史丹福模式應用於愛達荷州集水區之評估

An Evaluation and Application of A Watershed Model to An Idaho Watershed

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中 文 摘 要

集水區模式在水利工程研究與應用上甚廣，本文則為應用肯他基州集水區模式（史丹福集水區模式語法）於愛達荷州集水區。

由於愛達荷大學中 IBM 360/40 電子計算機儲存能量之限制，模式中小部份語言程式經筆者予以修改後，應用於面積 317 平方哩位於愛達荷州北部 Palouse 河流集水區，模擬該河流 1967–68 及 1969–70 水文年之年流量分別為 7.34 吋及 13.59 吋，與記錄之年流量 5.68 吋及 12.05 吋相較，有偏高之趨勢，但它低估了早期洪峯及春季退水流量，就一般而言，該模式之應用，尚未顯示有嚴重矛盾現象之發生，故認為可予採用。

ABSTRACT

Watershed models have many engineering applications in the areas of both research and project planning and management. In this study, the Kentucky Watershed Model, a FORTRAN version of the Stanford Watershed Model, was adapted for use in Idaho.

Due to limited storage capacity of the IBM 360/40 computer at the University of Idaho, minor changes and modifications of the program were made. The model application and evaluation was made to the Palouse River near Potlatch, a 317 sq.mi. watershed in northern Idaho. Daily streamflows were synthesized and plotted against recorded flows for the 1967–1968 and 1969–1970 water years. The synthesized annual water yield was found to be 7.34 and 13.59 inches respectively versus recorded values of 5.68 and 12.05 inches. A tendency to underestimate peaks early in the runoff season and to underestimate the spring recession was also observed. It was concluded that the application of the model to Idaho watershed conditions seemed feasible.

INTRODUCTION

The hydrologic regimes of streams and rivers provide the fundamental information used for the design, planning and operation of hydraulic projects and for watershed management. Thus a thorough understanding of the hydrologic cycle and the water budget is a necessary condition for optimal utilization of the water resource on earth. To better perform this task, simulation techniques have been brought into this field recently utilizing the high speed electronic digital or analog computer. Through computer simulation, an indirect investigation of the response and behavior of the interrelationships among the hydrologic components can be attained.

Simulation has been defined as the development and application of mathematical models to represent the timev-ariant interaction of physical processes (Simulation network Newsletter, 1970). Under this concept, watershed model is developed to describe the behavior of hydrologic system and used as a simulation tool. A digital watershed model can be viewed as a collection of quantitative hydrologic concepts with mathematical representation in the form of a digital computer program. Such comceptual mathematical model is usually designed to simulate streamflows over a preselected period of time with climatological data and physical characteristics of the study watershed as inputs.

Crawford and Linsley (1962, 1966) made a pioneering effort to make watershed modeling practical for general use through their development of the Stanford Watershed Model at Stanford University begining in 1959. They represented each hydrologic process by an equation or series of equations containing parameters which vary in value for different watersheds and whose specific values are read in as input data. It has been through four stages of development until Stanford Watershed Model IV was released in 1964. It is presently known the most comprehensive and the most generally applicable model in use.

One of the major difficulties of using the Stanford Watershed Model is the programming language. The original program was written in the SUBALGOL language used by the Stanford Computer Center. Douglas L. James of the University of Kentucky has translated and modified the model into FORTRAN IV language and is known as the Kentucky Watershed Model. It is the latest version (dated June 6, 1970) of the Kentucky Watershed Model that this study was based upon.

STUDY OBJECTIVES

The objectives of this study were:

(1) To adapt the Kentucky Watershed Model for use on the computer system available at the University of Idaho.

(2) To apply the model to an Idaho watershed and evaluate the effectiveness of the model in simulating the streamflow under the Idaho conditions.

THE WATERSHED MODEL

The Kentucky Watershed Model employed by this study is composed of one master program (MAIN) and seven subroutine programs. The schematic diagram of the operation of the hydrologic cycle in the model is shown in figure 1. Each box represents a hydrologic component or a classification of moisture storage. The arrows represent processes whereby moisture moves from one type of storage to another (James, 1972).

Precipitation and potential evaportranspiration are the major data inputs. Additional data are needed if snowfall is included in the model. Precipitation is first subjected

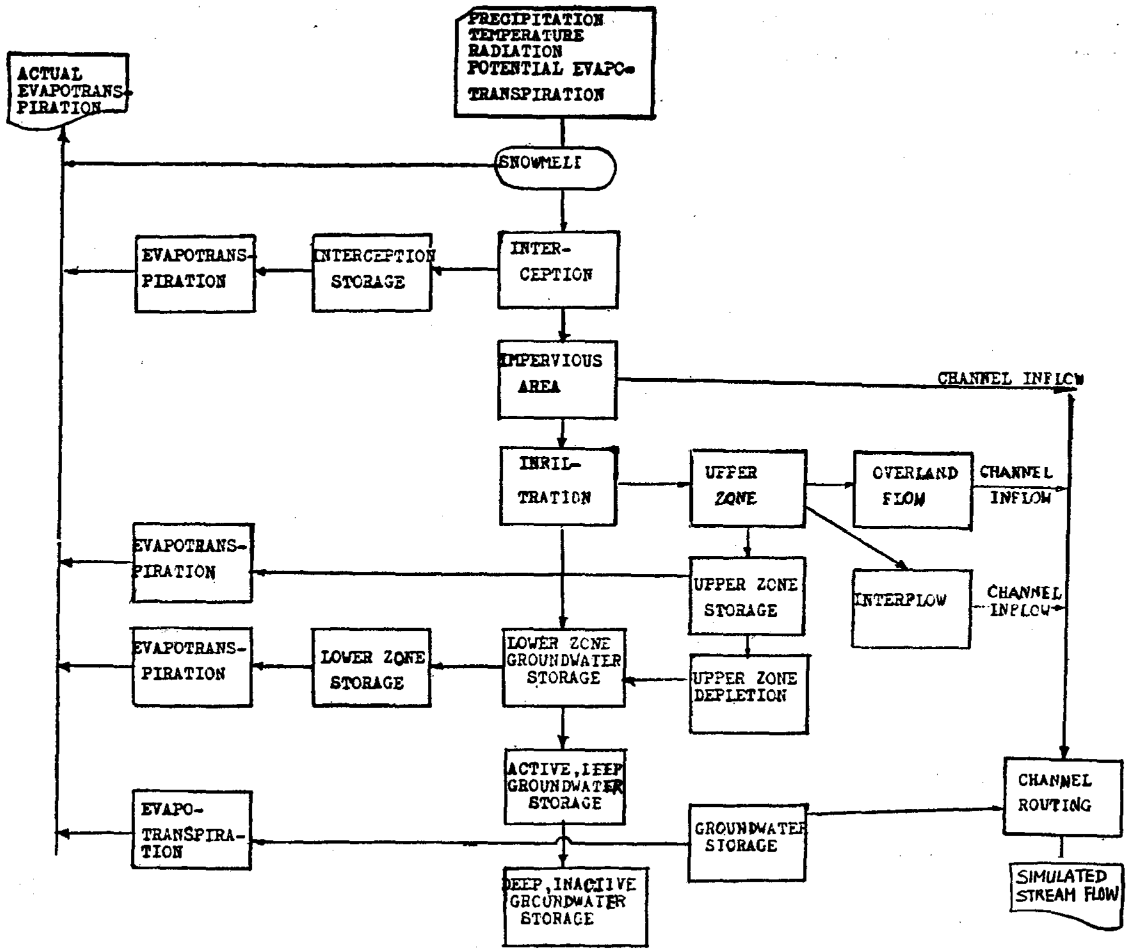

Fig. 1. Schematic diagram of the operation of Stanford Watershed Model

to interception, then is stored in the snowpack and in three soil moisture storages–upper zone storage, lower zone storage and groundwater storage. Precipitation falling on impervious areas contributes directly to the channel inflow. The upper zone and lower zone storage control the overland flow, interflow, infiltration and percolation to the ground water storage. Evaporation and transpiration may occur from all of these storages and remove water from the watershed. The basic moisture accounting is operated on fifteen minutes and one hour periods. The total channel inflow from impervious areas, overland flow, interflow and groundwater flow is then routed hourly to the watershed outlet by the time-area routing method. The result is hourly and daily streamflow data.

In order to make this model operational on the IBM 360/40 computer available at the Univessity of Idaho, some changes and modifications of the program were made. The primary effect of the modifications was reduction in the computer storage requirement and the program execution time. Some minor inprvements which appeared to be beneficial were also incorporated into the program. This modified version of the Kentucky Watershed Model consists of one MAIN program and five subroutines.

The input data required for a computer run may be grouped into the following:

(1) Data used to title the watershed, to identify the computer run, to specify the desired program options and to request specific output.

(2) Time-area histogram data.

(3) Data to describe climatological events during the water year.

(4) Data to initialize watershed moisture storage starting October 1 of the first water year being synthesized.

(5) Values for watershed parameters either measured or estimated.

(6) Daily recorded streamflow data for the purpose of correlating the recordrd and synthesized flows.

APPLICATION TO A WATERSHED

The Palouse River near Potlatch watershed (Figure 2) located in northern Idaho was selected to test the model. This 317 sq.mi. watershed receives its principal moisture from the Pacific Ocean and has average annual precipitation of 25 inches. Snowfall is the major form of precipitation during the winter month. The climate of this region is temperate with average annual temperature of 45°F. The higher elevations of the watershed are forest covered while cropland with interspersed timber is the major land use in lower elevations. Land slopes are moderate to steep and has mean channel slope of 0.5%. Bedrock strata in the basin are of the Precambrian Belt Supergroup: these are principally older rocks consisting of argillites, silty argillites and some quaitzites. Silt loam which has fairly good drainage characteristics is the dominant soil type throughout the area. The streamflow was simulated at the point where the stream gage is ls located 2.0 miles west of Potlatch.

The application to the Palouse River logically began with the collection of data. The climatological and streamflow data were collected from the monthly publication of

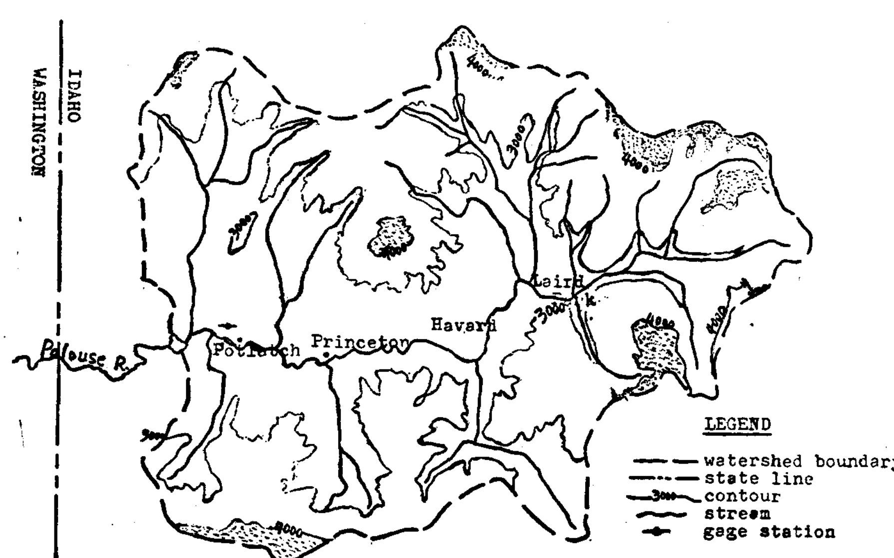

Fig. 2. The Palouse River near Potlatch watershed

the U. S. Department of Commerce and the U. S. Department of Interior respectively Measurable or assignable parameter data were obtained from a topographic map. Other model parameter data were have to be estimated initially from whatever physical and hydrologic data are available or with reference to other similar watersheds. Further adjustments of these parameters are required based on the feedback from trial simulations. Thus numerous simulation runs had to be conducted before a visually acceptable fit of the simulated and recorded hydrographs was obtained. The methodology used in these adjustments was by trial and error. It requires familiarity with the model employed and some understanding of the sensitivity of the parameters under study. This procedure was greatly aided by studying the information provided by James (1970), Ross (1970) and Liou (1970). However, the decision of selecting a final set of parameter values is essentially subjective. Figure 3 shows the set of parameters used in the Kentucky Watershed Model in a schematic diagram presented by Ross (1970). The model was calibrated using data for water year 1969-1970. A verifying run was also conducted for the 1967-68 water year.

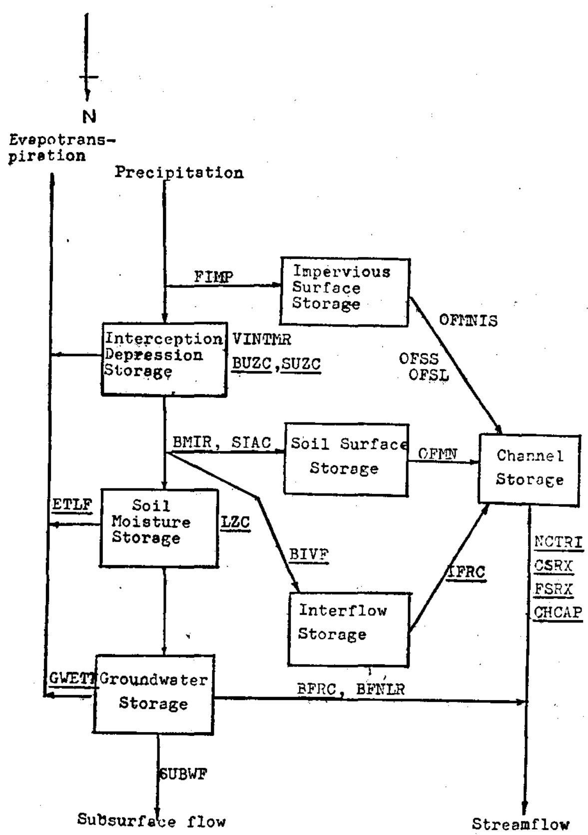

Fig. 3. Schematic diagram of the parameters used in the Kentucky Watershed Model

SIMULATION RESULTS AND DISCUSSION

Figure 4, 5 and Table 1, 2 show the simulation results in graphic and tabulated forms. The linear correlation coefficient (r) between simulated and recorded flows is calculated in the program for each water year and given an objective indication of the response of one value relative to another. The r value obtained is 0.8524 for water year 1969-70 and 0.9184 for water year 1967-68. It is observed that the agreement is considered acceptable for most months, although there were a few discrepancies in some months and peak discharges. In particular, the simulated runoff in the early portion of winter is overestimated while the spring runoff is underestimated. There are exceptions to this in some spring peaks which are overestimated. Additional manipulation of some parameters could lead to some improvement in matching the

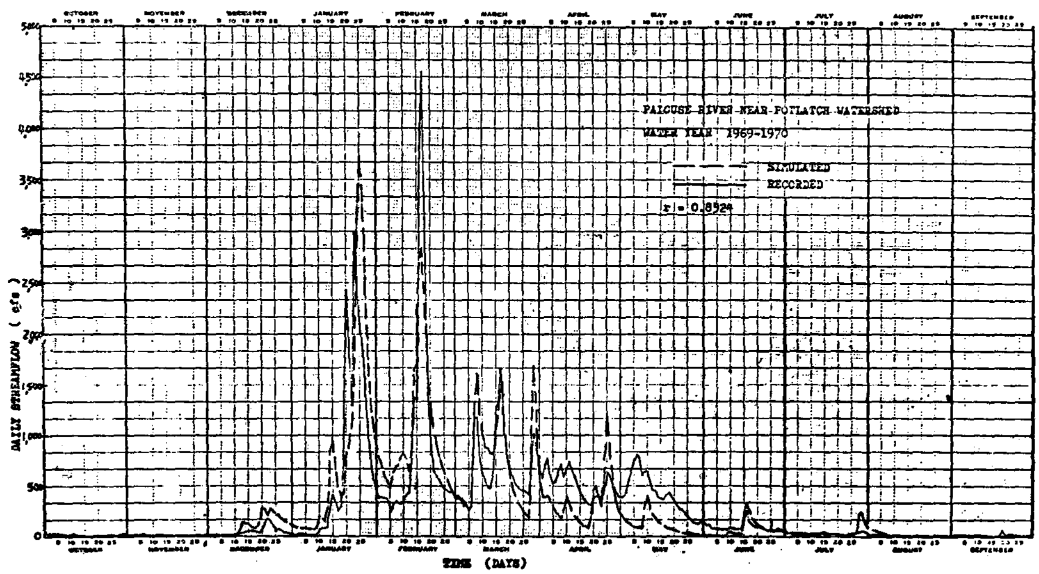

Fig. 4. Daily streamflow hydrograph for water year 1969-1970

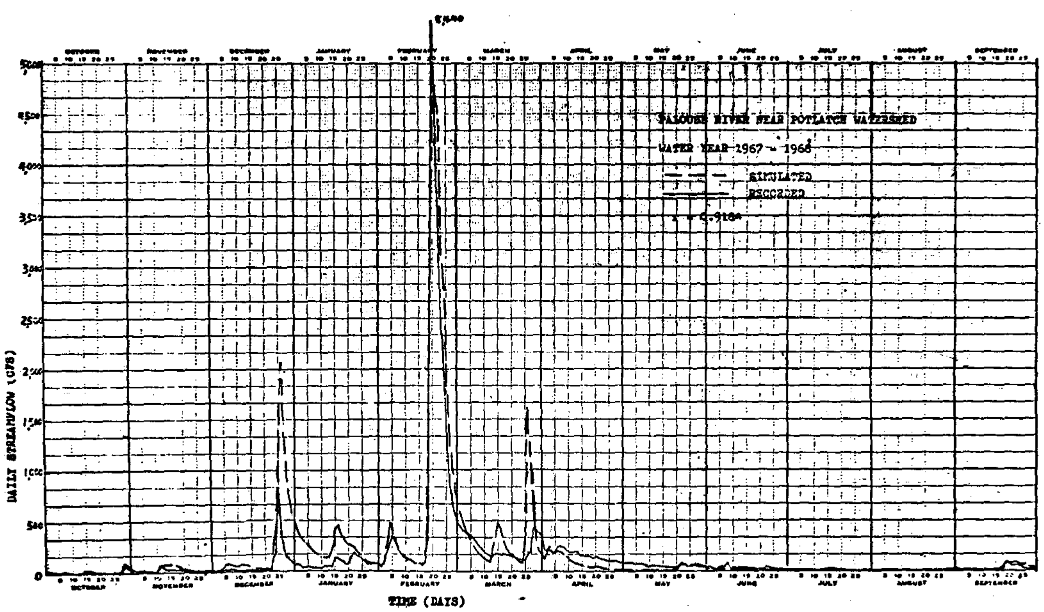

Fig. 5. Daily streamflow hydrograph for water year 1967-1968

flood peaks. An explanation of these discrepancies could be due to large spatial and temporal variation of some storms over the entire watershed. The lack of accuracy of the potential evaportranspiration data and the snowmelt routine might explain the low simulated monthly volumes in spring and summer. The model accuracy also could be affected by the assumption that watershed characteristics are evenly distributed throughout each time-area element. Any exception to this assumption could cause the departures between simulated and recorded streamflows. Heterogeneous watersheds with different climatological and physiographic characteristics could be handled by subdividing the watershed into subdrainages or subwatersheds, and combing the results for each subwatershed to obtain the final hydrograph.

Table 1. Monthly synthesized and recorded streamflows for water year 1969–1970 after precipitation adjustment.

Month	Synthesized (cfs-days)	Recorded (cfs-days)	Difference (%)
Oct.	310.6	387.3	+ 19.8
Nov.	261.1	418.9	+ 37.7
Dec.	3240.0	1335.8	−142.6
Jan.	27756.6	21994.0	− 26.2
Feb.	28659.0	25376.0	− 12.9
Mar.	22946.3	21334.0	− 7.6
Apr.	10372.5	15658.0	+ 33.8
May	3208.4	12154.0	+ 73.6
Jun.	2090.8	2517.0	+ 16.9
Jul.	1149.2	810.0	− 41.9
Aug.	455.8	309.8	− 47.1
Sep.	23.9	388.1	+ 93.8
Total	100473.9	102682.8	+ 2.2

Table 2. Monthly synthesized and recorded streamflows for water year 1967–1968.

Month	Synthesized (cfs-days)	Recorded (cfs-days)	Difference (%)
Oct.	455.0	418.0	− 8.8
Nov.	898.0	513.3	− 75.0
Dec.	8850.9	2409.0	−267.4
Jan.	6672.5	2332.0	−186.1
Feb.	31261.3	27798.0	− 12.5
Mar.	10176.6	6843.0	− 48.7
Apr	2487.6	4659.0	+ 46.6
May	596.8	1662.0	+ 64.1
Jun.	283.0	784.0	+ 63.9
Jul.	48.9	222.1	+ 78.0
Aug.	3.9	161.5	+ 97.6
Sep.	822.0	614.3	− 33.8
Total	62556.6	48417.1	− 29.2

SUMMARY AND CONCLUSION

The Kentucky Watershed Model has been adapted for use on the University of Idaho computer facility. The model application and evaluation was made on the Palouse River near Potlatch in Idaho. During the application, difficulty was encountered in collecting the hourly precipitation data for the watershed i.e. an adjustment had to be applied to recorded hourly precipitation because no data was available in the mountain area, and in obtaining a set of values for the model parameters that could give the best fit of the outflow hydrograph. Considerable understanding of the model is necessary before a proper, practical application can be made to a watershed. Following conclusions are drawn from this study:

(1) The Kentucky Watershed Model can be adapted to operate on the IBM 360/40 computer at the University of Idaho.

(2) The model appears to reproduce the daily hydrograph within the accuracy of basic input data.

(3) The application of the model to Idaho conditions seems feasible.

(4) Consideration should be given on the effect of precipitation variation over the basin. In mountainoue terrain, it may be necessary to divide the watershed into subwatersheds in order to account for this variation.

ACKNOWLEDGEMENT

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