SURFACE WATER GROUNDWATER INTERACTION SIMULATION USING AEM AND PARAMETER ESTIMATION USING GA

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Groundwater interacts with the surface water with wide variety of landscapes. Many natural processes and human activities affect the interaction of ground water and surface water. As urban, industrial and agricultural water use grows, the effective and cost efficient development and management of limited water resources is quickly increasing in importance. With the increasing awareness for optimal use of available resources, many man made structures are constructed such as check dams, weirs, percolation tanks etc. The construction and operation of surface water and groundwater features influences the interaction process. Understanding and evaluation of this process is required for conjunctive use management of surface water and groundwater. Considerable increase in activities and its spread necessitate user-friendly tools. Interaction of surface water and groundwater has been the focus of study for more than 100 years from the work of Boussinesq (1877). The simulation of this process has been done using variety of tools ranging from simple analytic solutions to sophisticated numerical techniques such as finite difference method or finite element method. The performance of simulation model entirely depends on correct representation of hydro-geologic features and their properties, and capabilities of simulation tools. An Analytic Element Method (AEM) was evolved to simulate the aquifers flow problems with accuracy similar to analytic solution and ease of representing hydro-geologic elements similar to finite elements or finite difference technique.

In AEM, discharge potential is introduced (Strack, 1989) to describe heads of both confined and unconfined aquifer condition. The contributions of discharge potential at any point due to different features are defined by analytic elements. To obtain a full description, these particular features must be superimposed. So the comprehensive potential describing the aquifer due to cross flow, wells, ditches, rivers, ponds, and lakes is:

$$\Phi = \Phi_c + \sum \Phi_w + \sum \Phi_d + \sum \Phi_r + \sum \Phi_p + \sum \Phi_l + C \tag{1}$$

Above equation is applied to control points of all elements for which heads are known. It is also applied to one reference point with known head. Thus unknown strength parameters are found. Once the strength parameters are obtained, the same equation is used to find discharge potential at any point in the aquifer. The value of discharge potential is then converted to head. The AEM formulation is implemented using object oriented design to develop a modeling tool HGEMS.

Hydrologic system comprises of many parameters such as hydraulic conductivity, storage coefficient, recharge rate, pumping rate, leakance, riverbed resistance etc. Field investigations are sometimes insufficient to estimate their values for modeling use. Genetic Algorithm (GA) have been increasingly applied to achieve optimal solution. GA based program HGPEST is developed for searching the best-fit values of parameters.

To test the model, an example problem is considered with streams, pond and a well. The heads are found for specified values of hydraulic conductivity of aquifer and recharge rate of pond. These heads are then used as observed values for model calibration. The HGPEST and HGEMS are used for estimating the hydraulic conductivity of aquifer and recharge rate of circular pond. HGPEST is used to generate the population (hydraulic conductivity, recharge rate) and HGEMS is used to generate the heads at desired points. The SSE (Sum Squared Error) is evaluated for each simulation. Results are obtained for 20 generations using chromosome size 20 and population size 20. The best-fit value of hydraulic conductivity is obtained as 2.25m/day and recharge rate as 0.048 m/day in 4^{th} generation. The Sum Squared Error for the estimated values is 0.008841 and corresponding fitness value is 0.991236. The predicted parameter values change while changing GA parameters, however the values predicted are quite acceptable. The values estimated by GA are quite satisfactory for planning and design of conjunctive use.

Analytic Element Method is very simple to construct a model. As no elements or grid generation is involved, the data requirement is minimum. The hydro-geologic elements such as streams, wells, ponds, etc can be easily constructed. The solution obtained by AEM is fast and precise. GA on other hand provides optimal solution with flexibility. The parameters are estimated using combination of AEM and GA with reasonable accuracy of about 1 to 2 percent. Thus coupling of GA code with AEM provides very powerful tool for parameter estimation.

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