Jal Vigyan Sameeksha—a publication of
Indian National Committee on Hydrology
Vol. IV, No. 2, December 1989

Application of P.C. in Ground Water Hydrology

S. K. Sharma

Scientist D, Central Ground Water Board, Ministry of Water Resources, New Delhi

Abstract : *The introduction of personal computers and exponential growth of chip technology has remarkably increased the data processing and computational speed. Personal computer has general advantage of providing accurate computation ability with huge data storage. It plays a vital role in the field of ground water hydrology. This paper deals with the uses of personal computer in solving various ground water problems like, computation of draw-down distribution in aquifers, evaluation of storage coefficient through solution of well equation, simulation of well discharge tests, Ground water models, Geo-inforfation system, hydrological and hydro-chemical maps, ground water data storage and retrieval, calculation of permeability from pumping test data base and analysis, well hydraulics and well construction. Ground Water balance computation and statistical data analysis. The list of the various water science related computer programmes which are available with Central Ground Water Board is also given at the end of the paper.*

Introduction

The introduction of Personal Computers (PC) and the exponential growth of chip technology has remarkably increased the data processing and computation speeds. It has reduced the cost of PC-based systems atleast by 20% every year in last 10 years. In India, things are changing as well. After the introduction of new computer policy in 1986 and later liberalisation schemes of the government, micros and PC are available almost at the international price and of international quality.

Before the advent of PC, earlier systems required more space. The room in which they were housed required temperature and humidity to be controlled, besides being dust free. Only limited persons were allowed to enter. The users had to give information on punch cards or on magnetic tapes to Computer Centre for processing. They used to get the processed output later. Against this PC's occupy less space and can work in normal room environment. Hence PC are becomming popular and are user friendly.

Computerisation and Management of Information, as it is said are the two sides of the same coin. The Management of information is one of the important activities of an organisation which makes it red or blue. Natural Resources are not infinite. It is thus very essential that natural resources are managed properly and no efforts be left unspared so as to maintain their quality.

Ground Water resource assesment like any other natural resource, has got tremendous boost with the application of PC. Traditional methods are giving way to modern technology. Computer is an important invention of science and technology which is now being used in various fields by different institutions/organisations at all levels. It has general advantages of providing accurate computation ability with huge data storage. It plays a vital role in the field of ground water hydrology.

Use of PC in Ground Water Science

The personal computers have very recently become available for use in developing countries. Ground water science involves application of numerical values of naturally occuring systems. The potential capability of PC to handle ground water related problems is described below :—

1. Functions

(i) Well functions

(ii) Bessel functions

(iii) Leaky well functions

(iv) Factorial functions

(v) Error functions

Several above mentioned functions are being used on PC based systems that play fundamental role in Ground Water Science. Further, such functions can be put to use in number of field applications in hydrology as for example in the analysis of Aquifer Tests etc.

2. Computation of Draw-Down Distribution in Aquifers

The draw-down distribution in various types of under mentioned aquifers can be computed through suitably programming Theis and other equations. Such aquifers are :—

(i) Draw-down distribution in nonleaky aquifers

Input : Number of Steps; Drawdown Discharge

Output : Specific Capacity; Well Efficiency; Equation

(ii) Draw-down distribution in Leaky confined aquifers

Input : Aquifer Transmissivity; Aquifer Storativity; Vertical Hydraulic Conductivity; Thickness of aquitard; Coordinates of the well-X-coordinate, Y-coordinate; Rate of flow; Time of Pumping; Coordinates of Observation Pond-X-coordinate, Y-coordinate

Output : Drawdown at any observation point $\{X(\theta), Y(\theta)\}$ due to well effect

3. Evaluation of Storage Coefficient Through Solution of well Equation

In the evaluation of storage coefficient the application of Newton method and solution of Thies equation for storage can now be achieved readily with use of PC which formally was not possible to be done in possible time by pocket calculators etc.

Newton Method

Inputs : Initial guess and given the option of suffixing that guess with a "d" if the calculations be done in double precision.

Output : Solution of the polynomial

Theis Equation

Inputs : Drawdown; Distance from the pumped well to the observation well; Transmissivity; Pumping Rate; Duration of Pumping.

Output : Storage Coefficient

4. Simulation of well Discharge Tests

The discharge test in various types of aquifers including multistage discharge test have now become practical with the use of specially developed Programs of use on PC based computing systems. Such Programs produce behavioural pattern of draw-down likely to occur in ground water system during a stepped rate test.

Inputs : Distance from discharging well to observation well; storage Coefficient;

Transmissivity; Vertical hydraulic conductivity of aquitard; Thickness of aquitard; Discharge rate for the first step; Finishing time of first step; Discharge rate for the second (last) step. Finishing time of the second step; Distance from the discharge well to the boundary; Distance from the piezometer to the boundary.

Output : Time; Drawdown; Pump Discharge.

Ground Water Models

Ground water matrix models such as transient state discharge or recharge models can be developed on PC based system. One can now carry out Aquifers & Ground Water Basin Modelling excercises on PC based systems using suitable optimal Programs. This is now possible specially in shortest periods of time because most aduance PC have math-coprocessor provided with it. Using computers, groundwater models can be prepared on various aspects of groundwater resource evaluation and future prediction for providing a long term projection of the basic behaviour of the aquifer system. The modelling can help in scientific planning of the development of resources. Modelling can be also help to understand the behaviour of complex aquifer system and to solve other ground water problems.

Disiflaq

It is worth emphasizing that the input which is necessary to "build" a reliable model with a considerable detail is generally bulky and that the output is not the final product of a ground water study but rather a highly detailed and processed "data bank" presented in an easy format to enable the user to select any information needed for better understanding of the hydraulic aspects in the actual ground water system.

Inputs : Data on aquifer system geometry, boundary conditions, recharge, extraction and aquifer hydraulic coefficients given at a number of discrete points in plan relative to both aquifers.

Output : Quantitative aspect of ground water flow are determined like flow discharge through any given cross section, velocities and their direction, piezometric head changes through time and all derived answers such as depth to water level, saturated thickness, draw down from a given time and the evolution through time of a detailed water balance.

Matrix Model

Inputs : In Menu 1 are initial Head; Discharge/Recharge; Finished; in Menu 2 are Single Node; Single Column; Single Row; Block; Option to get print out and to go to previous menu; X coordinate of column; Y coordinate of bottom and top and value; Duration of discharge/recharge.

Output : Matrix of Piezometric head.

6. Geo-Information Systems

Computer assisted mapping and geo-information system is new innovation with which it has now become possible to extract information of use from various types of satellites using PC-based System. Development of geo-information provides real time inputs to mathematical modelling. Land and water information systems are now available and are recognised as versatile tool which integrate faster information to vector data and produce digital terrain models to serve as topographic hydrological models in conceptualising mathematical modelling.

7. Hydrogeological and Hydrochemical Maps

The maps like water table contour, depth to water, isochlore etc. can be prepared by using contouring software packages. The data for area of interest can be retrieved from data files and can be directly used for preparation of ground water maps. Computer

Programs are available which can be used in different field of hydrogeology such as for statistical analysis, preparation of well logs and lithological cross sections etc.

Contouring

Input : X; Y; Depth to water; etc.

Output : Contour Map.

Similarly contouring any other parameter of Ground Water and Water quality.

8. Ground Water Data Storage and Retrieval

Till now data collected in respect of ground water (water levels, hydrochemical, litholog, pumping test etc.) are mostly on paper files. It normally becomes difficult to locate and retrieve any particular information for a particular area in the desired formats. PC plays vital role in building data bases for use in ground-water resources.

CGWB has already started computerising the data of National Hydrograph Stations using DBase III DBMS package. The same can be retrieved for any location and for any time period and sent for plotting and for best-fit line analysis using graphics routines.

Input

Structure for database : obswell. dbf
Number of data records : 1019
Data of last update : 11/08/90

Field	Field Name	Type	Width	Dec
1	BOREHOLEND	Character	8	
2	OTHER NO	Character	5	
3	PROVINCE	Character	15	
4	DISTRICT	Character	15	
5	LOCATION	Character	15	
6.	X-COORDIN	Character	9	
7	Y-COORDINE	Character	9	
8	MAP-SHEET	Character	7	
9	SURF-ELEV	Character	7	
10	REFPNTELEV	Character	7	
11	TOTAL DEPTH	Character	6	
12	PUMP	Character	1	
13	WELLTEST	Character	1	
14	AQUIFERSYS	Character	10	
15	REM	Charactdr	10	
16	REGION	Character	2	
17	AREA	Character	20	
18	BASIN	Character	15	
19	SUBBASIN	Character	15	
20	GEOLOGY	Character	10	
21	M-P-	Character	12	
22	DIA	Character	6	
23	USE	Character	8	
24	BESTFIT	Character	18	
25	FLUCT	Character	8	
26	PERIOD	Character	7	
** Total **			247	

Structure for database ; grndwl. dbf
Number of data records : 3097
Date of last update : 04/09/91

Field	Field Name	Type	Width	Dec
1	BOREHOLENO	Character	8	
2	DAT	Character	8	
3	DEPTH	Character	6	
4	MONTH	Numeric	5	
5	GWDEPTH	Numeric	6	
6	PROVINCE	Character	15	
7	DISTRICT	Character	15	
8	LOCATION	Character	15	
** Total **			79	

Output : The data stored in the files namely obswelldbf and grndwldbf can be used to generate the required output.

9. Calculations of Permeability (K) from Grain Sizes

Computations of Permeability from grain-size and porosity data analysis takes now few moments with use of PC applying, specially programmed Hazen, Creager. Slichter, Zamarin, Kozeny and Terzaghi empirical formulae. All such formulae accept effective diameter (d 10) & water temperature as basic inputs for determining Hydraulic Conductivity of aquifers.

Input : d10; Water Temperature; Empiric Coeff.

Output : K

10. Computation of Permeability (K) from Pumping Test Data

Programmed Theim's formula determines hydraulic conductivity of confined aquifers. The information provided to computer includes pumping rate (m3/day) and distance is observation wells and head in metres. This accordingly produces value of K in metres / day instantaneously.

Input : Pumping rate; Obs. well no. 1; Obs. well no. 2;

Output ; K

11. Ground Water Chemistry Data Bases

With the use of data on ground water chemistry (cations, anions, trace elements) it is now possible to produce tables, cross-tables and diagrams for interpretations and analysis, Diagrams like Stiff-diagram, Piper and Wilcox diagrams are uses in few minutes on Computer which provide user friendly interaction.

Input

Structure for database : chemical . dbf
Number of data records : 1653
Data of last update : 07/91/89

Field	Field Name	Type	Width	Dec
1	PROVINCE	Character	15	
2	DISTRICT	Character	15	
3	LOCATION	Character	15	
4	WELLANO	Character	5	
5	DAT	Character	8	
6	PH	Numeric	5	2
7	SPCONDUCT	Numeric	5	
8	TDS	Numeric	5	2
9	CARBONATE	Numeric	6	1
10	BICARBON	Numeric	7	1
11	CLORIDE	Numeric	7	1
12	SULPHATE	Numeric	7	1
13	NITRATE	Numeric	6	1
14	FLORIDE	Numeric	5	2
15	PHOSPHATE	Numeric	5	2
16	CALCIUM	Numeric	7	1
17	MAGNESIUM	Numeric	7	1
18	SODIUM	Numeric	7	1
19	POTASSIUM	Numeric	6	1
20	IRON	Numeric	5	2
21	SILICA	Numeric	5	1
22	TOTAL HARD	Numeric	7	1
** TOTAL **			164	

Output : The data stored in the fiie namely chemical. dbf can be used to generate the required output.

12. Pumping Test Data Base and Analysis

Field data collected from an aquifer test carried out on a well can now be computed to obtain aquifer parameters using specially designed Programs.

Step-drawdown. Radius / depression test and all other kinds of Aquifer Analysis Tests can be performed on PC's to produce graphs, tables etc., for generating reports for Confined and Unconfined Aquifers, Programs for solving equations developed by Theis, Hantush Jacob using drawdown and recovery data are available on PC's to make instant analysis and interpretations.

Input : Time; Drawdown

Output :

Theis Method : Transmissivity; Standard Deviation; Number of Points; Iteration Number.

Jacob Method : Transmissivity, Standard Deviatlon; A0; A1; Number of Points.

Hantush Inflection Method : Transmissivity; Storage; Coefficient; Standard Deviation; Leakance; Number of Points;

13. Well Hydraulics and well Construction

Well Construction Programs on Computer help to select proper casing diameter, proper screen length which evaluate screen entrance velocity. By providing pumping rate, the casing diameter can be found.

Well Casing Diameter

Input : Pumping Rate

Output : Optimum Casing Diameter

Screen Diameter

Input : Screen Diameter; Screen Length; Open Area;

Output : Open Screen Area

14. Statistical Data Analysis

Specially developed statistical packages are now available for developing regression models and carrying out Time Series analysis of physically correlatable data sets with a view to making forecasts and predictions of ground-water variables using PC based Systems.

Input : Dependent variable (Water Level of one month); Independent Variable (Water Level of Second Month) ;

Output : Parameter : Intercept, Slope; Estimate : Intercept, Slope; Standard Error : Intercept, Slopo; T velue : Intercept Slope; Prob. Level : Intercept, Slope; Analysis of Variance - Source : Model - Sum of Squares; Df; Mean Squares; F-Ratio; Prob. Level; Prob. Level : Intercept, Slope; Analysis of Variance - Source : Model - Sum of Squares; Df; Mean Square; F-Ratio; Prob. Level Analysis of Variance - Source : Error - Sum of Squares; Df; Mean Square; F-Ratio; Prob. Level :

15. Ground Water Balance Computations

Simple to complex ground water balance equations can be programmed for making estimates of ground water recharge based on inflow, outflow, specific yield, changes in groundwater levels, return irrigation and pump-age. Additionally, assessment of groundwater component of stream flow can also be com-puted using recession equations.

Ground Water Balance Assessment System based on water table fluctuation method and the norms recommended by the Ground Water Estimation Committee :

Input : Master Data : This is fixed type of Data for the block and generally does not vary frequently over the years; Variable Data : This data base contains such data for the block which changes on year to year basis; Canals Data : This data base contains information about canals passing through the block (if any); Rivers Data : This data base contains informa-tion about the influent rivers passing through the block (if any); Crop data : This data base contains requisite information about the mon-soon and non monsoon crops grown in the block during the year.

Output : Following reports and tables are generated :

1. Table showing recharge due to see-page from lined/unless canals.
2. Table showing return seepage from surface water irrigation.
3. Table showing contribution from influent river seepage.
4. Table showing potential recharge
5. Detailed report on ground water balance study for the block.

In addition to the above generated reports, the system also generates as extract which gives the complete details pertaining to the selected block which comprises of the follow-ing information :

1. Monsoon Recharge.
2. Recharge due to seepage from canals.
3. Return seepage from surface water irrigation.
4. Seepage from tanks/lakes/ponds.
5. Seepage from percolation tanks.
6. Contribution from influent seepage.

7. Normalisation of Monsoon rainfall recharge
8. Non monsoon rainfall recharge
9. Total annual recharge
10. Potential ground water resource
11. Check of monsoon rainfall recharge by Water Table Fluctuation Method.
12. Total Ground Water Resources
13. Annual utilisable Ground Water Resources for irrigation
14. Gross annual ground water draft
15. Net annual ground water draft
16. Ground Water Balance
17. Categorisation of Block/Taluk based on the level of Ground Water development.

List of Programs Available in C.G.W.B.

1. Drawdown Distribution in non-leaky aquifers.
2. Drawdown distribution in leaky confined aquifers.
3. Digital Simulation of Flow through Two-Layered Aquifer Systems.
4. Two dimensional (Matrix) Ground Water Model.
5. SURFER for Contouring of Values.
6. WATER – Ground Water and Chemica Quality Data Storage and Retrieval System.
7. Groundwater Balance Assessment System.

References :

1. S.K. Sharma; Step drawdown test analysis by Computer; Bhujal News, Vol. 4, No. 2, April–June. 1989.
2. B.P. C. Sinha and S.K. Sharma; Trasient State Ground Water Head Model for Confined Aquifer; Bhujal News, Vol. 5, No. 4, October-December, 1990.
3. David Clarke; Developments in Water Science Microcomputer Programs for Ground Water Studies.
4. S.K. Sharma, Computation Drawdown distribution in non-leaky aquifers using Micro Computers; Bhujal News, Vol. 2. No. 1, January – March, 1987.