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Application of Artificial Neural Network to simulate groundwater level – A Review

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Abstract - Groundwater is among the Nation's most precious natural resources. The groundwater system as a whole is a three-dimensional flow field and is very complex in nature The measurement of water level in wells provide the most fundamental information about the status of this resource and are critical to meaningful evaluations of the quantity and quality of ground water and its interaction with surface water. Groundwater levels are controlled by the balance among recharge to, storage in, and discharge from an aquifer. Physical properties such as the porosity, permeability, and thickness of the rocks or sediments that compose the aquifer affect this balance. This paper describes about the application of Artificial Neural Network (ANN) in simulating groundwater level.

Keywords - Groundwater level, Simulation, Artificial Neural Network

I. INTRODUCTION

Groundwater is the largest source of fresh water on earth, and was little used until recently. Ground water systems are very complex and dynamic and adjust continually to short-term and long-term changes in climatic and hydrological parameters, such as the timing and amount of recharge provided by precipitation, discharge from the subsurface to surface-water bodies, and evapo-transpiration; ground-water withdrawal and land use. When the rate of recharge to an aquifer exceeds the rate of discharge, water levels or hydraulic heads will rise. Conversely, when the rate of ground-water withdrawal or discharge is greater than the rate of ground-water recharge, the water stored in the aquifer becomes depleted and water levels or hydraulic heads will decline. Water-level measurements from observation wells are the principal source of information about the hydrologic stresses acting on aquifers and how these stresses affect ground-water recharge, storage, and discharge.

The water-level measurements from observation wells will provide data representative of various topographic, geologic, climatic, and land-use environments. Meteorological data, such as precipitation data, helps in the interpretation of water-level changes in observation wells. In case of wells, located in alluvial aquifers or other aquifers that are connected to a stream or lake, hydrologic data, such as stream discharge or stage, are useful in understanding the interaction between ground water and surface water. Meteorological and stream flow data commonly are available from other sources; but if not, some monitoring of variables such as stream flow and precipitation may be needed to supplement the water-level data, particularly in remote areas or in small watersheds. In addition, water-use data, such as pumping rates and volumes of pumped water, can greatly enhance the interpretation of trends observed in water levels and explain changes in the storage and availability of ground water that result from water withdrawals over time.

The numerical model requires a vast and accurate dataset for such predictions. In case sufficient dataset is not available the empirical models such as Artificial Neural Network (ANN) provide good alternative. An Artificial Neural Network (ANN) is an information processing paradigm inspired by Biological nervous systems, such as our brain. It consists of large number of highly interconnected processing elements, called neurons, working together. An ANN consists of input, hidden and output layers and each layer includes an array of processing elements. Moreover empirical/data-driven models do not depend on an explicit physical-based representation of the system but instead utilize an empirically based input-output variable approach to capture the cause and effect relationships of the system behavior of interest [8]. The Artificial Neural Network (ANN) methodology is an alternative modeling and simulation tool, especially for dynamic nonlinear systems. The nonlinear nature of the relationship, universal function approximation, robustness, ability to learn, and the complexity of physically based models are some of the factors that have suggested the use of ANN in rainfall-runoff, stream flow, groundwater management, water quality simulation and precipitation [1]. In this study the application of Artificial Neural Network (ANN) in groundwater level simulation and effect of various climatic and hydro-meteorological parameters such as rainfall, temperature, humidity, evaporation, etc on groundwater level is studied.

II. LITERATURE REVIEW

The predictions of groundwater levels using ANN have been carried out by different researchers.

Coulibaly et al. (2001) developed a model to simulate water-table fluctuations in Gondo aquifer, Burkina Faso. The parameter used for this study consists of precipitation, maximum and minimum temperature, potential evapo-transpiration and water-levels of the observation wells recorded in last 7 years. The result showed that the model was able to capture the complex dynamics of large water table fluctuations, even with relatively short length of training data.

Coppola et al. (2003) prepared a model using ANN to predict transient water levels in a complex multilayered groundwater system. The parameters used for the prediction are, pumping and climate conditions. The absolute mean error of 0.16 m is observed between the ANN predicted water levels and the measured water levels, compared to the absolute mean error of 0.85 m achieved with the calibrated numerical model at the same locations over the same time period.

Daliakopoulos et al. (2005) developed a model to forecast Groundwater level for Messara Valley in Crete (Greece), using three different ANN architectures. The parameters used for prediction are past 20 years precipitation, temperature, discharge of Geropotamos Stream and groundwater levels. The result shows that accurate groundwater level prediction is achieved by standard feed forward neural network trained with Levenberg-Marquardt (LM) algorithm.

Feng et al. (2008) prepared a model to simulate regional groundwater levels of Minquin Oasis, Shiyang river basin, China in response to hydrological, meteorological, and human factors. The parameters used are ground water level, monthly total precipitation, monthly total water surface evaporation, monthly total surface water reservoir inflow, population, monthly synthesis irrigation ratio, and irrigation area. The results showed that human activities have more effect on change in groundwater level.

Ahmet Dogan, et al. (2008) prepared a model to predict GWL in Magnolia and Brooklyn Lakes in north-central Florida using ANN approach. The parameters used for forecasting are lake levels; groundwater levels, rainfall, and evapotranspiration. The correlation between these parameters is determined using ANN-based models and multiple-linear regression (MLR) and multiple-nonlinear regression (MNLR) models. All the models were fitted to the monthly data series and their performances were compared. ANN-based models performed better than MLR and MNLR models in predicting groundwater levels.

Sreekanth et al. (2009) prepared a model to predict groundwater level in Maheshwaram watershed, Hyderabad, India. The standard Feed Forward Neural Network (FFNN) trained with Levenberg-Marquardt (LM) algorithm was used. The results showed that for precise and accurate groundwater level forecasting, ANN appears to be a promising tool.

Mohsen Behzad, et al. (2010) carried out a comparative study of, a data-driven modeling approach, support vector machines (SVMs), and artificial neural networks (ANNs) to predict transient groundwater levels in a complex groundwater system i.e. Towaco Aquifer, Morris County, New Jersey, under variable pumping and weather conditions. As both ANN and SVM are empirical-based modeling approaches, they do not require nor depend on aquifer parameters such as transmissivity or recharge parameters that typically vary over space, and/or time. Instead, more directly measurable variables such as pumping rates, precipitation, and temperature can be used to represent the sink and source terms that influence groundwater level changes, with initial groundwater levels also used as an input which indirectly capture potential boundary condition effects such as leakage. It was found that SVM outperformed ANN particularly for longer prediction horizons when fewer data events were available for model development.

Jan Adamowski, et al. (2011) developed a new method to forecast ground water level data using coupled Wavelet-Neural Network models (WA–ANN) and is found to provide more accurate results compared to regular ANN models. The parameters used are monthly total precipitation, average temperature and average ground water level data of last 7 years, recorded at two sites in the Chateauguay Watershed in Quebec, Canada. WA-ANN models used the input as sub-series components (DWs), which are derived from Discrete Wavelet Transform (DWT). It requires fewer amounts of data and less computation time as compared to ANN.

Kavitha et al. (2011) developed groundwater level prediction models for Thurinjapuram watershed of Thiruvannamalai district, Tamilnadu, India using ANN and Fuzzy Logic techniques (FL) and compared the efficiencies of these two techniques. From the results obtained it is observed that ANN performs better than FL.

V. Nourani, et al. (2012) prepared a model to classify groundwater level (GWL) data using Self Organizing Map (SOM) and to predict future groundwater level in Ardabil located at northwest of Iran, using ANN. In first stage, SOM developed clusters representing piezometers with similar groundwater level pattern and then identified the dominant piezometers within each cluster, which can detect the best groundwater levels of the particular region. In second stage, ANN is trained for each piezometers as identified by SOM, to predict the groundwater level one month ahead. The parameters used for modeling are rainfall, runoff and previous groundwater values. The result showed that ANN in conjuction with SOM provided satisfactory results.

Amir Jalalkamali, Hossein Sedghi, et al. (2013) developed a model to predict groundwater level in Kerman plain, Iran. The model is developed using Neuro-Fuzzy (NF) and Artificial Neural Network (ANN) techniques to predict the groundwater levels. Two different NF and ANN models comprise various combinations of monthly variablities, that is, air temperature, rainfall and groundwater levels in neighboring wells. The result suggests that the NF and ANN techniques are a good choice for the prediction of groundwater levels in individual wells. Also based on comparisons, it is found that the NF computing techniques have better performance than the ANN models in this case.

Mohammad Mirzavand, et al. (2014) developed a model to forecast groundwater level fluctuation using ANN in arid and semi-arid environment of Kashan plain, Esfahan province, Iran. Rainfalls, rivers, transitional water resources from other basin and spring discharges (as aquifer recharge components), evaporation, and aquifer discharges (borehole wells) (as aquifer discharge components) were taken as inputs, and the groundwater levels of Kashan plain aquifer in five clusters (36 Piezometric well) were the outputs. A back propagation (BP) neural network model with Momentum, Levenberg-Marquardt (LM) algorithm, Quick Prop and Delta-Bar-Delta algorithms have been studied in different hidden layers. The Delta-Bar-Delta and Levenberg-Marquardt algorithms provided better results as compared to other algorithms. The study showed that training the artificial neural network with respect to effect of hydrological, meteorological and human factors on the dynamic groundwater levels gives good results.

Yabin Sun et al. (2016) prepared a model to forecast groundwater levels in a Nee Soon Swamp Forest of Singapore. A standard feed forward neural network trained with the Levenberg–Marquardt (LM) algorithm is used to develop a model. The input parameters used are three reservoir levels and rainfall while the output parameter is the observed groundwater tables at four piezometers. The model so developed is compared with Multiple Linear Regression (MLR) technique. The results showed that ANN model performs better than MLR model.

III. CONCLUSION

During the literature review it was observed that different researchers use different parameters and tools for simulation/ prediction of groundwater levels. In case where other tools such as Fuzzy Logic or Multiple linear regression (MLR) tool failed to predict groundwater levels, Artificial Neural Networks (ANN) and Support Vector Machine (SVM) performed really well even in case sparse dataset was available. In general, Artificial Neural Networks can be a promising tool for simulating groundwater levels.

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