INTRODUCTION TO COMPUTER APPLICATION IN GROUND WATER HYDROLOGY

Computer have been used to apply technology that has mostly been available. Computer associated mathematical developments have remarkably increased the scope, speed, accuracy and efficiency with which available technology can be applied.

Computing in water resources has evolved dramatically in the past three decades. At least three eras have occurred. The era of hostile computers (1950's and 1960's), the era of interactive computers (1970's) and the era of user friendly computers (The 1980's to date). During this period of transition, the major themes that have emerged are that the users of computers expect that their interaction with the computer be convenient, that they want to understand what tasks the computer is performing and that they desire the capability to modify programs for their specific needs.

There are many reasons or purposes for water development: water supply, hydroelectric power, navigation, flood control, irrigation, water quality, fishery and recreation. In water resources planning, whether planning for a single purpose or multipurpose, multiple means are considered. Surface water storage and ground water withdrawal are traditional engineering approaches which will continue to be needed in the future. Water resource planning must also consider alternatives such as : water rights, regulation, land zoning, conservation, educational and economic adjustments. Such diversity makes water planning inter disciplinary. The broad beneficial effects of water development are identified as economic development, environmental quality, social well being and income redistribution. Analysis in planning is not limited to hydrology, hydraulics and system, but includes environmental analysis and financial analysis. Models and computer are necessary for planning of water resources.

→Lecture delivered by G.C.Mishra

Substantial progress towards the solution of problems of management of groundwater and surface water resources have been achieved through the use of mathematical tools (Pinder and Bredehoeft, 1968; Prickett and Lonnquist, 1971). All these models have been designed to predict the hydrologic behaviour of the system in response to a particular set of numerical values of the excitations (e.g. pumping rates at a given well over several time periods). These models have not been designed to provide a functional relation between the response and the excitation. At first the hydrologic model was viewed as an end in itself. Currently the hydrologic model is viewed as a necessary intermediate component of a more complex system involving economic and legal aspects. The computational advantages of providing a functional relationship between response and the controllable variables was realised by Maddock (1972). The same approach was developed independently by Morel-Seytoux et al(1975).

Let us consider the following example:

Two wells are located a distance l apart. The total quantity of water to be pumped during a certain time period is Q_p. The aquifer is assumed to be initially at rest condition. The piezometric level at site 1 is at a depth of G_1 below ground surface and at site 2 it is at depth G_2 below ground surface. Find the quantities to be pumped at each well so that the cost of pumping is minimum. To solve this management problem it is necessary that the drawdown at each site should be expressed explicitly in terms of Q_1 and Q_2.

$$Q_1(1) + Q_2(1) = Q_p \qquad \ldots(1)$$

Drawdown at site 1 is given by

$$s_1(1)=Q_1(1)\delta(r_w,1)+Q_2(1)\delta(l,1) \qquad \ldots(2)$$

Drawdown at site 2 is given by

$$s_2(1)=Q_2(1)\delta(r_w,1)+Q_1(1)\delta(l,1) \qquad \ldots(3)$$

The coefficient $\delta(r,m)$ is given by

$$\delta(r,m)=1/(4\pi T)[E_1\{r^2\phi/(4Tm)\}-E_1\{r^2\phi/(4T(m-1)\}] \qquad \ldots(4)$$

$$E_1(x)=\int_x^{\infty} e^{-u}/u \, du \qquad \ldots(5)$$

Cost of energy spent in pumping, C_E, is given by:

$$C_E=C[Q_1(1)\{G_1+s_1(1)\}+Q_2(1)\{G_2+s_2(1)\}] \qquad \ldots(6)$$

in which C is the cost of lifting unit volume of water through unit height. Substituting expression of $s_1(1)$ and $s_2(1)$ in equation(6)

$$C_E=C\,Q_1(1)\,[G_1+Q_1(1)\delta(r_w,1)+Q_2(1)\delta(1,1)]$$
$$+C\,Q_2(1)\,[G_2+Q_2(1)\delta(r_w,1)+Q_1(1)\delta(1,1)] \qquad \ldots(7)$$

From equation $Q_2(1)=Q_p-Q_1(1)$ ...(8)

Substituting equation(8) in equation(7)

$$C_E=C\,Q_1(1)\,[G_1+Q_1(1)\delta(r_w,1)+\{Q_p-Q_1(1)\}\,\delta(1,1)]$$
$$+C\,\{Q_p-Q_1(1)\}\,[G_2+\{Q_p-Q_1(1)\}\,\delta(r_w,1)+Q_1(1)\delta(1,1)] \qquad \ldots(9)$$

or

$$C_E=C\,[Q_1(1)G_1+Q_1^2(1)\delta(r_w,1)+\{Q_pQ_1(1)-Q_1^2(1)\}\,\delta(1,1)]$$

$$+C\,[\{Q_p-Q_1(1)\}\,G_2+\{Q_p^2-2Q_pQ_1(1)+Q_1^2(1)\}\,\delta(r_w,1)+$$

$$+\{Q_pQ_1(1)-Q_1^2(1)\}\,\delta(1,1)] \qquad \ldots(10)$$

Differentiating C_E with respect to $Q_1(1)$ and equating it to zero

$$G_1+2\,Q_1(1)\delta(r_w,1)+\{Q_p-2Q_1(1)\}\,\delta(1,1)-G_2+\{-2Q_p+2Q_1(1)\}\delta(r_w,1)$$
$$+\{Q_p-2Q_1(1)\}\,\delta(1,1)=0 \qquad \ldots(11)$$

or

$$Q_1(1)=[G_2-G_1+2Q_p\{\delta(r_w,1)-\delta(1,1)\}]/[4\,\{\delta(r_w,1)-\delta(1,1)\}] \qquad \ldots(12)$$

Since the drawdown was expressed explicitly in term of $Q_1(1)$, it was possible to find the optimal solution easily. The other approach would have been a search technique.

The advantages of discrete kernel approach over the other approaches results from the following facts(Morel-Seytoux,1975):

a) A finite difference model is used only to generate basic response functions to specialised excitation (e.g. ,pumping from a single well at a unit rate for the first period of time and no pumping there after) in an aquifer without any stream interaction. Once these basic response functions have been calculated for a particular aquifer and saved, simulation of the aquifer behaviour to any pumping pattern is obtained without ever making use any longer of the (costly) numerical (e.g., finite difference) model.

b) Because the finite difference model is used only to generate the response functions (or influence coefficients) smaller grid sizes and time increments can be used to calculate accurately the influence coefficients than is usually feasible when performing a large number of simulation runs under many varied pumping patterns. Also with this procedure the accuracy of the calculations for an actual simulation remains that with which the influence coefficients were obtained. In typical simulation approaches the accuracy of the finite-difference model is usually tested against an analytical solution using small time and space increments. When the simulator is used on an actual aquifer, vastly different time and space increments are used and the accuracy of the results is to a large degree unknown.

c) Because the response functions are known explicitly in terms of the controllable (decision) variables (e.g. pumping rates at this or that well) many management problems can be solved through the efficient algorithms associated with a well structured Mathematical Programming formulation. With the simulation approach responses (e.g., drawdowns) to a given strategy (e.g. set of pumping rates) are given as numbers in response to numbers. No clue is given from the response numbers of what is likely to be the new response when the excitation numbers are changed. An optimal strategy is obtained by comparison between alternatives and in the trial and error runs, as more runs are made, many alternatives (and more and more so) are generated which are inferior to already generated ones. In the end one is never sure that the strategy is truly the optimal one. When the response are known explicitly , functionally, in terms of the excitation (decision) variables, then interior strategies are never generated in the optimization algorithms and in the end the optimal strategy is attained.

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