater to decline. The recharge/extraction process keeps the groundwater in a state of dynamic condition. The decline in rainfall can also affect the groundwater storage as observed by Asoka et al (2016) who reported a decline of 2 cm yr^{-1} due to substantial reductions in precipitation in north India. Researchers have found that the decline in precipitation in monsoon season over the Gangetic Plain resulted in increased frequency and intensity of droughts and this significantly contributed towards enhanced abstraction of groundwater simultaneously reduced recharge of groundwater.

Data loggers

The fluctuating level of groundwater over different time scales (diurnal, seasonal, annual decadal etc) is monitored using manual or semi-automatic or automatic loggers. These loggers are installed in the piezometers and observation wells and the high frequency data is downloaded. The automatic water level loggers measure the overlying water head pressure (total pressure minus the barometric pressure) and converts it in the units of water level. Increasing and decreasing levels of groundwater levels are interpreted in terms of groundwater recharge (from rainfall and other surface water sources) and draft respectively. Annual deficit or excess of groundwater balance can be viewed from the long term record of groundwater level trend (also termed as groundwater hydrograph). For interpretation, along with the groundwater data, rainfall and stage of the interacting surface water sources is also recorded.

Historical data

The data collected from other agencies can also be interpreted to see the water level changes over a period of time. The water level changes can be correlated with the precipitation. Asoka et el. (2017) have reported estimated changes in the groundwater well depth using CGWB data for 1996-2013, and observed decreasing trend in north India in monsoon season as compared to non-monsoon season, while increases in water level are observed in majority of wells in South India with some exceptions. A case from Shadnagar from hard-rock region of Andhra Pradesh depicts rising level of hydrograph in response to the rainfall recharge and falling thereafter due to adjustment with regional groundwater level and/or due to local groundwater withdrawal (Briz-Kishore and Bhim Shankran, 1981).

Data analysis

Sometimes, raw groundwater level data shows a misleading picture of rising or falling trend due to varying rainfall pattern. A proper mathematical analysis is therefore used to get pure trends due to natural and anthropogenic effects. Various methods used by various researchers are cross-correlation analysis (Berndtsson, 1987; Krishan et al, 2014; Lee and Lee, 2000), component analysis (Hsiao, 2017), Discrete Fourier Transform (Lee and Lee, 2000), head variation and head analysis (Liu et al., 2015) etc.

The temporal variation of groundwater balance in a basin helps identification of variation in recharge, draft and base flow conditions (Zomlot et al., 2015). Paucity of data for basin scale hydrological modelling can be overcome by using satellite based data. Large amount of satellite based global scale hydro-meteorological data gridded to few km resolutions over time intervals from daily to annual period is available from various sources. For hydrological modelling the required parameters from these sources can be downloaded and down-scaled to the regional scale and, the data available at local levels are integrated to regional scale. Temporal data is analysed for high and low frequency trends and their changing amplitudes. The futuristic models extend the resultant time series by incorporating population growth, economic reforms and developments, changing rainfall and temperature pattern, food productivity and its requirement etc over the required time scales. Based on such models suitable steps can be taken up to recoup, use and manage the groundwater aquifers.

Groundwater level and hydrological evaluations

Groundwater flow direction visualisation using groundwater level

Groundwater flow is usually visualised in a region by plotting groundwater level contours in units of meter above mean sea level. From the contour map it is possible to visualise regional flow pattern, rapid and slow flow paths, recharge (concentrated mounds) and discharge (depressions) zones, zone of influence of surface water with the nearby groundwater etc.

Groundwater resource estimation and management

Groundwater level time series has been widely used in groundwater resource evaluation and its management. The variability analysis using additive and multiplicative models of groundwater levels is done to pool long-term groundwater levels and correlating with rainfall and climatic cycles which help in the long term planning of groundwater utilisation. The groundwater in a large region like India, the long term groundwater trend is complicated from the influence of several parameters like population growth, land-use change, change in agricultural practices, change in vegetation cover, recharge measures, developments of dams, reservoirs and canal structures, inter-basin water transfer, changing rainfall pattern, climate change etc. Of these, climate change indirectly affects the groundwater resource. The change in climate modifies the rainfall and temperature pattern which affects surface water sources and food productivity and this in turn affects the groundwater recharge/withdrawal pattern and thereby affecting the groundwater resource.

Annual deficit leading to falling groundwater levels and excess balance leading to rising groundwater levels requires management measures to avert risk of drying groundwater resource and water logging problem, respectively. Aquifers in the hard-rock regions usually have low permeability and poor regional interconnectivity; therefore, in these aquifers, local recharge or withdrawal takes long time to adjust with regional groundwater levels. Therefore, the local groundwater level contours may develop mounds and depressions structures more prominently compared to alluvial aquifers. At global scale, changes in the distribution can also be detected by satellite based measurement on changing mass distribution around the planet. This is available from the Gravity Recovery and Climate Experiment (GRACE) satellite data since 2002 and has provided immense information on the depletion rate of groundwater over northern India (Rodell et al., 2009), California (Famiglietti, et al. 2011) and in other parts of the world.

The groundwater crisis is making several countries to develop comprehensive management plans (Tornburgh, 2016). In recent years, focus is also given on transboundary aquifers which connects and passes groundwater from a country its neighbouring country falling in the downstream (MacDonald et al., 2016). These transboundary aquifers are managed by international laws or through the transboundary groundwater sharing treaty developed on the basis of data and through dialogue and communication between the countries falling in the trans-boundary aquifer region (Podolny, 2010; Villar, 2016).

Conclusions

The fluctuating level of groundwater over different time scales (diurnal, seasonal, annual decadal etc) should be regularly monitored and a more in-depth analysis of fluctuation in groundwater level time series should be done to pool long-term groundwater levels and correlating with rainfall and climatic cycles. A proper mathematical analysis should be used to get pure trends due to natural and anthropogenic effects. The futuristic models extend the resultant time series by incorporating population growth, economic reforms and developments, changing rainfall and temperature pattern, food productivity and its requirement etc over the required time scales. Based on such models suitable steps can be taken up to recoup, use and manage the groundwater aquifers. It is further recommended that the sectors working on water resource should consider the establishment of rainfall recording equipment close to the water level monitoring recorders. This would enhance the reliability of the correlation between rainfall and water level fluctuations. Groundwater level records contain important information on the long-term behaviour of aquifers that have not been studied in any great detail, but could provide valuable information in future that will be beneficial to the managers of the national water resources.

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