Regional Aquifer Modelling in Areas With Limited Data

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ABSTRACT

The use of digital models for simulation of aquifer systems has become a common practice in the recent past. However, most of the times, the modeller is faced with a task of calibrating the model with inadequate/unreliable data which in turn causes lack of confidence over the results thus obtained. An attempt is made in this paper to suggest reasonably viable method for calibration of ground water models for regional modelling provided the behaviour of water table is in a state of dynamic equilibrium. The concept of mean year is introduced and the calibration strategy is indicated. A two layer biseasonal finite difference, Tyson-Weber model is choosen for indicating the calibration strategy.

INTRODUCTION

Basically the approach for solving the problems which are encountered at the time of planning of any developmental project shall be different from the approaches that are required at subsequent stages. Most of the times, the planner is required to very the feasibility of a project in the light of economical technical and other considerations. It is not his interest to solve any specific aspect of the problem. Though the development of a number of different types of digital groundwater simulation models has been reported in hydrological literature in recent years, the adaptability of such models depend on their use for a specific purpose. The extent of confidence that one can repose on

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the results depends on how best a model could be calibrated to represent the aquifer media and how closely the behaviour is simulated under different conditions of stresses. Naturally this implies that the data base should be sufficiently good. However, as is known, the data base at planning stages of any developmental project is rather poor. This necessitates to develop a methodology for modifying the calibration strategies so as to simulate the behaviour of the model as close to the real system as possible. A two layer biseasonal finite difference Tyson-Weber model is used to elaborate strategies for calibration.

Model Formulation

The following aspects have been taken into consideration while formulating the model, viz., Recharge and extraction to or from the aquifer; presence of gradient and no flow boundaries; the perennial canals and small rivers which form internal boundaries and act as line source and sinks and the spatial variation of the aquifer thickness which affects the transmissivity. Because of the intricate geological characteristics and nature of ground water exploitation, a two layer model linked through a conceptual leakance interface is adopted. For model formulation horizontal flow is assumed to occur in each of the layers. Mass transfer between the two layers is simulated as a leakance term determined by their governing vertical head differences and percentage of aquitard material in two layers. The differential form of Laplace equation converted into a difference equation is used to achieve the solution. Such a difference equation is established for each polygon of the discritized space and each term of the equation is a discharge crossing the conceptual boundaries of the polygon. The Tyson Weber method belongs to the finite difference approach and its particularity among others is the way the field space is geometrically discretized. The techniques to simulate the behaviour of two layer system is by treating each aquifer layer separately. The link between the layers is assured in assuming that the vertical leakance flow between the layers is equal and of opposite signs. To solve the transient problem, besides the discretization of space, time discretization (into two seasons) is also required by approximating the differentials by in finite difference expressions. The iterative procedure consists in solving the equation for each polygon of the lower and upper aquifer layers for each time step. The only unknown of the equation would be the piezometric head at the polygonal node at later times. All other terms are kept constant during the evaluation of the equation. Since the unknown can not be solved explicitly, an iterative method by trail and error is used until the solution is satisfactory.

Dynamic Equilibrium Condition

The monthly piezometric data that are available which when plotted against time at any particular location shall indicate the movement of water table in the vertical direction at that point of space.

Naturally, during the monsoon season, the water table will rise and move towards the ground surface indicating that the system is getting recharged (since the recharge components during monsoon season are generally larger than the abstraction components of the corresponding period), while during the non-monsoon season the movement will be away from ground surface. It is to say that generally the groundwater reservoir is replenished during monsoon period while it is depleted during the non-monsoon period. From the analysis of data if it can be seen that the fall in water/piezometric levels during the non-monsoon season is compensated by subsequent rise during the monsoon season and among the year to year variations are not significant over a period of time, it can be said that the water table at that location is in a state of dynamic equilibrium. And, if this observation is true within a reasonable limit over a region the water table regime over that region is considered to be in dynamic equilibrium condition. Under such conditions, even if data for certain period or for certain locations are not available, the calibration of the model could be achieved to a reasonable degree of accuracy.

Mean Year

The concept of mean year in the present context is important. The basic data from which recharge and abstraction components are computed can be collected to the extent possible and average values are computed. However, care is to be taken to verify that the different data considered for different components should have the same time base. This mean year data is used to estimate the recharge and abstraction components for subsequent use for calibration of the model under dynamic equilibrium condition.

Calibration Strategy

The calibration of the ground water model consists of three stages (1) Steady state calibration (2) calibration under dynamic equilibrium conditions and (3) validation. The main objective of steady state calibration is to establish the leakance term representing extent of interaction between the layers.

a) Steady state calibration

The vertical permeability parameter of the conceptual interface can be adjusted to give a reasonable reproduction of the vertical head difference. The input for the model includes:

-lower Zone abstraction for mean year,

-steady state heads for upper layers for mean year,

-initial heads in the lower layer obtained from net annual recharge per polygon for upper layer computed by using the recharge/abstraction program, and

-vertical head difference maps for steady state between upper and lower layer.

b) Dynamic equilibrium calibration

The calibration for dynamic equilibrium conditions is intended for determining storage characteristics of the system.

The mean year has been divided into two seasons, monsoon (5 months, June to October) and non-monsoon (7 months, Nov. to May) with the corresponding data of recharge and abstraction used in each season. In this calibration, the seasonal mean conditions are used. The solution commences with some initial trial heads at the nodes for the pre-monsoon conditions and with the inputs of the mean year monsoon season. It calculates the final heads for the nodes at the end of the season (post monsoon) during which iterations are made till the residue error term for overall model reduces to a threshold value. Using these results the calculations are made for the next season (non-monsoon) where against iterations are repeated for minimisation of residual error.

A sequence of such monsoon/non-monsoon time steps are repeated for a number of years, say, 20 years (with the corresponding seasonal inputs of the mean year) till the pre-monsoon and post-monsoon piezometry do not change any more from year to year and the storage as indicated on non-monsoon time step within permissible limits.

After the numerical convergence is obtained for the model run, the following procedure is adopted to check the consistency of results with the observed data.

The water table levels given by model for pre-monsoon as well as post-monsoon should be compared with those established for mean year conditions from observed data. In case the match is not achieved to the required degree, the parameters may be appropriately changed within permissible limits and if the difference between model and observed piezometry is localised for some areas necessary modifications may be incorporated in recharge abstraction components keeping in view relevant physical information wherever available.

After a reasonable reproduction of water table levels is obtained as mentioned above the seasonal base flows in rivers given by the model are compared with those estimated from available data. Suitable modification in the assumptions of model strategy may become necessary for getting required level of agreement between estimated base flow and those given by model. Similar comparison has to be made for seepage losses from main and branch canals which will contribute to the ground water recharge.

The model is completely calibrated once the estimate of permeability ratio is obtained and the values of horizontal permeability, specific yield, etc. are determined so as to give satisfactory reproduction of observed piezometry as well as agreement between observed and computed base flows and canal seepage.

The basic requirements for this step include:]

- -head in upper and lower layers obtained from step-1,
- -two seasons mean annual net recharge for each polygon obtained from Recharge/Abstraction program.
- -mean water level fluctuations as the mean water level change maps for each season, and
- -typical ground water level hydrographs for different locations.

c. Validation using historical data

Models are fitted to real physical processes on the basis of historical data. In order to test the suitability of the fitted model to a physical system, it is necessary to validate the fitted model on the basis of independent data not used in fitting the model.

Results obtained from the model will then be compared with field observations during these years particularly with respect to overall change in pre-monsoon water levels as well as observed hydrographs in the vicinity of some selected polygon nodes. Other points of comparison include base flow in rivers, canal seepage and change in ground water storage. The calibration can be considered as complete if the simulated and observed values of water levels are within reasonable limits of variation.

CONCLUSION

using an independent data for validation of a calibrated model would increase the reliability on the behaviour of the model. Thus the procedure described above leads to the validation of the calibrated model with an independent data. Also the missing data has little impact for the model calibration. Tyson-Weber Model was developed for ground water model studies in the Institute and the calibration strategy which was described above yielded highly satisfactory results.

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