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A decision support system for flood flow analysis in complex watersheds

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Abstract The basic concepts of a Decision Support System are described. The ABC5win model is presented for flood flow analysis in complex watersheds. The model analyses flood hydrographs obtained by conventional synthetic methods and allows for the analysis of multiple solutions for flood control, including channel and reservoir routing. A user-friendly graphic interface for Windows has been developed for the input of watershed data and rainfall characteristics and for the model output. The ABC5win System may be utilized for teaching purposes and as a tool for professional studies or projects.

Un sistema de apoyo a las decisiones para el análisis de flujo de crecidas en cuencas complejas

Resumen Se describen los conceptos básicos de un Sistema de Apoyo a las Decisiones. Se presenta el modelo ABC5win para el análisis de flujo de crecidas en cuencas complejas. El modelo analiza hidrogramas de credidas obtenidos por métodos sintéticos convencíonales, y permite el análisis de soluciones múltiples en control de crecidas, incluyendo routing de canales y de represas. Se desarrolló una interfase gráfica compatible con Windows para el ingreso de datos de las cuencas y caracteristicas de la precipitación, así como para las salidas del modelo. El Sistema ABC5win puede ser utilizado para fines didácticos y como herremienta en estudios o proyectos profesionales.

INTRODUCTION

The ABC5win Decision Support System was originally developed for teaching purposes. However, under its present stage of development it is utilized professionally, due to the ease of using the graphic interface. As a basic idea, the use of synthetic methods for the determination of maximum flows in small basins has been adopted where availability of data is a constraint (typically urban and small rural basins). Throughout its evolution, the system started within the DOS environment (ABC3), moving ahead through the Windows environment (ABCD4), arriving at the present more friendly stage, provided by use of the graphic interface (ABC5win).

THE DECISION SUPPORT SYSTEM

The last two decades have witnessed the birth and development of a methodology to support the decision making process, which has been intensively based on the utilization of databases and mathematical models, as well as on the ease of dialogue provided by the interface between users and computers. This methodology, generically known as the Decision Support System (DSS), has been applied with success to many fields of human activity whenever making a decision is very complex, such as the management and planning of water resources systems.

Decision Support Systems consist of software developed to help decision-makers to solve nonstructured, or partially structured problems. Non-structured problems are those not able to be solved through well-established algorithms, which make them incapable of being easily handled by computers. Consequently, their solution requires a close interaction between man and machine, which happens to be one of the main characteristics of the DSS.

The concept of support (aid or help) is fundamental for understanding the usefulness and operational capacity of a DSS. A Decision Support System should be made available to users in order to support the assessment of information, to formulate and identify problems, to create and analyse alternatives and, finally, to provide support for the choice of the best line of action. A DSS is not aimed at making decisions by itself, but at supporting the process of making decisions.

Decision Support Systems are usually structured in four modules as follows:

(a) The models database is generally made of mathematical models reproducing the behaviour of the real system, allowing for the analysis of alternative scenarios (simulation models), and helping the user to find optimal dimensions or policies (optimization models).

(b) The database, in addition to containing significant information about the system under consideration, must allow for the correlation between data and for quick and effective data retrieval. This module must also feed the models database with the necessary data.

(c) The knowledge database allows for the incorporation into the system of some kind of information, which is generally not able to be treated by the previous modules, but that is essential for making decisions with regard to the system under consideration. Typically, this information is related to the experience of experts, empirical knowledge, standards and codes of practice, etc. Usually, this database is formed by rules of the type *If... Then...*, which, put together, represent an important share of knowledge about the system. Manipulated by an inference mechanism, these rules can lead to logical conclusions and to increased knowledge about the system. These are called "expert systems".

(d) The dialogue module consists of interfaces that facilitate communication between the user and the computer, to provide data, propose problems, formulate scenarios and analyse results. The evolution of microcomputers and the advent of object programming languages, have brought about a real revolution in this field. Nowadays the dialogue with the user can be simple, intuitive and has plenty of communication resources (such as graphics, photographs, animation, sound, virtual reality, etc). This module is invaluable since it allows for the participation of novices in the evaluation process and decision making.

Today's available technology in these fields allows for the development of powerful Decision Support Systems, making use of no more than models and applicative programs already available in the market, most of them under public dominion or available at low cost. This condition reduces substantially the necessity for additional work to develop new models, allowing for the concentration of effort in the integration of the modules, in the acquisition of information and knowledge about the systems, and particularly in the relationship of the DSS with the decision maker and, in a broad sense, with society as a whole.

Experience has also shown that Decision Support Systems are efficient tools to support the so-called Groups of Decision Makers. Within these groups, the members' natural conflicts of interest, points of view, ideologies and background make it difficult (or even impossible) to choose of the best line of action. The central idea in this case is to warrant each member the right to evaluate the response of his/her own ideas with the help of generally accepted models, starting from a common basis of information. This approach leads to the development of integrated and generally accepted solutions which tend to be supported and committed to by the group. Examples of success in this domain are many, including in Brazil and South America where these techniques are still inceptive.

THE ABC5win MODEL

This computational system for hydrologic analysis of flood flows was developed following the layout of a Decision Support System and is able to perform the following functions:

(a) Interfaces of graphic inputs and outputs, allowing for the analysis of various interconnected hydrographic basins, through the creation of a schematic topology on screen.
(b) Evaluation of design storms (spatial and temporal distribution of precipitation) for the return periods chosen by the user.
(c) Calculation of flood hydrographs starting from the design storm as a function of the physical characteristics of the hydrographic basin.
(d) Routing of hydrograph waves throughout the basin (through natural and artificial reservoirs and channels).
(e) Formulation of alternatives and scenario analysis by the user.

SYSTEM REVIEW AND DIALOGUE WITH THE USER

The ABC5win System was developed in Visual Basic language for Windows in an effort to facilitate handling and to make possible a high level of interaction with the user. Most of the hydrologic routines were adapted from the ABC4 program and are organized in modules.

The dialogue is made through a sequence of modules, with the user being responsible for the solution of problems and the study of alternatives:

Topology module

This module allows for the input of data related to the structure of the system under analysis (connection of the various components of the system). It utilizes a framework in the form of a network flow made of nodes and arcs defined as follows:

- nodes: representing starting and end points and junctions of basins or reservoirs; when a node represents a reservoir, it contains full information characterizing this reservoir (spillway crest level, reservoir bottom level, width of spillway, curves of levels × flows and levels × volumes, etc.);
- arcs: representing hydrographic basins and stretches of natural and artificial channels; for hydrographic basins, each arc contains the information characterizing the basin and one transformation function responsible for the production of an output (flow) associated to an input (rain); for channels, the transformation function is the attenuation of the input hydrograph along the reach, while the output is the attenuated hydrograph at its end.

Interval module

This module allows the user to introduce the time interval for computational purposes.

Model module

Within this module it is possible to choose among four recognized models for calculation of rainfall excess: Horton formula, Green and Ampt formula, Soil Conservation Service method and Fi Index method (SCS, 1971; Morel-Seytoux, 1981). It is also possible to decide which hydrograph model to use for determination of the flood hydrograph, according to the user's preference and the peculiarities of the problem under analysis: Sta Barbara, Clark method and the SCS triangular hydrograph (Ponce, 1989; Wanielista & Yousef, 1993).

Data module

This module accommodates information related to the hydrographic basin, such as the drainage area, format, slopes, soil use, infiltration characteristics and other data needed to determine the flood hydrograph, starting from the design storm. The data corresponding to the sub-basin under analysis are shown above the "Basin–Data Input" screen. Also shown are the calculation models for the exceeding rain and for sketching the hydrograph.

The data module allows for the determination of the design storm, starting from the precipitation, directly provided by the user or by means of the intensity–duration–frequency relationships. (Ing. Otto Pfafstetter equations, general equations and lnln equations). For this purpose the ABC5win model includes a database (presently with 117 equations) allowing not only for the assessment of IDF relationships, already published, but also for the introduction of others of interest to users. This module also contains routines for spatial and temporal distribution of rain.

Still in association with the data module, the ABC5win model allows the configuration of the storm wave propagation through the watershed, along the stretches of channels. At this stage it is possible to introduce the channel length and the attenuation coefficient. The system generates three parameters (C0, C1 and C2) which are utilized for the attenuation of the flood hydrograph throughout the channel (it utilizes the Muskingum hydrologic method for the attenuation calculation).

Finally, within the data module, the ABC5win System allows for the configuration of peak attenuation reservoirs.

Output module

In this module it is enough to click any point within the node of interest to retrieve the corresponding results. Results of the total precipitation, rainfall excess and hydrographs are shown in tabular and graphical form.

Every hydrograph is saved into a sub-directory, which allows the user to analyse the hydrograph related to different scenarios.

APPLICATION EXAMPLE

One of the many applications of the ABC5win System is to support the elaboration of zoning laws. If a city is crossed by a river, it is possible to develop a study of the maximum flow as a function of the impervious area within the watershed. By utilizing the ABC5win System for a high intensity rain lasting for 6 h and with a return period of 50 years, the maximum flow can be derived according to the variation of the impervious area of the basin, as illustrated in Figs 1–3.

This example illustrates one of the many possible applications of the ABC5win System. It is important to stress that, since the example depicted is a simplified one, the concentration time has not been changed while changing the impervious area.

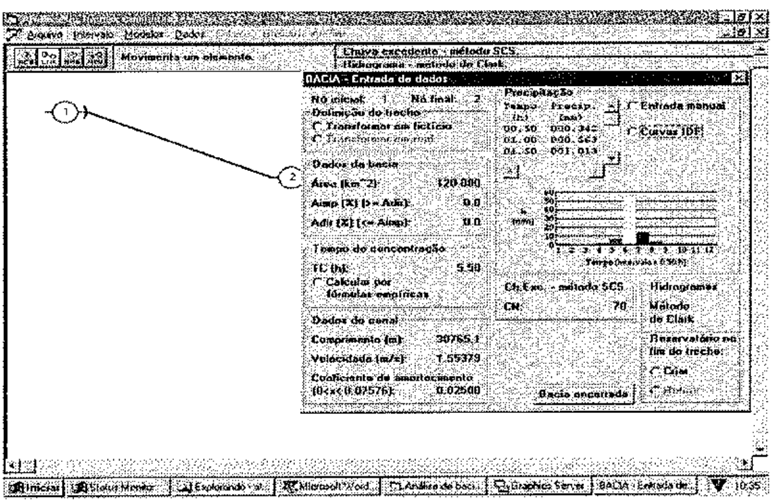

Fig. 1 Schematic representation and screen with data input.

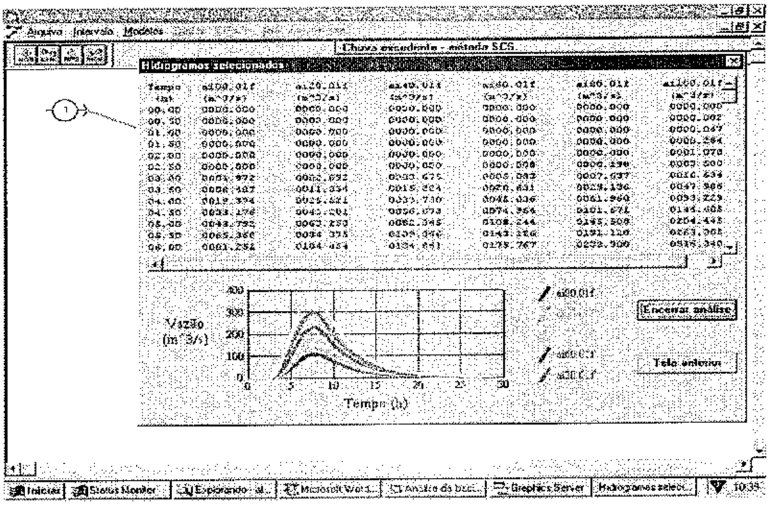

Fig. 2 Final analysis of the situation under consideration showing several hydrographs corresponding to different levels of imperviousness.

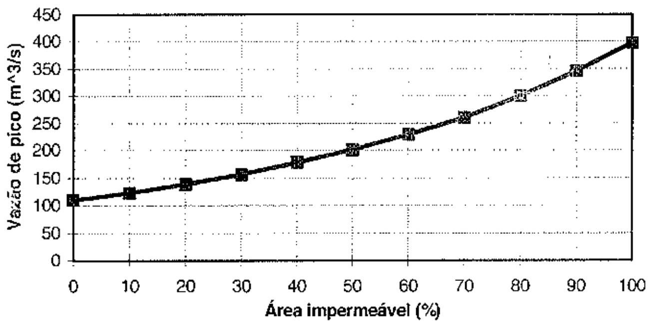

Fig. 3 Variation of the peak flow as a function of the impervious area of a basin.

NECESSARY RESOURCES

The system is relatively compact needing about 3.5 Mb of free space on the hard disk. It can be installed on computers with Windows 3.x or Windows 95 operation systems, and in any of the partitions of the hard disk (C:, D:, etc.). The complete structure of directories and sub-directories necessary for program operation is generated on installation.

CONCLUSION

The ABCwin5 System for flood flow analysis in complex watersheds allows for the study of several scenarios, providing significant support for decision making. The graphic interface developed is user-friendly and can be operated with relative ease. This system can be obtained in shareware version and, in spite of being designed for teaching purposes, provides ground for professional applications.

As a developmental step, future versions should include other algorithms for calculation of infiltration and generation of hydrographs. In addition, integration of the system with geographical information systems is already being implemented.

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