MODELLING OF NONLINEAR BEHAVIOUR OF DRAINAGE BASINS

BY

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C E R T I F I C A T E

This is to certify that the thesis entitled "MODELLING OF NONLINEAR BEHAVIOUR OF DRAINAGE BASINS", which is being submitted by RAO P. RAMAKRISHNA to the Indian Institute of Technology Delhi for the award of degree of Doctor of Philosophy, is a bonafide research work carried out by him under our guidance and supervision. His thesis has reached the standard, fulfilling the requirements of the regulations relating to the degree.

The results contained in this thesis have not been submitted in part or in full to any other University or Institution for the award of any degree or diploma.

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V I T A

RAO P. RAMAKRISHNA was born at Kakinada, Andhra Pradesh, India on February 15, 1935. He completed his High School Education in 1950 from the Pittapur Rajah's Collegiate High School, Kakinada. He joined the Pittapur Rajah's College, Kakinada and passed the Intermediate Examination in Science of the Andhra University in the First Class with distinction in Mathematics, Physics and Chemistry in 1952. On the basis of merit, he was admitted to the Government College of Engineering, Kakinada in 1952. He qualified for the degree of Bachelor of Engineering (Civil) of the Andhra University with a First Class in 1956.

He worked for the Government of Andhra Pradesh from May 1956 to November 1956 as Junior Engineer in the Tungabhadra Hydro-electric Scheme. He then joined the Central Water and Power Commission of the Union Government as Design and Engineering Assistant at New Delhi. On selection through the Union Public Service Commission, he was promoted to the post of Extra Assistant Director in January 1959. He was awarded the Nederlands Govt. Fellowship which enabled him to attend the Technological University at Delft from October 1961 to September 1962. During his stay in Nederlands, he

studied Reclamation Engineering under Professor Volker and obtained the Post-Graduate Diploma in Hydraulic Engineering with additional endorsement for special studies in Ground Water Recovery. On his return to India, he was elevated to the post of Assistant Director and was engaged on Designs and Research pertaining to many Major Irrigation and Power Projects.

He was deputed to the Department of multipurpose Projects and Power, Government of Himachal Pradesh, Simla, from September 1967 to April 1969 to assist in the establishment of a Design and Planning Cell. On his return to the Central Water and Power Commission in April 1969, he was posted as Deputy Director (Instrumentation) and he held this post till February 1970. During this period, he brought out a research report entitled "Prediction of Creep Characteristics of Rubble Concrete of Koyna Dam". From February 1970, he has been conducting hydrological research as Deputy Director (Flood Estimation). A research report entitled "Estimation of Design Flood Peak for Design of Bridges" prepared by him has been recommended for the use of field engineers as a Standard Code of Practice.

After a three months training, from May to August 1971, at Computer Centre, Department of Statistics,

Government of India, he qualified for the Certificate of Proficiency in Computer Technology. He set up a library of software for processing of hydro-meteorological data and for simulation of hydrologic systems. He guided a thesis entitled "Study of the Generation of Streamflow Sequences" by S.L. Pahuja submitted to Roorkee University in October 1974 for the degree of Master of Engineering.

He was Secretary to the Committee of Experts on "Utilisation and Development of the Ravi and the Beas Waters" from April 1970 to February 1971. He was Member-Convener for two Sub-Committees of the National Committee of Science and Technology to formulate R and D Plans for Water Resources Sector and two reports covering the following aspects were submitted in February 1973:

(i) Computerisation, Mathematical Modelling and Simulation

(ii) Evapo-transpiration, Runoff, Recharge and Floods.

The Central Water and Power Commission permitted him to undertake the present investigation in addition to his official duties. Since March 1970, he has been working on his Doctoral Thesis under the supervision of Dr. S. Chander, Professor, Civil Engineering Department, Indian Institute of Technology, Delhi and Mr. Y.K. Murthy, Chairman, Central Water and Power Commission and Ex-officio Secretary to the Government of India, New Delhi.

S Y N O P S I S

This study is devoted to the Simulation of Surface Runoff Systems with a view to organize the research results systematically for practical applications.

The runoff dynamics of the drainage basins is briefly reviewed and a model of complex network of non-linear reservoirs with appropriate areas and storage-discharge relationships is found to preserve the essential information of the prototype. An equivalent model, parsimonious in number of parameters, is evolved for achieving computational efficiency and for facilitating its use in the solution of engineering problems. Theoretical studies on the performance of the model are made and then the model is tested with natural catchment data. The model is capable of representing both lumped as well as distributed systems.

The properties of the network model, which would help in the representation of drainage basins with such network models, are presented. It has been found that the dimensionless instantaneous unit hydrograph is unique for a given non-linear network model. The relationship between the response of the non-linear network model and that of a single non-linear reservoir, both having same area and recession parameters,

has been worked out; this relationship helps in predicting, for any input, the values of lag, peak and weighted mean discharge of network model representing the catchment, through the single reservoir model.

The sensitivity of the network model to the different empirical/subjective techniques of baseflow separation and rainfall excess evaluation is examined and the significance of the results for practical application is evaluated. It is observed that, if the baseflow separation is effected by a horizontal line, the maximum error is involved only in the rising limb of the outflow hydrograph, whereas the peak and the recession part are not significantly affected. The shape of the input hyetograph is found to have no significant effect on the outflow hydrograph under certain conditions and the ϕ-index method can be adopted in such cases to evaluate the time-distribution of rainfall excess. These conditions have been identified.

To extend the applicability of the principle of superposition to the non-linear reservoirs, a new method based on the concept of linearised input has been introduced. The process of transformation of input into output by non-linear reservoirs can be decomposed, according to this concept, into two elements with memory, a non-linear lag-one element and a linear time-lag element. The method is shown to be simpler than, but as accurate as, the method of numerical integration of the differen-

tial equation of the system and hence, can be adopted for day-to-day design practice where accessibility to sophisticated electronic computers is extremely limited.

The relationship between the parameters of a network of linear reservoirs to those of a network of non-linear reservoirs, both networks having practically the same response when fed with the same input, is investigated. This relationship enables the application of the theory of linear systems in the analysis of non-linear systems.

The concepts developed in the study are tested with observed hydrologic data of a few catchments. General conclusions are summarised and the scope for further work is indicated.

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