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CATCHMENT MODELING AND INITIAL PARAMETER ESTIMATION FOR THE NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM

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Preface

The enclosed papers were prepared for the International Symposium and Workshop on the Application of Mathematical Models in Hydrology and Water Resources Systems held in Bratislava, Czechoslovakia, on 8-13 September 1975.

The papers are being published in this format because the distribution of the original reports was extremely limited. There is a need for this information to be available to potential users of the catchment model of the National Weather Service River Forecast System. This system comprises a number of hydrologic models which are being incorporated into an operational river forecasting program. The system is being implemented by the Hydrologic Services Division and the Hydrologic Research Laboratory of the Office of Hydrology.

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CATCHMENT MODELING WITH THE UNITED STATES NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM

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ABSTRACT. The system (NWSRFS) of conceptual hydrologic models and other procedures, used in the operational river forecasting program of the United States National Weather Service, is briefly described. Complete information on the system as it existed in 1972 was published. However, since then the operational system has been expanded and revised frequently. Information on new procedures will be published in the technical literature.

A major revision has been made in the soil moisture accounting for the catchment model. The components for soil moisture accounting of the Sacramento Model have replaced those of the modified Stanford Model as used in the original system. The conceptual features and characteristics of the Sacramento Model are discussed. The demonstration in the workshop of this symposium will be limited to the catchment model.

INTRODUCTION

In 1971, the United States National Weather Service decided to develop and publish the National Weather Service River Forecast System (NWSRFS) (NOAA, 1972). This system is a comprehensive collection of the latest hydrologic techniques and includes the basic hydrologic techniques needed by the NWS River Forecast Centers to perform their operational functions. Each technique has been developed and/or evaluated by the Hydrologic Research Laboratory of the National Weather Service. These hydrologic techniques include, but are not necessarily limited to, the following:

1. A catchment model which, through the use of soil moisture accounting formulations and the mathematical modeling of flow through and above the soil mantle and within the channel, convert moisture input (rainfall or snowmelt) to a hydrograph of channel discharge at the outlet of the catchment.
2. A mathematical model of the accumulation and ablation of snow.
3. Channel routing models which model the translation and attenuation of a flood wave as it moves between two points in a channel.
4. Techniques for modeling the areal distribution of precipitation, to be used for computing the moisture input to a catchment on the basis of point values measured at rain gauges.

In addition to the hydrologic techniques, the system includes three other categories of material.

A - Procedures for archiving, retrieving and processing the types of data needed to apply the system.

B - Methods needed to calibrate the various hydrologic techniques, that is, to evaluate the parameters to apply a hydrologic or hydraulic model to a specific location.

C - Computer programs necessary to execute the hydrologic techniques and support procedures described above, in both the development and operational modes.

The system was begun in 1971, along the lines described above and published as NOAA Technical Memorandum NWS HYDRO-14, National Weather Service River Forecast System Forecast Procedures. As originally published, the system included a modification of the Stanford Watershed Model IV, based on the work of Crawford and Linsley (1966).

The nature and concept of the system are such that it may be expected to be constantly changing. New hydrologic techniques become available from time to time and, if they are judged to be superior to those in the system, substitutions are made. Changes and increases in the needs of forecast users may present a need for new hydrologic products and the techniques needed to produce them. Advances in computing equipment and/or changes in the equipment available to the service also require revisions to the computer programs.

NWSRFS MODIFICATIONS

Additional procedures are being included in the NWSRFS to expand the flexibility of the system. A major change has been made in the basic soil moisture accounting. The soil moisture accounting system of the catchment model developed in the NWS Sacramento, California River Forecast Center by Burnash, et al. (1973), is now included in the system. The method employed includes a minor modification of the temporal distribution function from that described in the original Sacramento model.

SOIL MOISTURE MODEL

The soil moisture models that have been used in NWSRFS have been conceptual in design. This resulted from a firm belief that a number of benefits accrue from a strong physical base. Some of these are:

1. The performance of the model in simulating the past is the only available objective measure of the model's ability to predict the future. It is, however, an indirect and imperfect measure. Where accurate simulation of the past has been attained, a high degree of conceptuality enhances the probability of adequately predicting future events. This is especially true in the case of extreme events involving values of variables not experienced in historical data, or, experienced values of the variables but in unexperienced combinations.

2. Models of this type are necessarily complex and involve a large number of parameters. The evaluation of parameter values for a specific catchment is a very serious problem, always involving a number of successive approximations. The chances of obtaining something close to the true values of the parameters are increased if the first approximation is reasonable. If the parameters have real physical meaning, good first approximations of their values may be inferred from streamflow records and various observable basin characteristics.

3. Parameters based on conceptual considerations can sometimes be subjectively altered to reflect changes made or to be made to the physical characteristics of the catchment thereby mitigating the need to wait for a new data base to be developed.

4. A conceptual model can be applied to problems other than discharge prediction. Some examples are, movement of pollutants through the soil mantle, water temperature prediction and determination, and prediction of soil moisture levels for agricultural purposes.

5. A model that is conceptually based provides a more effective structure for future modification and research.

The demonstration in the workshop associated with this symposium will be limited to the portions of the system pertaining to a single catchment area. There would not be adequate time to demonstrate all of the flexibility of NWSRFS. Therefore, only the significant hydrologic concepts of the catchment (Sacramento) model and minor modifications as made for its adoption in NWSRFS are discussed.

Model Classification. The Sacramento soil moisture model is of the deterministic, lumped input, lumped parameter type. The originators, while fully cognizant of the variability of physical characteristics and hence parameters within a catchment, did not feel that any existing method of modeling this variation, or any they could devise at that time, was adequate or realistic. They therefore opted to design their model as a lumped parameter technique. They did, however, include a "variable impervious area" and an incrementation of lower zone free water when tension water is not completely satisfied. These two features give the model some of the characteristics of a probability distributed parameter model.

Model Structure. Two zones, upper and lower, are defined. The upper zone represents the upper soil layer and interception storage while the lower zone represents the bulk of the soil moisture and longer groundwater storage.

Moisture Storage. Each zone is thought of as storing moisture in two forms, "tension water" and "free water." Tension water is that which is closely bound to the soil particles in contrast to the water that is free to move. For any zone, the maximum amounts of tension water and of free water which the zone can hold are specified as model parameters. The amount of water in each of these storages at any time is a model variable. The basic storage mechanics are that moisture entering a zone is stored as tension water until the tension capacity is filled. In the lower zone, however, a portion of the water entering that zone may be diverted to free water storage before tension water is filled. Once tension water capacities are filled, then additional water will be stored as free water. Depletion of free water occurs vertically as percolation, horizontally as channel inflow and non-channel groundwater outflow or as evapotranspiration. Tension water is depleted only as evapotranspiration.

Channel Flow from Groundwater. In order for a continuous model to accurately simulate extended periods of fair weather flow, it must have a rather complex groundwater flow withdrawal function. In this model, this is accomplished by defining two lower zone free water storages: primary, which is slow draining and longer lasting, and supplementary, which is faster draining. The outflow from each of these is, in each computational time period, the product of the contents and a constant withdrawal parameter. The two parameters (primary and supplementary) are not equal to each other. While the depletion functions are simple, the total groundwater outflow is governed by these functions acting in combination with some rather involved mechanics which apportion inflow to the lower zone between the two free water storages, and balance tension and free water storages. The originators of the model believe the concept of two separate groundwater components to have some basis in fact and have had a degree of success in identifying them from observed streamflow records.

Percolation. The flow of water from the upper zone to the lower zone is expressed by a formula considered to be the "heart" of the model. In this formula, a percolation rate "PBASE" is defined as the maximum lower zone flow-through rate. This is numerically equal to the outflow from the lower zone under saturated conditions.

Under conditions of unlimited moisture availability in the upper zone, the actual percolation rate may vary between "PBASE" when the lower zone is full, and a maximum value which would occur if the lower zone were empty. This maximum rate is defined by a percolation parameter, "ZPERC," such that the maximum rate is equal to the product of "PBASE" and "1+ZPERC."

The variation of percolation rate between the minimum and maximum values thus defined occurs as a function of the lower zone deficiency ratio. This ratio (DEFR) is simply the difference between lower zone contents and capacity divided by the capacity. The ratio may vary from zero (lower zone full) to unity (lower zone empty). In its computation, both tension and free water are considered. In order to permit the effect of the deficiency ratio to be non-linear and to vary among catchments, a parameter "REXP," which is dependent upon soil type, is applied to the ratio as an exponent. Thus, the actual percolation rate under conditions of unlimited moisture availability in the upper zone is given by:

$$\mathrm{RATE} = \mathrm{PBASE}\ (1 + \mathrm{ZPERC} * \mathrm{DEFR}^{\mathrm{REXP}})$$

where:

RATE is the percolation rate as defined above.
DEFR is the lower zone deficiency ratio.

The true percolation rate is equal to the product of "RATE" and the "upper zone driving force," which is the ratio of upper zone free water contents to upper zone free water capacity. Thus, the percolation will be zero if upper zone free water is empty and equal to "RATE" if the upper zone is full.

The formula involves eight model parameters. Two of them, ZPERC and REXP, appear only in this formula. The remaining six serve their primary purpose in other parts of the model. Four model variables, related to storages in both zones, also appear. The formula interacts with other model components in such a way that it controls the movement of water in all parts of the soil profile, both above and below the percolation interface and is, in turn, controlled by the movement in all parts of the profile.

Variable Impervious Area. A portion of the water entering the basin is assumed to be deposited on impervious areas directly connected or adjacent to the channel system and thus becomes channel flow. This portion is defined by two parameters representing its minimum and maximum values. The actual area used in the computation varies between these limits as a function of the amount of water in storage.

Flow Components. The model recognizes and generates five components of flow:

1. Direct runoff, resulting from moisture input being applied to the variable impervious area.
2. Surface runoff. When moisture input is supplied at a rate faster than it can enter the upper zone, the excess appears as surface runoff.
3. Interflow, lateral drainage from upper zone free water.
4. Supplementary base flow, lateral drainage from lower zone supplementary free water.
5. Primary base flow, lateral drainage from lower zone primary free water.

Evapotranspiration. Evapotranspiration rates in the Sacramento model may be estimated from meteorological variables or from pan observations. Either day-by-day or long-term values may be used to derive the demand curve. The catchment evapotranspiration - demand curve is a product of the computed evaporation index and a seasonal adjustment curve. The seasonal adjustment curve reflects the state of the vegetation. The moisture accounting within the model applies the evapotranspiration loss, directly or indirectly, to the various storages and/or to the channel. The amount taken from each location in the model is determined by a hierarchy of priorities and is limited by the availability of the moisture as well as by the computed demand.

Computational Technique. The movement of moisture through the soil mantle is a continuous process. The rate of flow at various points varies with the rate of moisture supply and with the contents of various storages. This process is modeled by a quasi-linear, open form computation. A single time step computation of the drainage and percolation loop involves the implicit assumption that the movement of moisture during the time step is defined by the conditions at the beginning of the time step. Since this assumption is not valid, the resultant approximation can be made acceptable only by the use of a short time step. In the model, the length of the step is volume dependent. That is, it is selected in such a way that no more than 5 mm of water may be involved in any single execution of the computational loop. The 5 mm limit is arbitrary. It was selected by the originators as being small enough to logically fulfill its function, and not so small as to cause excessively long execution times on the computer (IBM 1130) which was used to develop the model. Sensitivity tests to determine the optimal size of this limit should have a dependency upon soil type. The current limit represents a compromise to eliminate the need for an additional parameter.

Parameters. The soil moisture accounting portion of the Sacramento model, exclusive of the evapotranspiration demand curve, involves seventeen parameters. The demand curve can be defined by a series of ordinates, twelve in number, or by a formula involving five parameters. The temporal distribution function, which converts runoff volumes to a discharge hydrograph, involves a unit hydrograph, and, in some applications, a channel routing function.

The original Sacramento model applied the unit hydrograph to only the upper three components of flow. The two lower zone components were added to the channel flow in the time period in which they were released from the lower zone. In the NWSRFS version, the unit hydrograph is applied to the sum of all five components.

The application of the model in the NWSRFS involves moisture input in 6-hour time periods, and computed 6-hour runoff volumes. The short, repetitive computational time step described above is a subdivision of the 6-hour period and has mathematical significance only. The computations are accumulated over a 6-hour period and applied to a unit hydrograph function representing a 6-hour duration event.

Calibration. A very difficult problem which always accompanies the use of a hydrologic model is that of calibration or "parameter optimization." A model is obviously useless if its parameters cannot be evaluated. Yet, the determination of the optimal values of fifteen to twenty interrelated parameters is a formidable task. The National Weather Service has used a combination of manual and automatic optimization techniques. The term "manual" refers here to a procedure in which subjective adjustments to various parameters are made on the basis of specific characteristics of the output of previous computer runs. Automatic techniques are those in which the computer itself adjusts parameters in a semi-random manner, based on changes in the value of a single numerical error function. The method used is an application of the "Pattern Search" technique described by Monro (1971).

There is no doubt that a good set of parameters can be obtained using only manual methods. However, the procedure is time consuming in terms of man-hours and requires a degree of interplay with the computer often not available from larger systems. In addition, the hydrologist performing the optimization must possess a considerable degree of skill acquired through experience with the model. Automatic methods, on the other hand, are fast and simple to use. Besides being expensive from a computer usage standpoint, they have some inherent disadvantages. Some of these are: complete dependency on one error function, failure to attain an optimal solution due to non-convexity of the response surface in the vicinity of the starting point, and failure to recognize the effect of perturbing a group of parameters simultaneously. At its worst, such a procedure can degenerate into pure curve fitting and produce a set of parameters which fit the calibration data reasonably well, but which are hydrologically unrealistic.

Experience in fitting the model to a large number of catchments under operational conditions indicates that the procedure should be one involving both manual and automatic fitting where the strong points of each compensate the weak points of the other. Generally, much more is achieved by fitting manually first, then using the automatic optimizer after a reasonable fit has been obtained.

Data requirements for the model are somewhat greater than for simpler "event" type models, since the model utilizes a continuous record rather than a fragmentary one covering selected periods.

The length of the data base required for adequate calibration depends on a number of factors including the hydro-climatic characteristics of the catchment and the amount of hydrologic activity during the period in question. Typically, however, it runs 8 to 10 years.

COMPLETE NWSRFS

The National Weather Service River Forecast System is continually being updated and expanded. It contains many models and procedures including the catchment model. Routing and data handling and processing procedures required to adapt the system to a particular river basin are also included in the complete NWSRFS system.

The modular form of the NWSRFS permits the incorporation of additions and improvements with a minimum of programming effort. A snow accumulation and ablation model (Anderson 1973) has been added to the original system. Dynamic (implicit) routing techniques for use on major rivers where serious backwater problems are encountered due to interconnected river systems or tidal effects (Fread 1973) are being incorporated into the system.

It is not planned to publish the entire revised NWSRFS since it is an operational system and subject to frequent modifications. The complete system will be available only on the NOAA's central computer system for use by the NWS River Forecast Centers. However, information on new and revised techniques will continue to be published in the literature.

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CALIBRATION OF NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM: INITIALIZING PARAMETERS FOR THE CATCHMENT MODEL

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ABSTRACT. Use of the catchment model in the National Weather Service River Forecast System (NWSRFS) requires the determination of 16 model parameters. The calibration process is greatly enhanced if rational initial estimates of model parameters can be found. Techniques are developed to derive initial parameter estimates directly from the hydrometeorological data base of a catchment. The techniques utilize catchment maps, precipitation records, and streamflow records to estimate the magnitudes of soil moisture storage components and appropriate drainage coefficients. Step by step demonstrations of the estimation procedure are included. As an example, parameter estimates are obtained for simulation of the South Yamhill River near Whiteson, Oregon.

INTRODUCTION

The soil moisture accounting program of the catchment model developed in the National Weather Service (NWS) Sacramento, California, River Forecast Center by Burnash, et al. (1973), is presently used in the National Weather Service River Forecast System (NWSRFS) (NOAA 1972). A general description of the model is given in the companion paper prepared for this workshop (Peck 1975). Figure 1 is a flow diagram illustrating the various paths water takes in the model. A listing of the NWSRFS subroutine for this model appears in appendix D.

Calibration of the catchment model requires determination of values for 16 parameters associated with soil moisture accounting. This section describes methods for determining initial parameter values. All the parameters are depicted in figure 1.

REQUIREMENTS FOR HYDROGRAPH SIMULATION

Simulation required to test the validity of the soil moisture parameters involves three other elements. These are:

1. Mean Areal Precipitation (MAP). This includes all the techniques and procedures necessary to arrive at basinwide estimates of mean areal precipitation for use by the soil moisture accounting portion of NWSRFS. Included are methods for estimating missing precipitation amounts, distributing estimated or accumulated precipitation, and adjusting precipitation data for orographic and/or other effects. In basins in which snow occurs, input to the catchment program consists of the liquid water reaching the soil mantle from a combination of rainfall and snowmelt . The snowmelt may be either estimated or computed from the NWSRFS snow accumulation and ablation model (Anderson 1973).

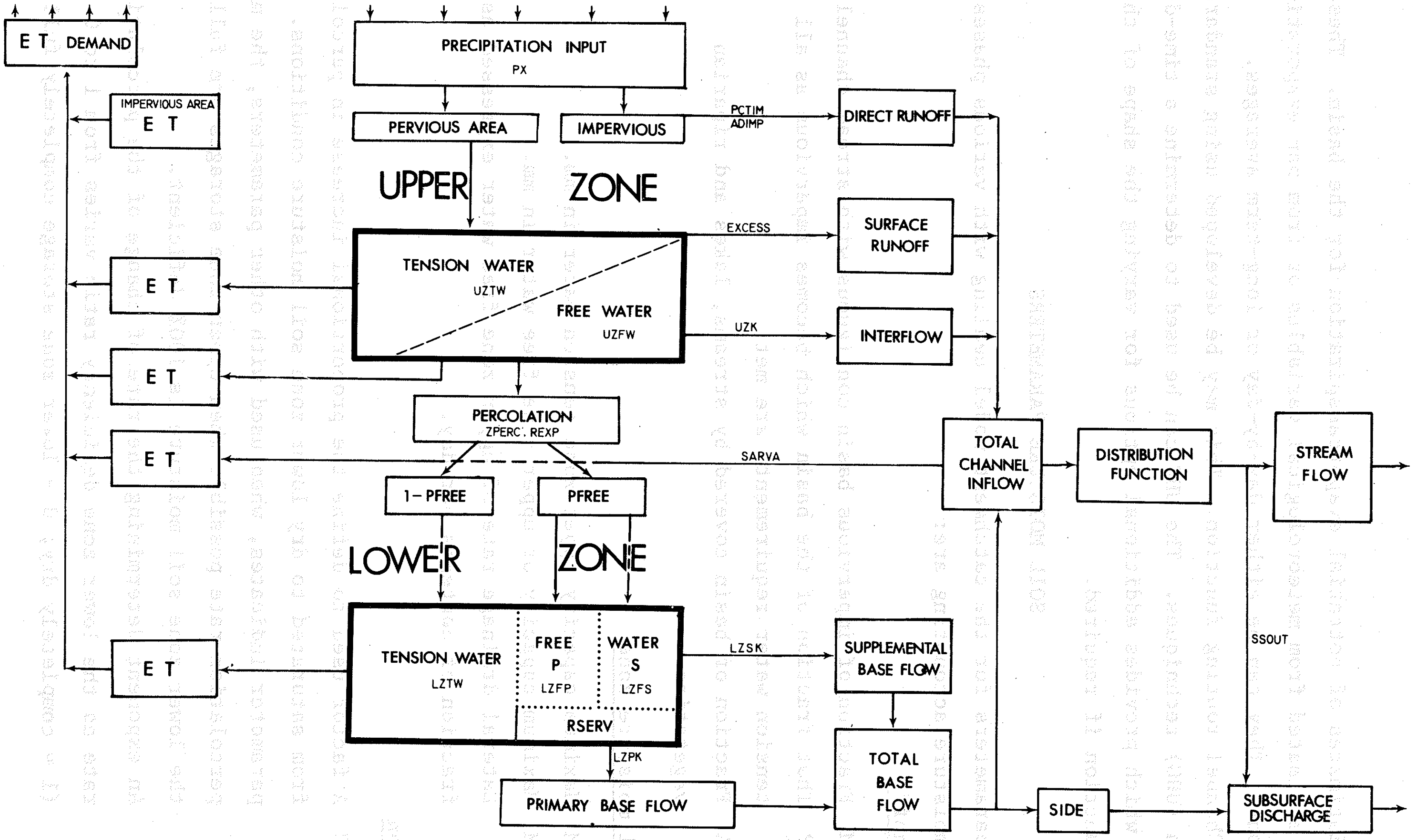


Figure 1.--NWSRFS catchment model (Sacramento).

2. Estimates of potential evapotranspiration for the basin. These values can be estimated from meteorological variables or from pan evaporation observations. They can be either day-by-day or long-term averages.

3. Channel routing function. This may be developed using standard unit hydrograph (UHG) techniques. The UHG can be used to determine a time-delay histogram which provides additional options for varying the shape of the routing function if required.

SOIL MOISTURE PARAMETERS

The parameters for the catchment model dealing with various phases of the soil moisture accounting are:

Direct runoff

PCTIM	Fraction of impervious basin contiguous with stream channels.
ADIMP	That fraction of the basin which becomes impervious as all tension water requirements are met.
SARVA	Fraction of basin covered by streams, lakes and riparian vegetation.

Upper soil moisture zone

UZTWM	Maximum capacity upper zone tension water in mm.
USFWM	Maximum capacity of upper zone free water in mm.
UZK	Lateral drainage rate of upper zone free water expressed as a fraction of contents per day.

Percolation

ZPERC	A factor used to define the proportional increase in percolation from saturated to dry lower zone soil moisture conditions. This parameter indicates, when used with other parameters, the maximum percolation rate possible when upper zone storages are full and the lower zone soil moisture is 100% deficient.
REXP	An exponent determining the rate of change of the percolation rate as the lower zone deficiency ratio varies from 1 to 0 (1 = completely dry; 0 = lower zone storage completely full).

<u>Lower zone</u>

LZTWM	Maximum capacity of lower zone tension water in mm.
LZFSM	Maximum capacity of lower zone supplemental free water storage in mm.
LZSK	Lateral drainage rate of lower zone supplemental free water expressed as a fraction of contents per day.
LZFPM	Maximum capacity of lower zone primary free water storage in mm.
LZPK	Lateral drainage rate of lower zone primary free water expressed as a fraction of contents per day.
PFREE	The percentage of percolation water which directly enters the lower zone free water without a prior claim by lower zone tension water.
RSERV	Fraction of lower zone free water not available for transpiration purposes (incapable of resupplying lower zone tension water).
SIDE	The ratio of unobserved to observed baseflow.
SSOUT	A fixed rate of discharge lost from the total channel flow.

PARAMETER GROUPINGS

If the conceptual model is realistic for the basin, such that parameters have physical meaning, good first approximations for some of the parameters may be inferred from streamflow records, precipitation records, and other basin characteristics. The chances of obtaining the most representative set of parameters are increased with successive approximations if the first approximations are reasonable.

The soil moisture model parameters may be grouped according to the methods for obtaining first approximations. The parameters and their associated classifications are:

1. Parameters readily computed from observed hydrograph and precipitation

LZFPM
LZPK
LZFSM
LZSK
PCTIM

2. Parameters more difficult to estimate from observed hydrograph

LZTWM	SSOUT
UZTWM	UZFWM*
UZK	PFREE*

*Relative size only.

3. Parameters estimated from maps of water area

SARVA

4. Relative values could possibly be estimated for the following parameters from soil percolation characteristics. However, the best first estimate is to use values from similar nearby basins that have been previously simulated.

ZPERC

REXP

5. Nominal starting values used

SIDE

ADIMP

RSERV

INITIAL PARAMETER DETERMINATION

The South Yamhill River near Whiteson, Oregon, U.S.A., has been selected for use as an example for this workshop. Appendix A contains semilogarithmic plots of the observed hydrograph for this river for the water years 1963 (Oct. 1962 to Sept. 1963) and 1965 (Oct. 1964 to Sept. 1965). These plots contain sufficient variations in observed flows for computing those initial soil moisture values determined from observed hydrographs.

Hypothetical examples are discussed in this section to guide the workshop participant in selecting initial parameters for the South Yamhill Basin. For comparison purposes, actual examples of determination of initial parameter values for the South Yamhill Basin will be demonstrated in appendix B. The South Yamhill Basin was selected for an example since it has a large variation in hydrologic flow conditions, which makes it ideal for demonstrating determination of initial parameters.

Semilogarithmic hydrograph plots have commonly been used to separate hydrographs into principal flow components of surface runoff, interflow, and groundwater recession as shown in figure 2 (Linsley, Kohler, and Paulhus

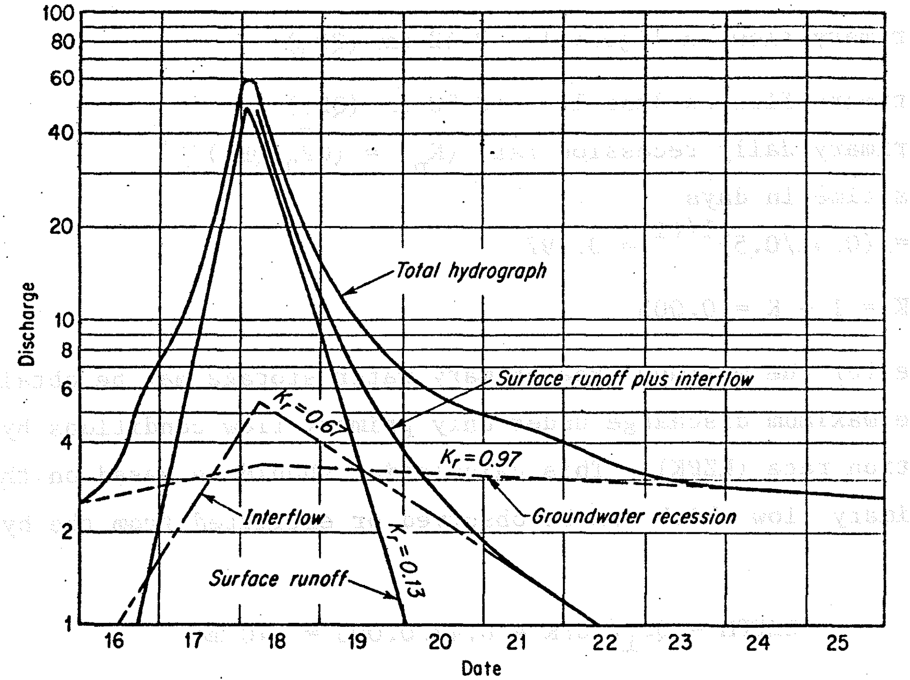


Figure 2.--Semilogarithmic plotting of a hydrograph, showing method of recession analysis.

1975). The characteristics of the hydrograph recession may be used to obtain initial values for the maximum capacities and depletion coefficients for the lower zone free water storages (LZFPM, LZFSM, LZPK, and LZSK).

If a groundwater recession continues for some time, the recession is characterized by two distinct slopes, with a much flatter recession occurring after a prolonged dry period. The developers of the soil moisture model believe the base flow can be modeled with two slopes representing two separate sources of base flow with separate exponential decaying functions. For the model being used, these are the supplemental and primary free water storages of the lower zone. Analyses of the recession provide methods for estimating the depletion rates and storages for the two zones. This is accomplished for each free water storage as follows:

Primary (LZPK and LZFPM)

Select a period when the recession is the flattest (least decay with time) with a minimum of precipitation and calculate a slope during this period.

Example:

Primary flow on August 1: 0.42 mm (QP_2)

Primary flow on June 1: 0.50 mm (QP_1)

Primary daily recession rate $(K_p) = (QP_2/QP_1)^{1/t}$

where: t is time in days

$K_1 = (0.42/0.5)^{1/61} = 0.997$

$LZPK = 1 - K = 0.003$

A value for the maximum free primary water storage may be obtained by dividing the maximum discharge under only primary flow conditions by the daily depletion rate (LZPK). This calculation should be based on the largest value of primary flow which can be observed or estimated from the hydrograph trace.

$$LZFPM = QP_1/LZPK = 0.42/0.003 = 140 \text{ mm}$$

Supplemental (LZSK and LZFSM)

Computations similar to those used for the primary storage values are used for the supplemental values. In this case, estimates of the primary baseflow contribution to the observed flow must be subtracted before the slope representing the supplemental baseflow is computed.

Example:

Period selected: March 1 to April 9

Discharge	March 1	April 9
Observed	8.10 mm	1.68 mm
Estimated primary	0.10 mm	0.08 mm
Estimated supplemental	8.00 mm	1.60 mm

Supplemental daily recession rate $(K_s) = (1.60/8.00)^{1/40} = 0.960$

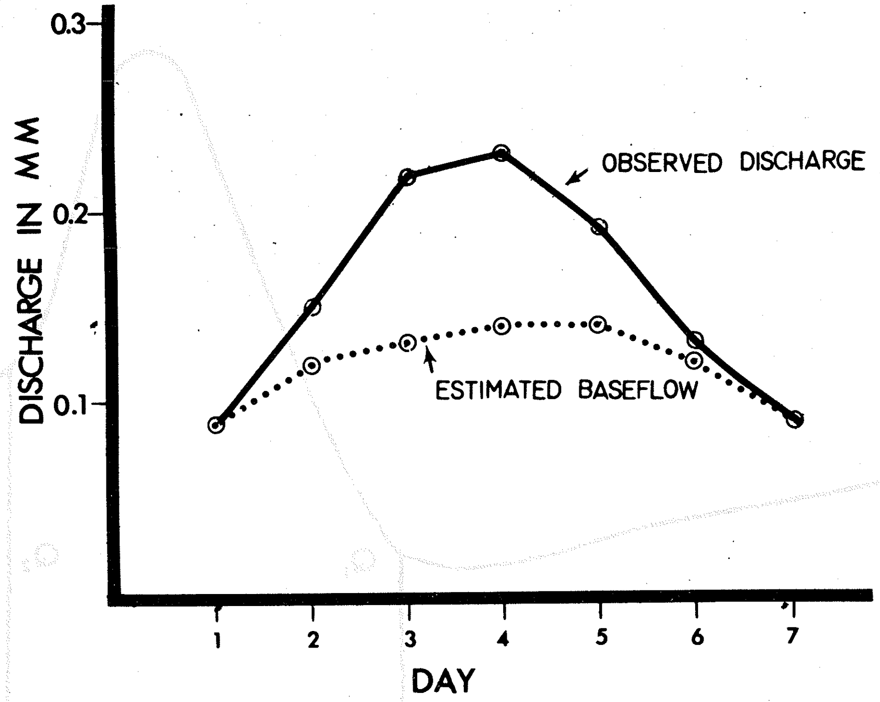
$LZSK = 1 - K_s = 1 - 0.960 = 0.040$

and

$LZFSM = 8.00/0.040 = 200 \text{ mm}$

Percent Impervious (PCTIM)

A small rise on the hydrograph during an extended dry period may be used to compute a value for PCTIM. This is calculated as shown in figure 3.



Day	Basin rain (mm)	Observed discharge (mm)	Estimated baseflow (mm)	Estimated direct R.O. (mm)
1	0.0	0.09	0.09	0.00
2	30.0	.15	.12	.03
3	19.0	.22	.13	.09
4	0.0	.23	.14	.09
5	0.0	.19	.14	.05
6	0.0	.13	.12	.01
7	0.0	0.09	0.09	.00
	49.0			0.27

$$\text{PCTIM estimate} = \frac{\Sigma \text{Direct R.O.}}{\Sigma \text{Rain}} = \frac{0.27}{49} = 0.0055$$

Figure 3.-- Calculation of PCTIM

Lower Zone Tension Water Maximum (LZTWM)

Select a period following an extended dry period, as indicated on figure 4, where the discharges Q_1 and Q_2 represent only baseflow. A time t_1 should be selected immediately prior to the occurrence of direct and/or surface runoff and time t_2 immediately following a period of interflow.

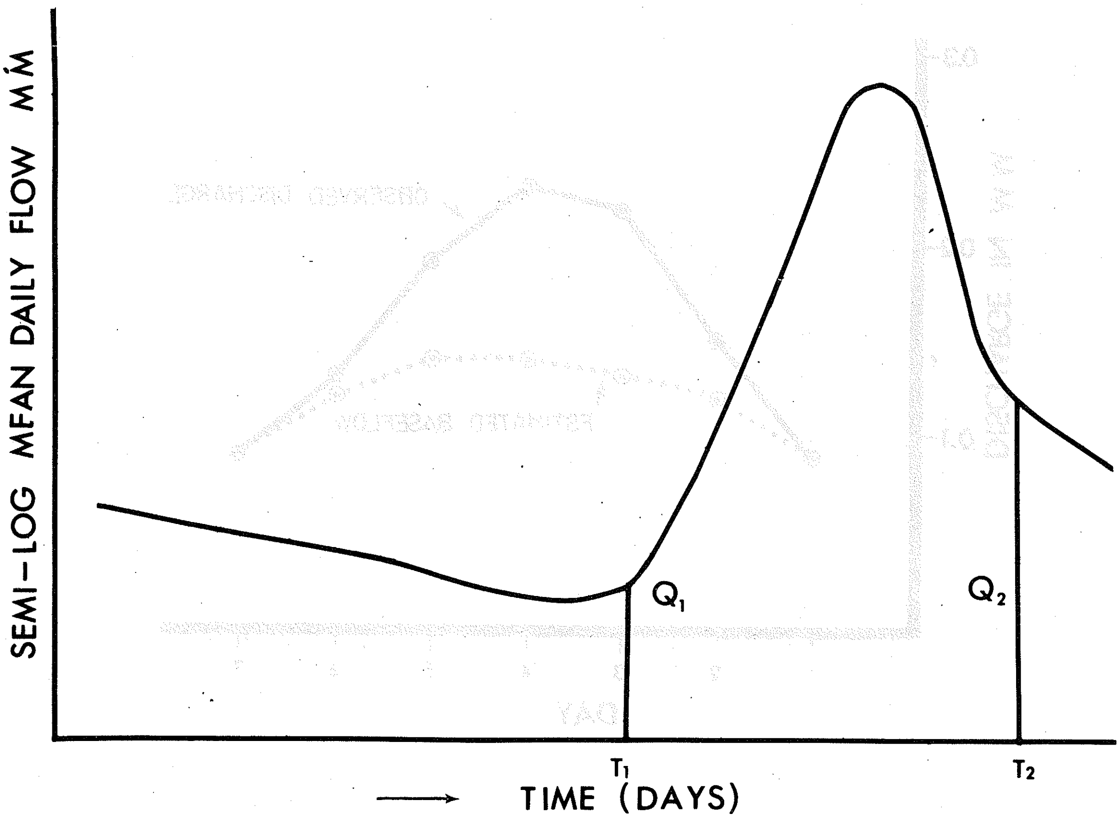


Figure 4.-- Hydrograph for determination of LZTWM

The discharges Q_1 at t_1 and Q_2 at t_2 can be separated into the supplemental and primary baseflow components by projecting primary baseflow backwards from later periods.

At t_1: $Q_1 = QS_1 + QP_1$ and at t_2: $Q_2 = QS_2 + QP_2$

Primary and supplemental free water storages (LZFPC and LZFSC) for each of the two times are computed by dividing the storages by the appropriate drainage rates.

$$LZFPC = QP/LZPK$$
$$LZFSC = QS/LZSK$$

Assuming that UZTW is full and UZFWC is empty at times t_1 and t_2, the water balance for the period may be expressed as:

$$Px - R0 - PE - \Delta LZFSC - \Delta LZFPC - \Delta LZTWC = 0$$

where: Px is precipitation during the storm in mm.
R0 is the total runoff in mm.

PE is the evaporation from the basin in mm (for most wet periods, this would be small and can be neglected).

ΔLZTWC is the change in the lower zone tension water.

All values except ΔLZTWC are measured or estimated. The ΔLZTWC represents the increase in the LZTW during the time interval and not necessarily LZTW being completely filled. This is an indication of the lower limit of LZTWM. Since the LZTW would probably not have been entirely empty prior to the storm, a small percentage (10% to 20%) should be added to ΔLZTWC for small storages of LZTW, to arrive at an estimate for LZTWM. For large lower zone tension storage the percentage to be added should be larger (10-40%). For cases where these ideal conditions following an extended dry period can not be found then a water balance for a larger period of 3 to 4 months can be used to compute LZTWM.

Upper Zone Tension Water Maximum (UZTWM)

An estimate of UZTWM from the hydrograph is feasible. All periods of rain following a dry period should be checked to determine the amount of precipitation the pervious area can hold without surface runoff occurring. Where the precipitation is associated with only the one period, the entire amount can be used in making the estimate. If precipitation occurred over several days, it is more difficult to calculate the value since evaporation losses during the period must also be considered.

For the Yamhill River near Whiteson, the following were observed to have occurred.

Approximate date	Remarks
17 Oct. 1958	3-day storm of 76 mm with surface runoff. Low UZTW prior to storm.
4 Sept. 1959	3-day storm of 42 mm overflowed UZTW. Condition of UZTW at start of storm not certain.
23 Oct. 1960	6-day storm of 76 mm. Produced some overflow of UZTW.
23 Aug. 1963	3-day storm of 23 mm and a 5-day storm of 31 mm. Produced no overflow of UZTW.
13 Sept. 1973	4-day storm of 35 mm with no overflow of UZTW.

Upper Zone Free Water Maximum (UZFWM) and Drainage Rate (UZK)

The UZFWM cannot be obtained directly from the interflow recession as can be done for the lower zone storages since it does not produce a straight line on semi-log hydrographs. The upper zone free water storage must satisfy percolation and evaporation demand requirements before any water is discharged to the channel. Thus, it is not a simple depletion as for the lower zone free water storages.

Although UZK cannot be obtained directly from analysis of the hydrograph, it is roughly related to the amount of time that interflow occurs following a period with major direct and surface runoff. The longer the period of interflow, the smaller the value of UZK. If we assume that interflow becomes insignificant when its contribution reduces to about 10% of what it is at maximum rate, then the following simple relation can be used to compute a value for UZK:

$$(1 - \text{UZK})^N = 0.10$$

where: N is the average number of days that interflow is observed.

A value of UZFWM can be determined using the UZK computed above and the discharge, corrected for supplemental and primary baseflow, at the time of the highest interflow with ut surface water contribution. It must be recognized that this is a rather rough estimate. The general range for UZFWM has been found to be from 6 to 85 mm with an average of about 25 mm.

Percolation Water Percentage (PFREE)

An estimate of the relative importance of PFREE can be determined from investigating storms following long dry spells that do produce runoff (UZTW completely filled). If the hydrograph returns to approximately the same baseflow as before (indicating little or no addition to the lower zone free water storages), then PFREE is of little significance and has a very small value ranging from 0 to 0.2. If there is a significant increase in baseflow following this type of storm, then PFREE can have a value as high as 0.5. The nominal value for PFREE is 0.3.

Sub-surface Outflow Along Stream Channel (SSOUT)

It is recommended that the value of zero be used. A value for SSOUT other than zero can be applied only if the Q log plot requires a constant addition to the baseflow in order to achieve a valid recession characteristic.

Fraction of Basin Covered by Streams, Etc. (SARVA)

This factor is determined directly from maps showing water and riparian vegetation areas. SARVA can also be inferred from changes in baseflow associated with changes in ET.

Percolation Parameters (ZPERC and REXP)

An understanding of the important role played by the percolation parameters is essential to understanding the model and gaining an ability to properly fit the model. Figure 5 demonstrates the part played by the parameters in determining the maximum rate of percolation in relation to the lower zone soil moisture deficiency (DEFR). This curve represents the rate if the upper zone free water is full.

If the lower zone free water storages are full (and the upper zone free water is also at its maximum), then the rate of percolation is equal to PBASE, which is defined by:

$$PBASE = (LZFPM * LZPK + LZFSM * LZSK)$$

This is the maximum outflow that can occur from the lower zones and under steady conditions would represent the percolation to replace the amount removed from the lower zone free water storages as baseflow. As the lower zone soil moisture becomes deficient, the percolation rate increases. When the lower free water storages are completely dry (100% deficient), the percolation rate (assuming UZFW full) occurs at its maximum rate. This is equal to:

$$\text{Maximum percolation rate} = (1 + ZPERC) * PBASE$$

The shape of the percolation curve is determined by the parameter REXP as shown in figure 5.

Initial values of ZPERC must be estimated using as a guideline some evaluation of the possible maximum percolation rate that would be expected for the basin when the upper zone free water storage is full. The ability to estimate this value would increase as additional basins in an area are fitted. With no other means of estimating REXP, a nominal starting value of 1.80 is suggested.

Once an initial simulation is made, the four parameters controlling the

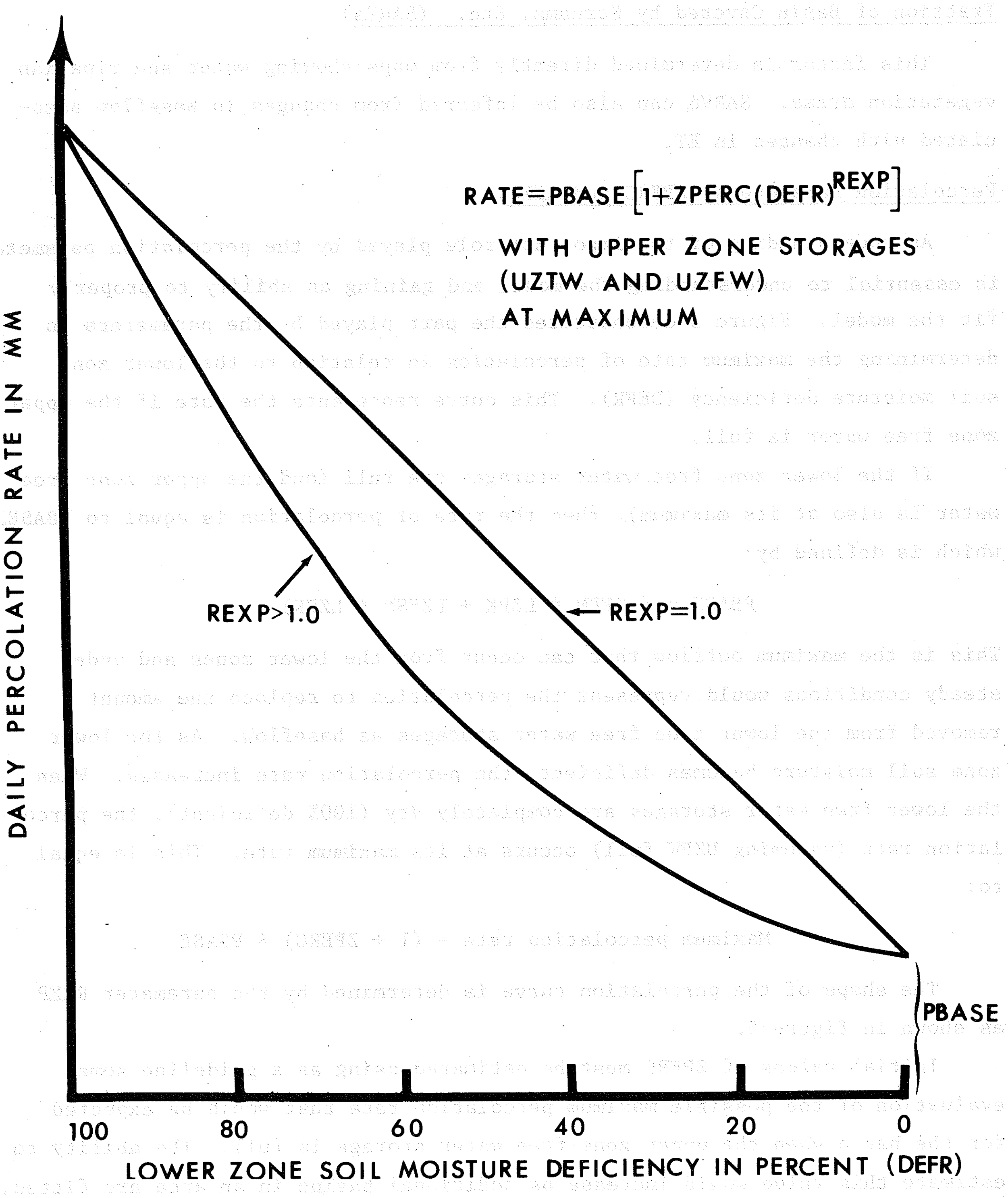


Figure 5.--Percolation representation.

percolation curve are very important for improving the simulation fit. For example, if following an extended dry period the simulated runoff is much less than observed, the percolation curve may be too high for large deficiencies in lower zone storages. Similar analyses of simulated versus observed runoff for periods when the lower zone moisture deficiency would be small will indicate if the curve should be raised or lowered for these conditions. The raising and lowering of the curve can be accomplished by changing ZPERC and/or the value of PBASE. PBASE is related to the maximum values for the lower zone free water storages (LZFSM and LZFPM). The relative values of the supplemental and primary storages are important for the division of the free water contribution to the recession. However, the total value of the storages is primarily important in positioning the percolation curve and may be changed for this purpose. Thus, you should not change the value of ZPERC without considering the necessity to also alter the total capacities of the lower zone free water. The value of REXP allows flexibility in the change in slope over the different values of the lower zone soil moisture deficiency. The fitting of the percolation curve to insure proper initiation of runoff under various lower soil moisture conditions is generally the most important fitting requirement after the first simulation if the volume of runoff is reasonable.

Parameters Requiring Nominal Starting Values (SIDE, ADIMP, and RSERV)

Initial value for SIDE is zero. Where it is known from geological or hydrological studies that considerable groundwater bypassed the surface channel, a value other than zero should be used.

The initial value for RSERV is 0.30 and this parameter is generally not optimized.

The additional area of the basin which becomes impervious as all tension water requirements are met (ADIMP) is generally given a nominal starting value of 0.01. Recent investigations suggest that remote sensing techniques using radiation measurements (infrared) can define areas as are indicated by ADIMP. Such measurements may be a means of providing future input for this parameter.

SIMULATION FOR SOUTH YAMHILL RIVER

Copies of the worksheets for determination of initial parameters for the South Yamhill River near Whiteson, Oregon, are shown in appendix B. These may be used to compare with those obtained in the workshop.

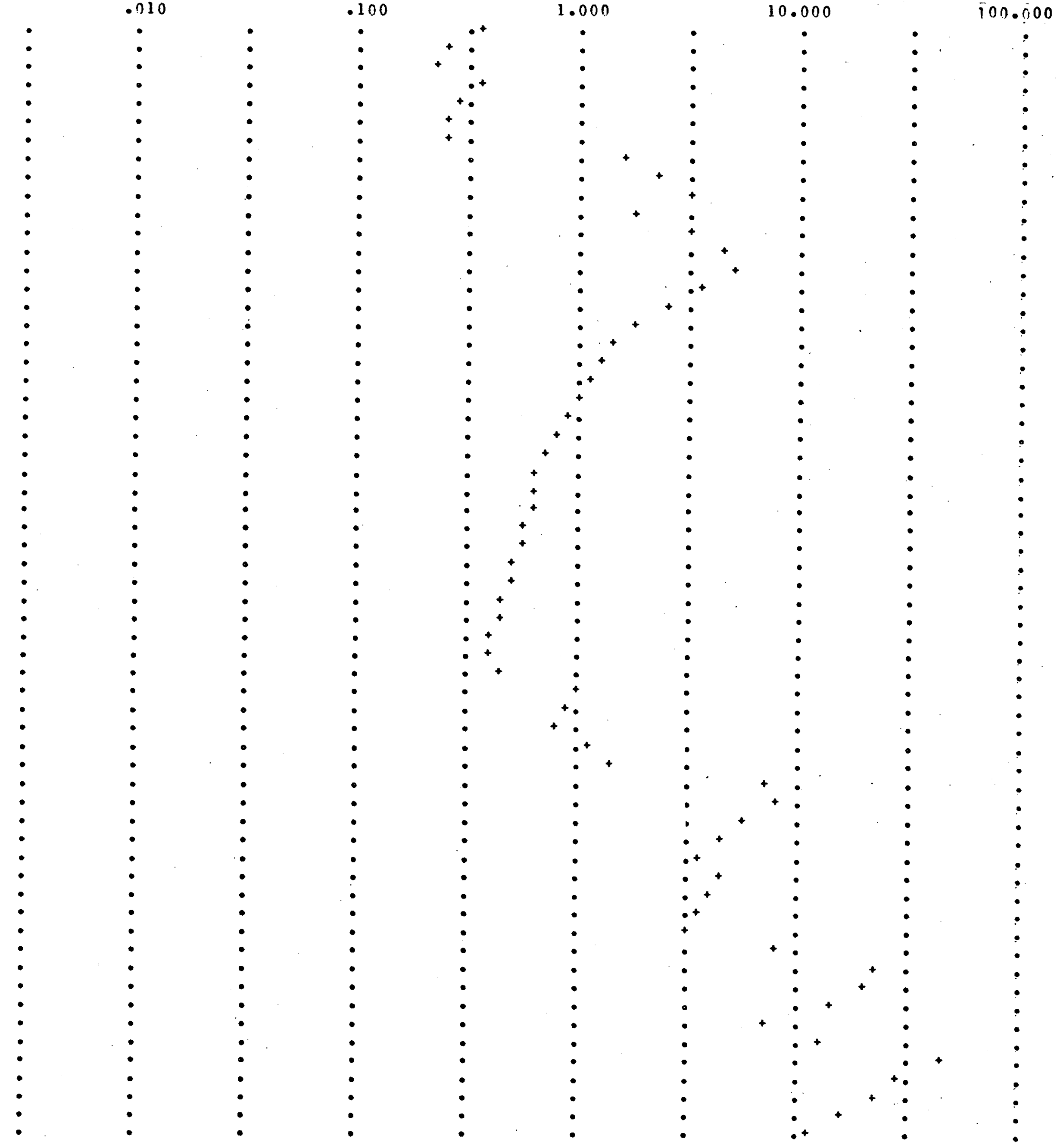
Appendix C contains the copies of the following printouts of the initial simulation.

1. Input parameters and other initializing entries.
2. Summation sheet of the statistical summary for the 5-year simulation (Oct. 1962-Sept. 1967).
3. Sample of yearly summary showing soil moisture accounting volumes for each month and listing of soil moisture variables at the end of each month.
4. Semilogarithmic hydrographs for all 5 years of observed and simulated discharges with daily numerical values of the observed discharges, simulated discharges, and liquid water reaching the soil mantle from a combination of rainfall and/or snowmelt (rain + melt).

ACKNOWLEDGMENTS

Special thanks are extended to Eric Anderson and Robert Burnash for the technical advice they provided and to the many members of the Hydrologic Research Laboratory who assisted in preparing the material.

```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)     SOUTH YAMHILL NR WHI     WATER YEAR 1963     *=SIMULATED     +=OBSERVED
OCT-NOV
```



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 5 *    0.000     .294    5.3
 6 *    0.000     .248    3.0
 7 *    0.000     .258   43.2
 8 *    0.000    1.600   15.0
 9 *    0.000    2.127   21.1
10 *    0.000    3.181    8.4
11 *    0.000    1.844   31.5
12 *    0.000    3.181   33.5
13 *    0.000    4.667    7.6
14 *    0.000    5.307    6.6
15 *    0.000    3.388    2.3
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22 *    0.000     .871    0.0
23 *    0.000     .783    0.0
24 *    0.000     .719    0.0
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26 *    0.000     .627    1.3
27 *    0.000     .598    0.0
28 *    0.000     .574    0.0
29 *    0.000     .534    0.0
30 *    0.000     .508    0.0
31 *    0.000     .482    0.0
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 3 *    0.000     .420    0.0
 4 *    0.000     .410    9.9
 5 *    0.000     .454   17.0
 6 *    0.000     .994    0.0
 7 *    0.000     .903    8.4
 8 *    0.000     .817    2.5
 9 *    0.000    1.076    7.6
10 *    0.000    1.440   51.3
11 *    0.000    7.453    5.6
12 *    0.000    8.055   12.4
13 *    0.000    5.514    2.5
14 *    0.000    4.460     .8
15 *    0.000    3.501   21.6
16 *    0.000    4.441    1.0
17 *    0.000    3.877   10.7
18 *    0.000    3.482     .3
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22 *    0.000   20.514    1.0
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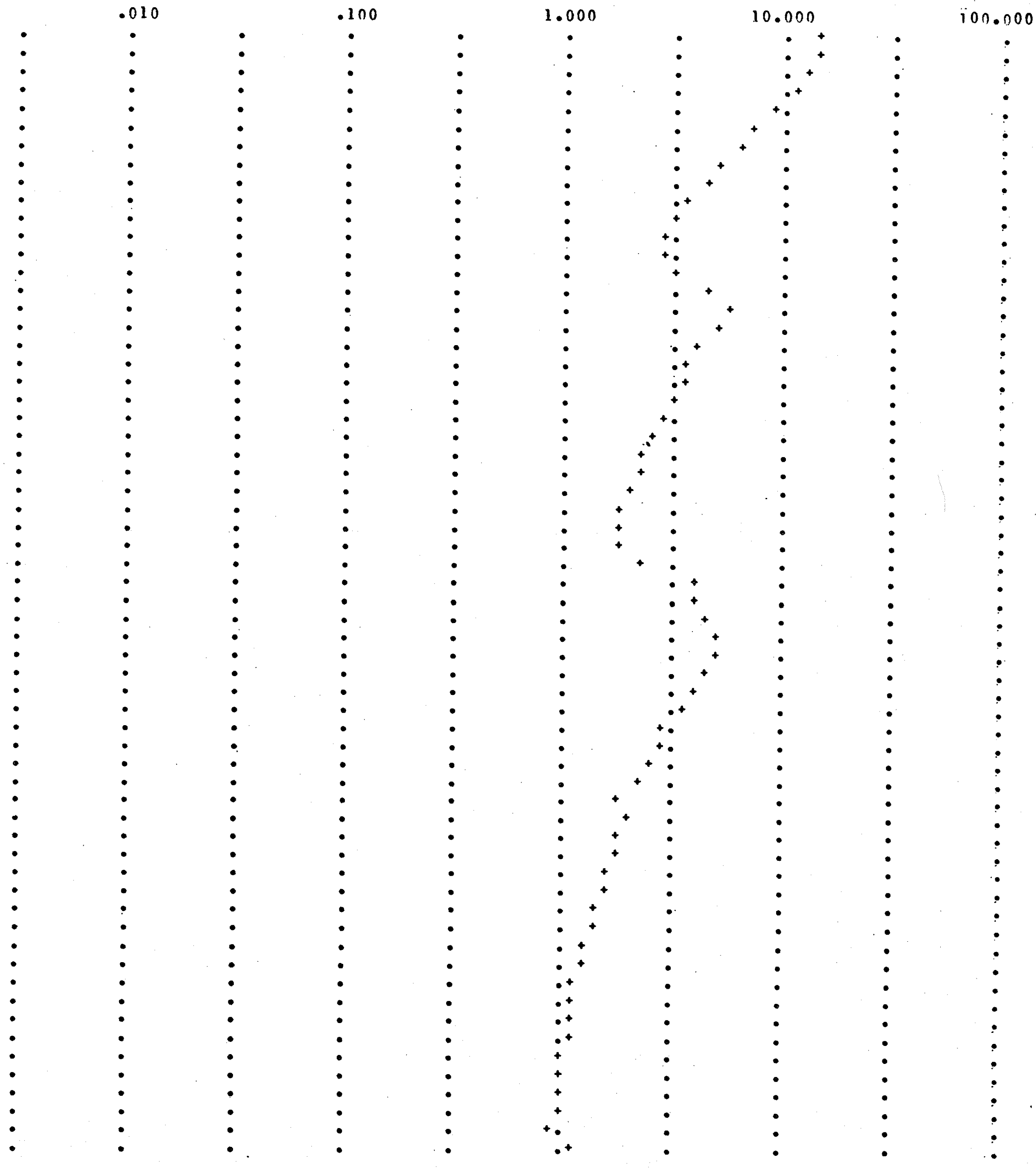
24 *    0.000    7.415   50.8
25 *    0.000   13.061   89.4
26 *    0.000   45.356   11.4
27 *    0.000   29.735    4.6
28 *    0.000   22.019     .8
29 *    0.000   15.545   11.9
30 *    0.000   11.518   27.4
```

APPENDIX A

```
DEC-JAN
```



```
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 4 *    0.000   11.405    2.0
 5 *    0.000    9.109    5.6
 6 *    0.000    7.453    0.0
 7 *    0.000    6.060     .8
 8 *    0.000    5.025     .3
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12 *    0.000    2.936    4.3
13 *    0.000    2.729   11.4
14 *    0.000    3.086   16.3
15 *    0.000    4.498    9.7
16 *    0.000    5.627    2.0
17 *    0.000    4.837    0.0
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19 *    0.000    3.708    3.6
20 *    0.000    3.482    0.0
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22 *    0.000    2.823     .3
23 *    0.000    2.578    0.0
24 *    0.000    2.352    0.0
25 *    0.000    2.127    0.0
26 *    0.000    1.976    0.0
27 *    0.000    1.848     .5
28 *    0.000    1.769    1.5
29 *    0.000    1.754   12.4
30 *    0.000    2.183   14.0
31 *    0.000    4.027    6.3
 1 *    0.000    4.027    7.9
 2 *    0.000    4.272   12.7
 3 *    0.000    5.194    1.0
 4 *    0.000    5.157    0.0
 5 *    0.000    4.441    0.0
 6 *    0.000    3.802    0.0
 7 *    0.000    3.350    0.0
 8 *    0.000    2.955     .8
 9 *    0.000    2.710    3.6
10 *    0.000    2.560    0.0
11 *    0.000    2.164    0.0
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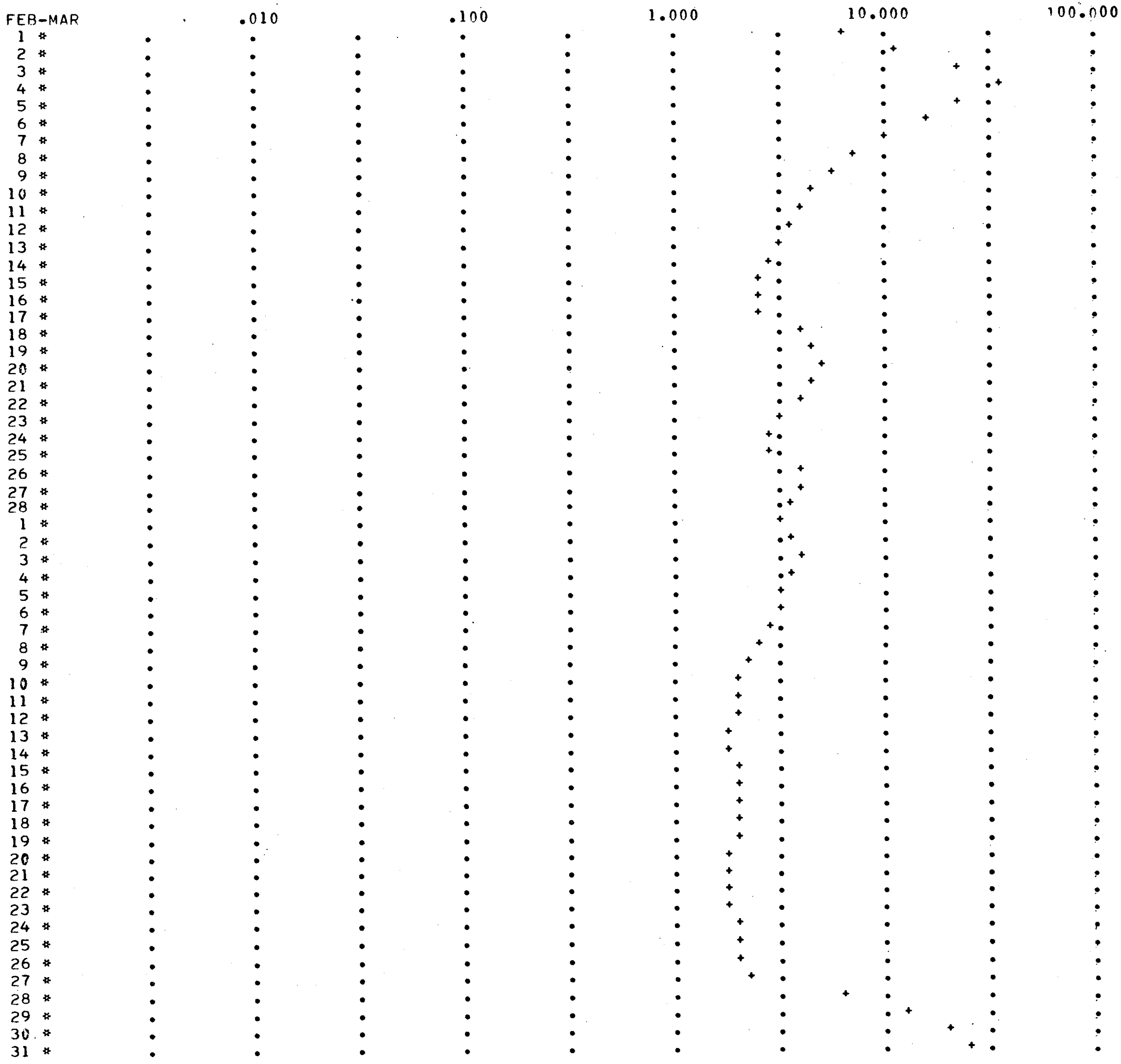
24 *    0.000    1.097     .3
25 *    0.000    1.063     .3
26 *    0.000    1.029    0.0
27 *    0.000     .984     .3
28 *    0.000     .969   10.7
29 *    0.000     .971    0.0
30 *    0.000     .903   22.6
31 *    0.000    1.127   48.5
```

```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)     SOUTH YAMHILL NR WHI     WATER YEAR 1963     *=SIMULATED     +=OBSERVED
```



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  4 *         0.000  33.499   15.0
  5 *         0.000  22.584    0.0
  6 *         0.000  15.809    4.6
  7 *         0.000  10.087    0.0
  8 *         0.000   6.945     .3
  9 *         0.000   5.552    0.0
 10 *         0.000   4.611    0.0
 11 *         0.000   3.877    0.0
 12 *         0.000   3.369    1.8
 13 *         0.000   3.068    4.6
 14 *         0.000   2.842    3.3
 15 *         0.000   2.635    3.8
 16 *         0.000   2.578    1.5
 17 *         0.000   2.409   19.6
 18 *         0.000   3.764    8.4
 19 *         0.000   4.667    6.3
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 24 *         0.000   2.974    0.0
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 26 *         0.000   3.915    3.6
 27 *         0.000   3.933    0.0
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  3 *         0.000   3.990    0.0
  4 *         0.000   3.613    0.0
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  6 *         0.000   3.030    0.0
  7 *         0.000   2.729    0.0
  8 *         0.000   2.465    0.0
  9 *         0.000   2.277    0.0
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 13 *         0.000   1.784     .8
 14 *         0.000   1.735    8.9
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 16 *         0.000   2.051    3.0
 17 *         0.000   2.089     .3
 18 *         0.000   1.957    1.0
 19 *         0.000   1.901    0.0
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 22 *         0.000   1.731    3.6
 23 *         0.000   1.724   12.4
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 26 *         0.000   1.957   15.5
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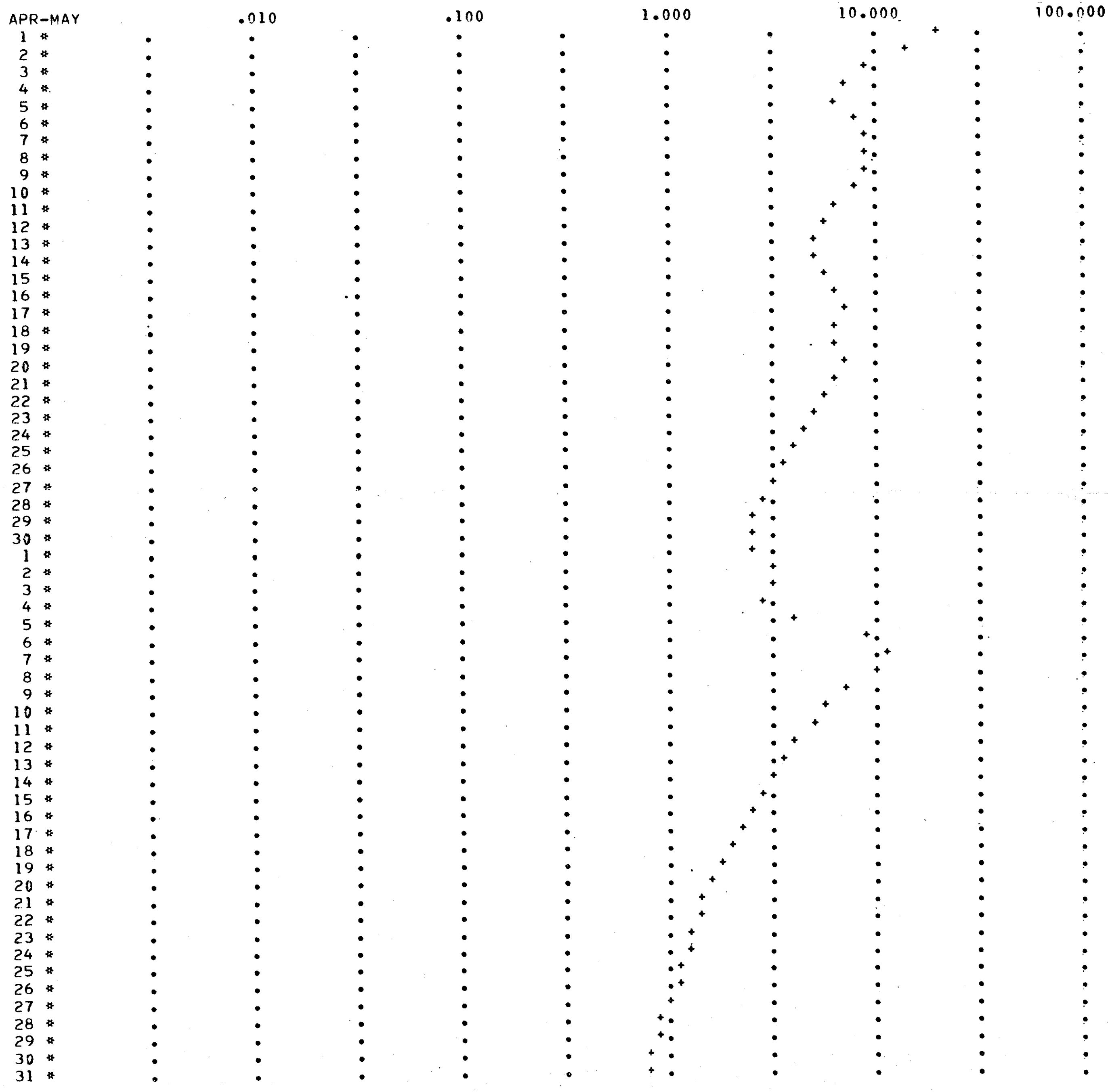

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  8 *         0.000   8.958    8.1
  9 *         0.000   9.015    2.5
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 11 *         0.000   6.361    0.0
 12 *         0.000   5.420    6.9
 13 *         0.000   4.893    3.0
 14 *         0.000   4.931   22.4
 15 *         0.000   5.853   16.0
 16 *         0.000   6.531    9.4
 17 *         0.000   6.888    2.0
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 29 *         0.000   2.635    5.1
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  2 *         0.000   3.049    7.4
  3 *         0.000   3.237    1.3
  4 *         0.000   2.879   13.7
  5 *         0.000   4.046   41.1
  6 *         0.000   8.977   14.0
  7 *         0.000  10.976    4.6
  8 *         0.000   9.937     .8
  9 *         0.000   7.490    3.6
 10 *         0.000   5.834    1.8
 11 *         0.000   4.761     .5
 12 *         0.000   3.990     .3
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 30 *         0.000    .834     .3
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```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)      SOUTH YAMHILL NR WHI      WATER YEAR 1963     *=SIMULATED    +=OBSERVED
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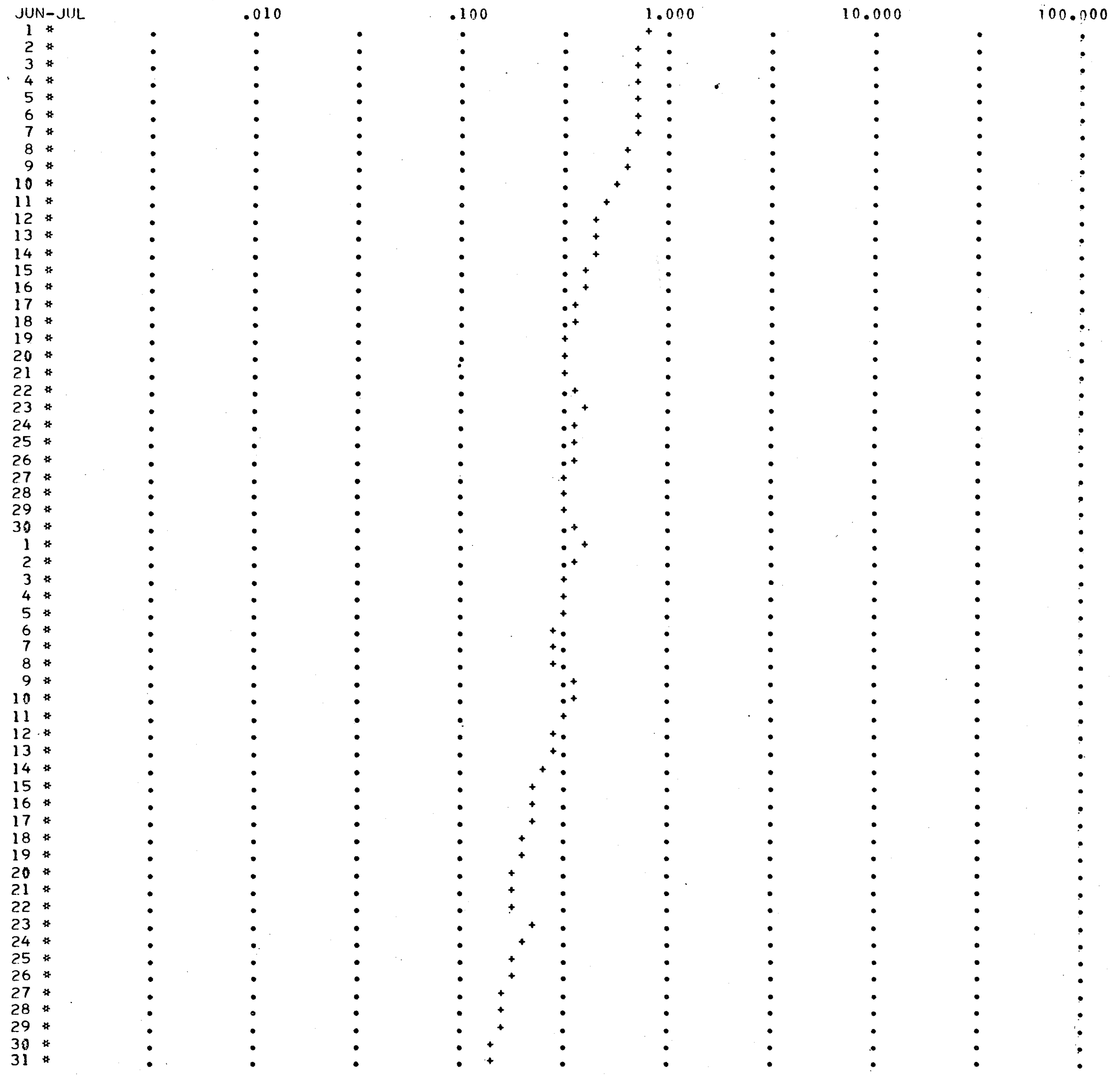

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 8 *     0.000   .632     .8
 9 *     0.000   .600     .3
10 *     0.000   .570    0.0
11 *     0.000   .512    0.0
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 2 *     0.000   .337    0.0
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 7 *     0.000   .271    3.8
 8 *     0.000   .288    7.9
 9 *     0.000   .344    1.0
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15 *     0.000   .231    0.0
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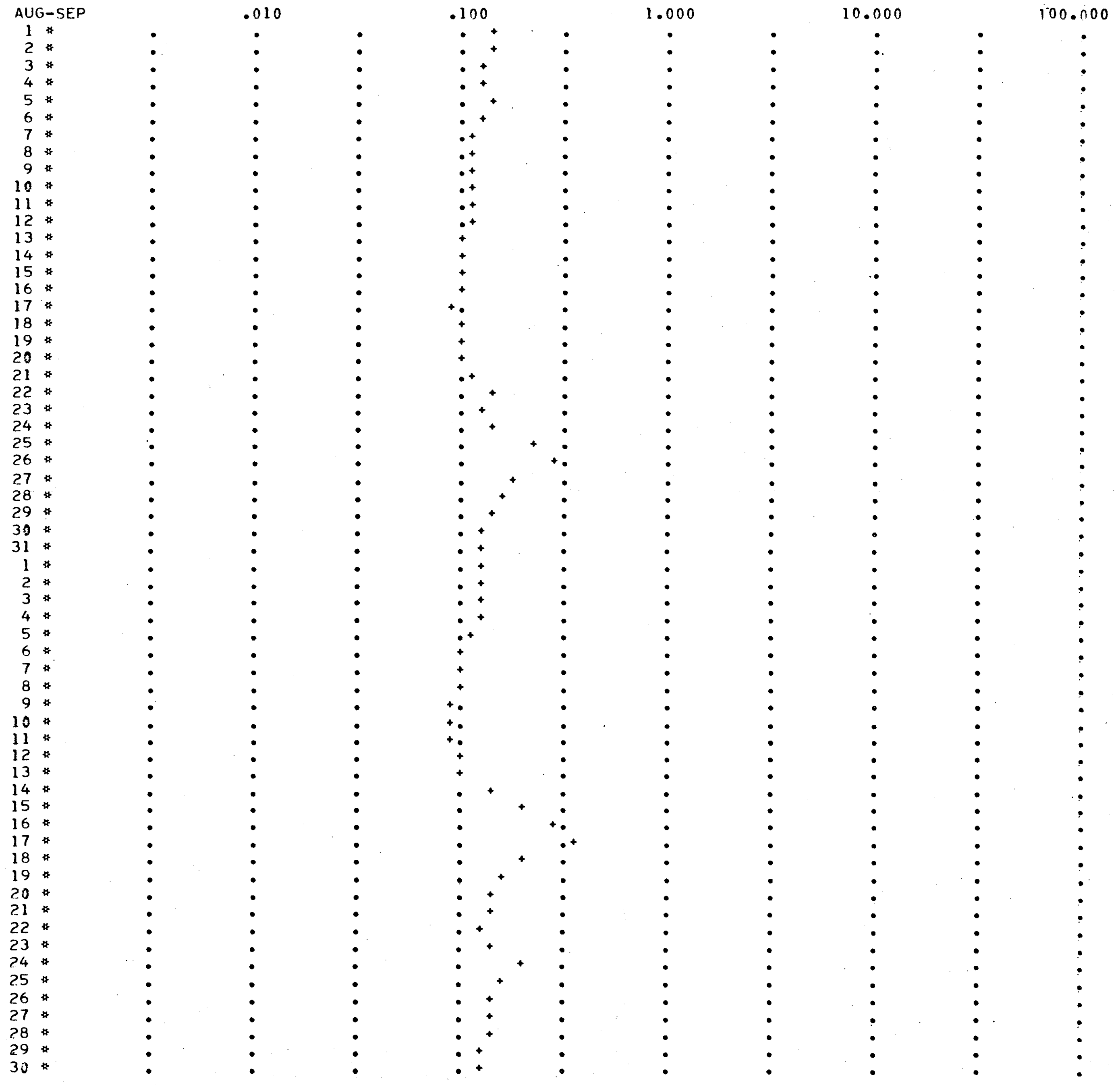

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 4 *     0.000   .130    0.0
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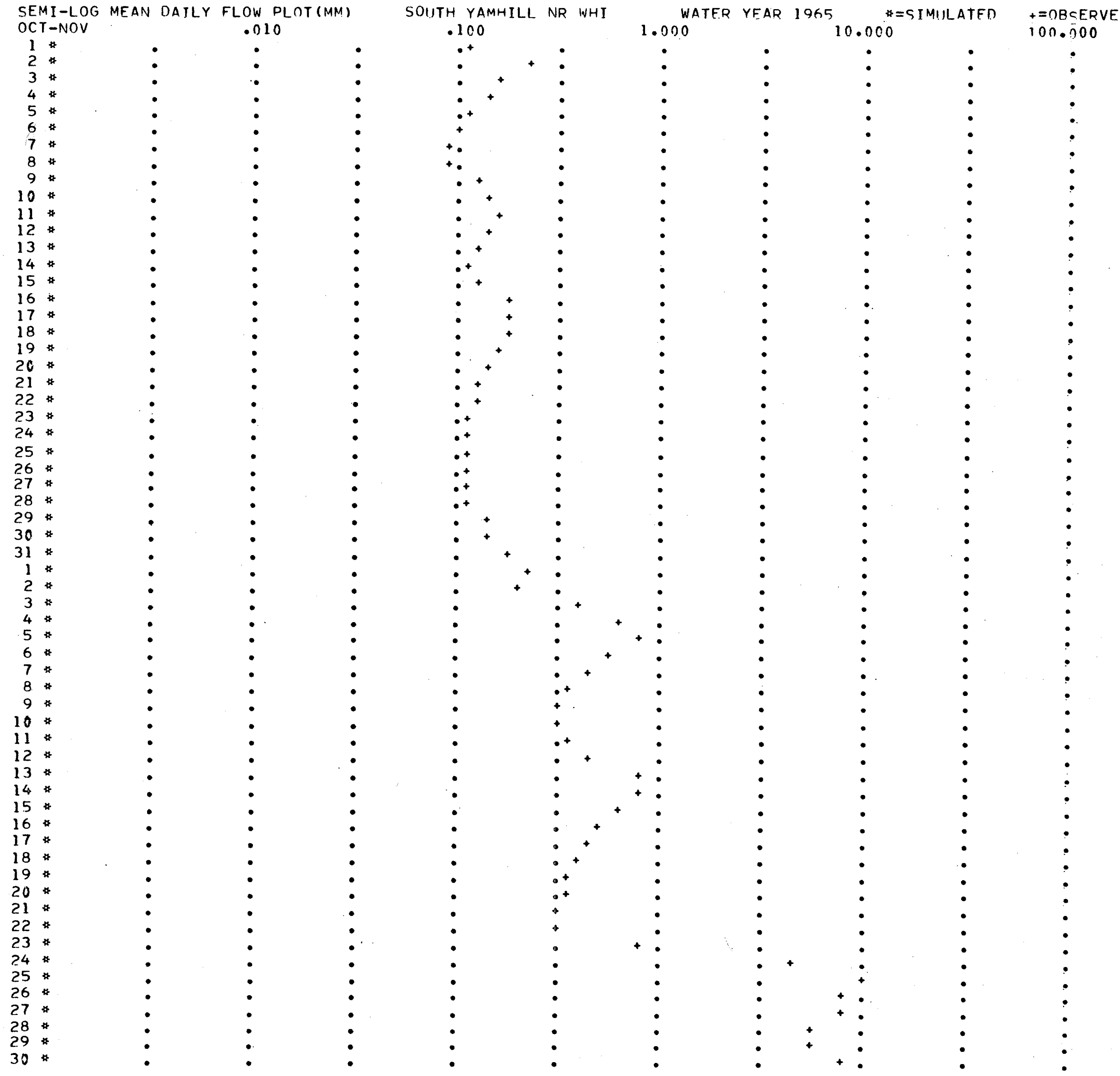
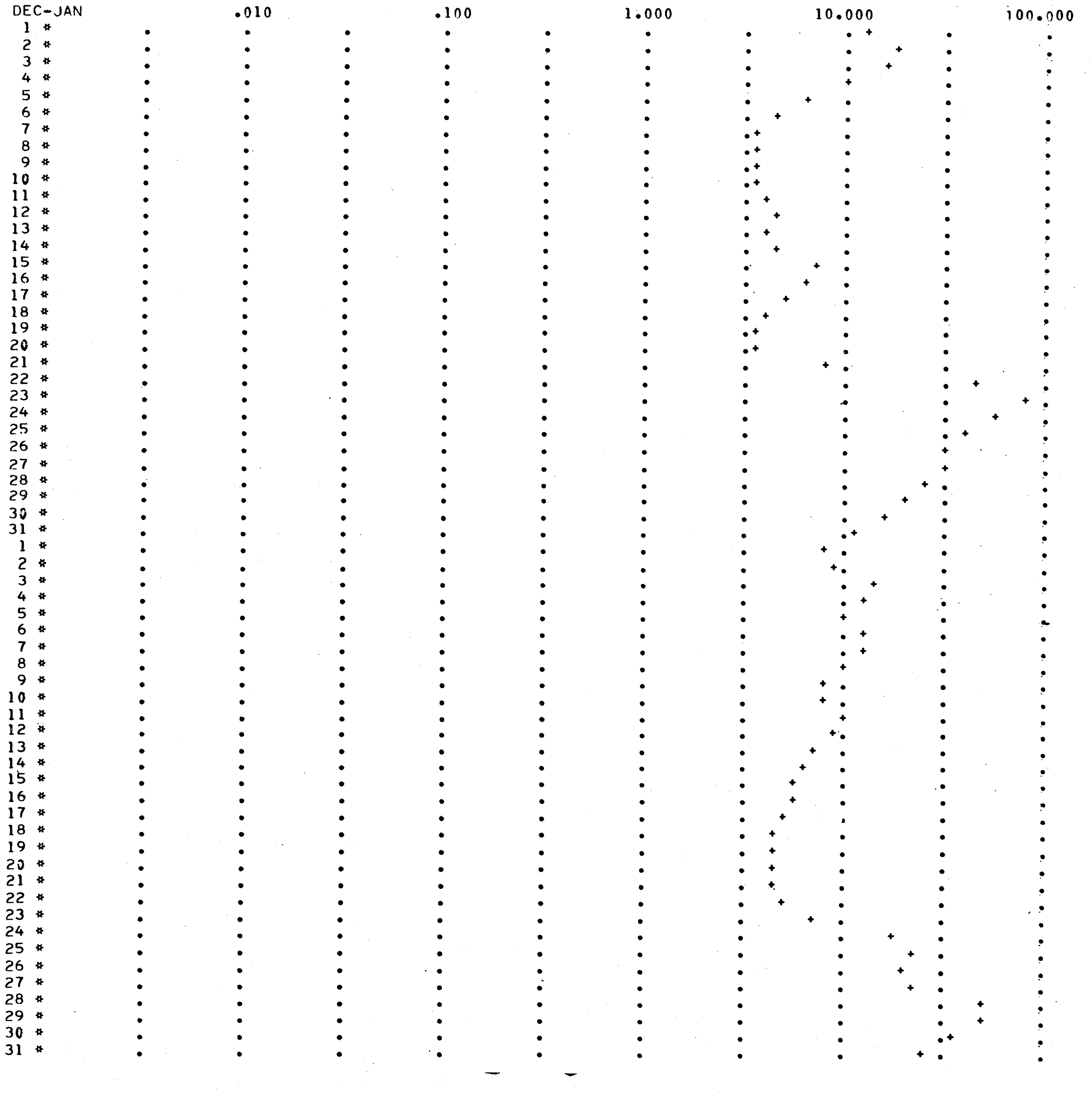
 7 *     0.000   .113    0.0
 8 *     0.000   .107    0.0
 9 *     0.000   .111    0.0
10 *     0.000   .109    0.0
11 *     0.000   .109     .5
12 *     0.000   .111    0.0
13 *     0.000   .100    0.0
14 *     0.000   .105    0.0
15 *     0.000   .100    0.0
16 *     0.000   .098    0.0
17 *     0.000   .092    0.0
18 *     0.000   .096    2.3
19 *     0.000   .100     .5
20 *     0.000   .104    4.8
21 *     0.000   .117    1.3
22 *     0.000   .145    2.0
23 *     0.000   .130    7.6
24 *     0.000   .145   15.5
25 *     0.000   .224     .5
26 *     0.000   .288    0.0
27 *     0.000   .186    0.0
28 *     0.000   .151    0.0
29 *     0.000   .139    0.0
30 *     0.000   .126    0.0
31 *     0.000   .120    0.0
 1 *     0.000   .126     .8
 2 *     0.000   .132    0.0
 3 *     0.000   .130    0.0
 4 *     0.000   .120    0.0
 5 *     0.000   .107    0.0
 6 *     0.000   .104    0.0
 7 *     0.000   .096    0.0
 8 *     0.000   .100    0.0
 9 *     0.000   .094    1.8
10 *     0.000   .092    1.3
11 *     0.000   .092    0.0
12 *     0.000   .096    1.8
13 *     0.000   .102    8.6
14 *     0.000   .134    6.6
15 *     0.000   .192   18.3
16 *     0.000   .267    3.6
17 *     0.000   .346    1.0
18 *     0.000   .211    0.0
19 *     0.000   .166    0.0
20 *     0.000   .149    0.0
21 *     0.000   .136    0.0
22 *     0.000   .128   13.0
23 *     0.000   .139    0.0
24 *     0.000   .201    0.0
25 *     0.000   .166    0.0
26 *     0.000   .141    0.0
27 *     0.000   .136    0.0
28 *     0.000   .139    0.0
29 *     0.000   .130    0.0
30 *     0.000   .120    0.0
```

```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)      SOUTH YAMHILL NR WHI       WATER YEAR 1965     *=SIMULATED     +=OBSERVED
OCT-NOV                  .010               .100             1.000              10.000            100.000     SIM.     OBS. RAIN+MELT
```



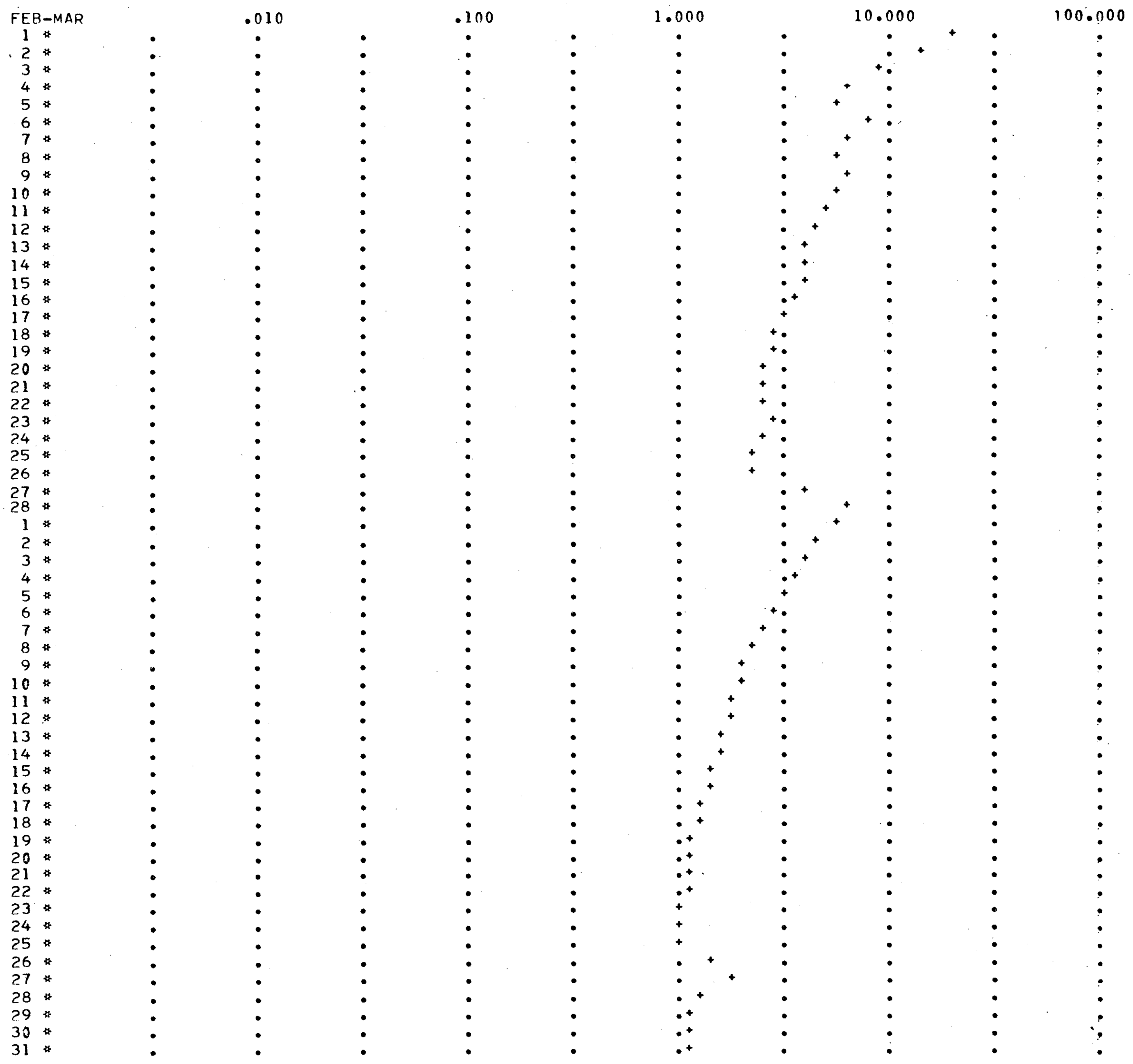
```
 1 *   0.000    .115     .5
 2 *   0.000    .218    1.3
 3 *   0.000    .151    0.0
 4 *   0.000    .136    0.0
 5 *   0.000    .117    0.0
 6 *   0.000    .098    0.0
 7 *   0.000    .090    6.6
 8 *   0.000    .094    4.3
 9 *   0.000    .122    2.8
10 *   0.000    .149     .3
11 *   0.000    .158    0.0
12 *   0.000    .139    0.0
13 *   0.000    .122     .5
14 *   0.000    .117    3.3
15 *   0.000    .124    5.6
16 *   0.000    .169    3.3
17 *   0.000    .171    0.0
18 *   0.000    .173    0.0
19 *   0.000    .158    0.0
20 *   0.000    .137    0.0
21 *   0.000    .130    0.0
22 *   0.000    .122    0.0
23 *   0.000    .117    0.0
24 *   0.000    .113    0.0
25 *   0.000    .111    0.0
26 *   0.000    .111    0.0
27 *   0.000    .109    7.1
28 *   0.000    .117    0.0
29 *   0.000    .139    6.1
30 *   0.000    .147    2.0
31 *   0.000    .183     .3
 1 *   0.000    .226   14.7
 2 *   0.000    .209    2.5
 3 *   0.000    .378   20.3
 4 *   0.000    .640   13.5
 5 *   0.000    .828    0.0
 6 *   0.000    .587    0.0
 7 *   0.000    .435     .8
 8 *   0.000    .361    2.0
 9 *   0.000    .324    2.8
10 *   0.000    .301   11.7
11 *   0.000    .344    6.1
12 *   0.000    .469   27.2
13 *   0.000    .802    4.8
14 *   0.000    .794    0.0
15 *   0.000    .610     .3
16 *   0.000    .491    0.0
17 *   0.000    .439    0.0
18 *   0.000    .397    0.0
19 *   0.000    .363    0.0
20 *   0.000    .339    0.0
21 *   0.000    .322     .3
22 *   0.000    .316   16.3
23 *   0.000    .798   31.7
24 *   0.000   4.705   39.1
25 *   0.000  10.313   26.7
26 *   0.000   8.187   23.4
27 *   0.000   7.679   15.2
28 *   0.000   5.947   10.7
29 *   0.000   5.740   13.2
30 *   0.000   7.810   46.7
```

```
DEC-JAN                  .010               .100             1.000              10.000            100.000     SIM.     OBS. RAIN+MELT
```

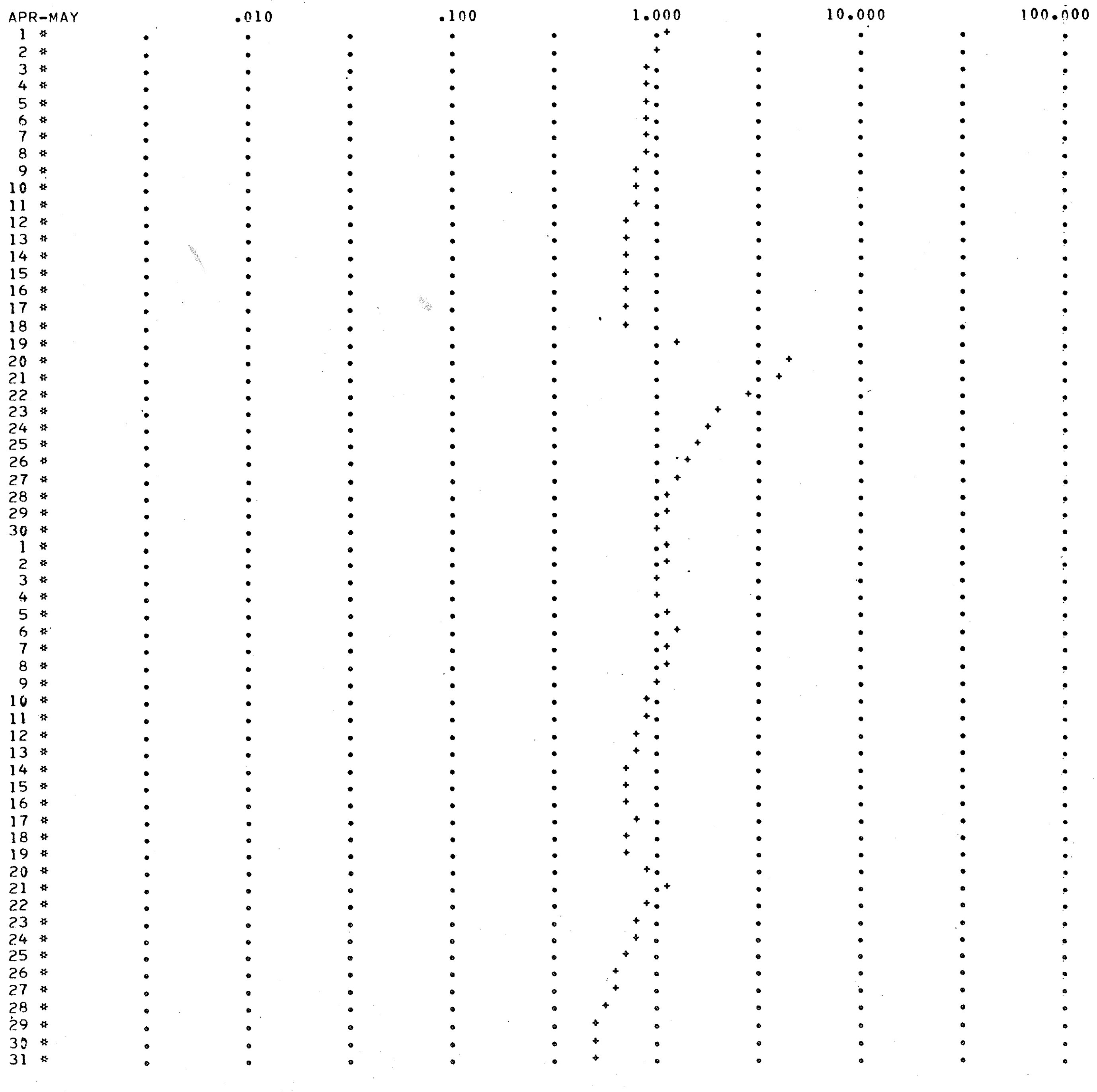


```
 1 *   0.000  13.268   19.3
 2 *   0.000  17.446    4.8
 3 *   0.000  15.225     .5
 4 *   0.000   9.673    8.9
 5 *   0.000   6.229    0.0
 6 *   0.000   4.667    1.0
 7 *   0.000   3.745    6.1
 8 *   0.000   3.388    6.3
 9 *   0.000   3.388    7.9
10 *   0.000   3.632   10.7
11 *   0.000   4.140    6.6
12 *   0.000   4.291    5.1
13 *   0.000   4.197    1.3
14 *   0.000   4.272   19.3
15 *   0.000   6.775    6.9
16 *   0.000   6.418    0.0
17 *   0.000   4.893    0.0
18 *   0.000   3.764    3.6
19 *   0.000   3.576   27.7
20 *   0.000   3.576   24.6
21 *   0.000   8.017   97.3
22 *   0.000  46.673   93.2
23 *   0.000  82.996   46.0
24 *   0.000  56.272   26.2
25 *   0.000  41.968   13.2
26 *   0.000  32.370   31.0
27 *   0.000  30.112   17.3
28 *   0.000  24.842   16.5
29 *   0.000  19.573   18.0
30 *   0.000  14.981   11.4
31 *   0.000  10.652    2.8
 1 *   0.000   7.697    7.9
 2 *   0.000   9.128   26.9
 3 *   0.000  13.701    9.1
 4 *   0.000  12.346    8.6
 5 *   0.000   9.956   21.8
 6 *   0.000  12.082   11.7
 7 *   0.000  12.910    3.3
 8 *   0.000  10.069    4.8
 9 *   0.000   8.017    6.3
10 *   0.000   7.641   13.7
11 *   0.000   9.448     .3
12 *   0.000   8.601     .3
13 *   0.000   7.227     .3
14 *   0.000   6.098    0.0
15 *   0.000   5.608    0.0
16 *   0.000   5.495    0.0
17 *   0.000   5.175    0.0
18 *   0.000   4.724    0.0
19 *   0.000   4.441     .8
20 *   0.000   4.366    3.6
21 *   0.000   4.686    5.8
22 *   0.000   5.119    4.1
23 *   0.000   6.794   69.6
24 *   0.000  17.446   18.3
25 *   0.000  21.831   20.6
26 *   0 000  21.078   17.0
27 *    .0 0  21.455   75.9
28 *    .000  49.496   51.1
29 *   0.000  52.319   15.0
30 *   0.000  35.381    6.3
31 *   0.000  25.783    0.0
```

```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)       SOUTH YAMHILL NR WHI        WATER YEAR 1965     *=SIMULATED     +=OBSERVED
```

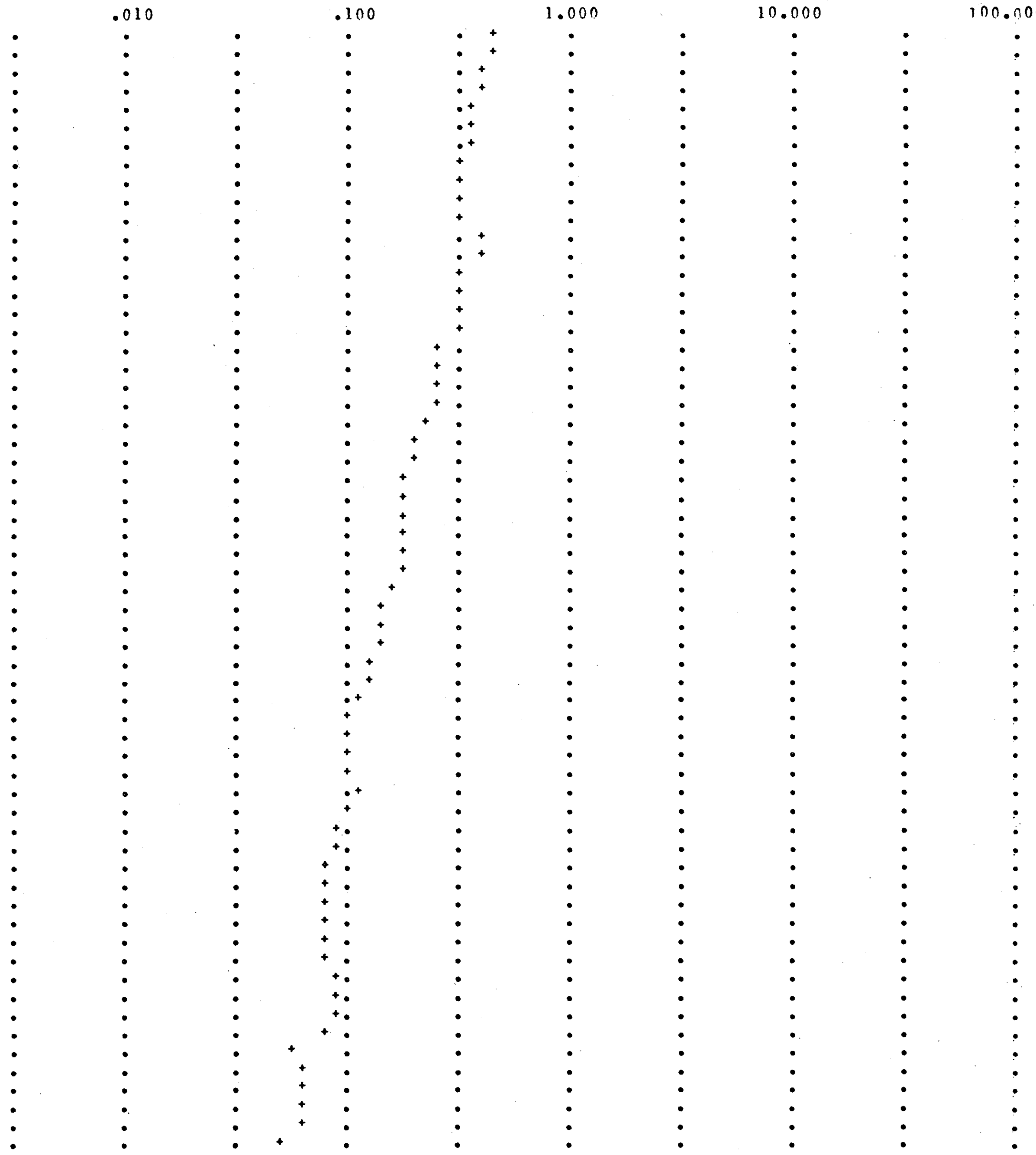


```
FEB-MAR   SIM.    OBS.  RAIN+MELT
 1 *     0.000   19.573     .3
 2 *     0.000   13.419    0.0
 3 *     0.000    8.714    1.0
 4 *     0.000    6.361     .3
 5 *     0.000    5.571   32.5
 6 *     0.000    7.773    1.8
 7 *     0.000    6.399     .3
 8 *     0.000    5.665   12.2
 9 *     0.000    6.436    0.0
10 *     0.000    5.646    1.3
11 *     0.000    5.025     .3
12 *     0.000    4.460     .8
13 *     0.000    4.046    3.0
14 *     0.000    3.802    8.6
15 *     0.000    3.839    1.5
16 *     0.000    3.501    0.0
17 *     0.000    3.181    0.0
18 *     0.000    2.955    0.0
19 *     0.000    2.767    0.0
20 *     0.000    2.578    0.0
21 *     0.000    2.447    7.1
22 *     0.000    2.635    7.9
23 *     0.000    2.804    1.5
24 *     0.000    2.503    0.0
25 *     0.000    2.296    0.0
26 *     0.000    2.183   29.0
27 *     0.000    4.065   23.4
28 *     0.000    6.493     .8
 1 *     0.000    5.759     .3
 2 *     0.000    4.724    0.0
 3 *     0.000    3.952    0.0
 4 *     0.000    3.406    0.0
 5 *     0.000    2.992    0.0
 6 *     0.000    2.691    0.0
 7 *     0.000    2.465    0.0
 8 *     0.000    2.258    0.0
 9 *     0.000    2.089    0.0
10 *     0.000    1.957    0.0
11 *     0.000    1.816    0.0
12 *     0.000    1.701    0.0
13 *     0.000    1.588    0.0
14 *     0.000    1.509    0.0
15 *     0.000    1.438    0.0
16 *     0.000    1.363    1.0
17 *     0.000    1.310    0.0
18 *     0.000    1.242    0.0
19 *     0.000    1.176    0.0
20 *     0.000    1.129    0.0
21 *     0.000    1.097    0.0
22 *     0.000    1.065     .3
23 *     0.000    1.033    0.0
24 *     0.000     .999    0.0
25 *     0.000     .982   19.3
26 *     0.000    1.468   10.7
27 *     0.000    1.741    0.0
28 *     0.000    1.316    3.6
29 *     0.000    1.188    0.0
30 *     0.000    1.114    0.0
31 *     0.000    1.065    2.5
```

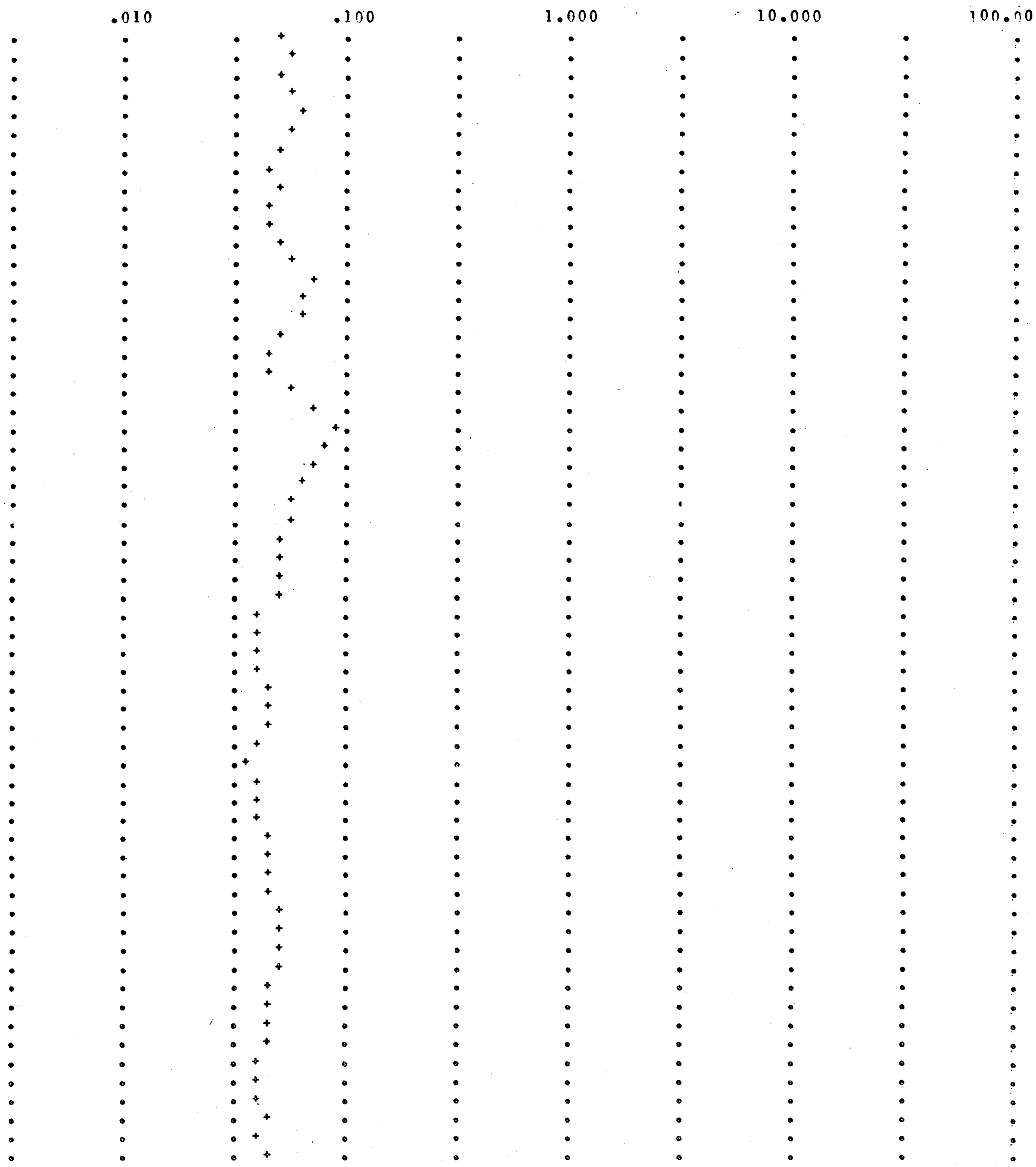


```
APR-MAY   SIM.    OBS.  RAIN+MELT
 1 *     0.000    1.060     .8
 2 *     0.000     .996    0.0
 3 *     0.000     .941    0.0
 4 *     0.000     .941    0.0
 5 *     0.000     .903     .3
 6 *     0.000     .866    1.0
 7 *     0.000     .866     .5
 8 *     0.000     .866    1.5
 9 *     0.000     .828    2.3
10 *     0.000     .828    2.8
11 *     0.000     .753    0.0
12 *     0.000     .715    0.0
13 *     0.000     .689    5.8
14 *     0.000     .711    0.0
15 *     0.000     .689    1.5
16 *     0.000     .672    4.8
17 *     0.000     .728    1.3
18 *     0.000     .715   15.5
19 *     0.000    1.323   33.3
20 *     0.000    4.441   11.9
21 *     0.000    4.009    0.0
22 *     0.000    2.691    0.0
23 *     0.000    2.089    1.3
24 *     0.000    1.795     .5
25 *     0.000    1.602    0.0
26 *     0.000    1.428    0.0
27 *     0.000    1.295    0.0
28 *     0.000    1.188     .3
29 *     0.000    1.095    0.0
30 *     0.000    1.033    5.6
 1 *     0.000    1.063    8.4
 2 *     0.000    1.142    1.3
 3 *     0.000    1.028    2.8
 4 *     0.000     .969    9.9
 5 *     0.000    1.092    8.9
 6 *     0.000    1.302    0.0
 7 *     0.000    1.171    0.0
 8 *     0.000    1.073    0.0
 9 *     0.000    1.001    0.0
10 *     0.000     .932    0.0
11 *     0.000     .866    0.0
12 *     0.000     .815    0.0
13 *     0.000     .764    0.0
14 *     0.000     .723    0.0
15 *     0.000     .693    2.5
16 *     0.000     .708    5.8
17 *     0.000     .821     .3
18 *     0.000     .700     .3
19 *     0.000     .672   14.7
20 *     0.000     .856    3.3
21 *     0.000    1.084     .3
22 *     0.000     .886    1.5
23 *     0.000     .796     .3
24 *     0.000     .751    0.0
25 *     0.000     .694    0.0
26 *     0.000     .638    0.0
27 *     0.000     .597    0.0
28 *     0.000     .555    0.0
29 *     0.000     .518    0.0
30 *     0.000     .499    0.0
31 *     0.000     .491    0.0
```

```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)      SOUTH YAMHILL NR WHI       WATER YEAR 1965     *=SIMULATED     +=OBSERVED
```



```
JUN-JUL      SIM.    OBS.  RAIN+MELT
 1 *        0.000    .470    0.0
 2 *        0.000    .440    0.0
 3 *        0.000    .407    0.0
 4 *        0.000    .380    0.0
 5 *        0.000    .365    0.0
 6 *        0.000    .358    0.0
 7 *        0.000    .339    0.0
 8 *        0.000    .320     .3
 9 *        0.000    .320    0.0
10 *        0.000    .320     .3
11 *        0.000    .301   16.0
12 *        0.000    .420     .8
13 *        0.000    .376    3.0
14 *        0.000    .320    3.8
15 *        0.000    .320    0.0
16 *        0.000    .320    0.0
17 *        0.000    .301    0.0
18 *        0.000    .263     .3
19 *        0.000    .263    0.0
20 *        0.000    .245    0.0
21 *        0.000    .245    0.0
22 *        0.000    .226    0.0
23 *        0.000    .207    0.0
24 *        0.000    .207    0.0
25 *        0.000    .188    0.0
26 *        0.000    .188    0.0
27 *        0.000    .188    0.0
28 *        0.000    .188    0.0
29 *        0.000    .179    0.0
30 *        0.000    .169     .5
 1 *        0.000    .160    0.0
 2 *        0.000    .141    0.0
 3 *        0.000    .141    0.0
 4 *        0.000    .141    0.0
 5 *        0.000    .122    0.0
 6 *        0.000    .122    0.0
 7 *        0.000    .113    0.0
 8 *        0.000    .104    0.0
 9 *        0.000    .104    0.0
10 *        0.000    .104    1.0
11 *        0.000    .104     .3
12 *        0.000    .113    0.0
13 *        0.000    .105    0.0
14 *        0.000    .094    0.0
15 *        0.000    .094    0.0
16 *        0.000    .075    0.0
17 *        0.000    .075    0.0
18 *        0.000    .075    0.0
19 *        0.000    .075    0.0
20 *        0.000    .075    7.9
21 *        0.000    .075     .5
22 *        0.000    .085    0.0
23 *        0.000    .094    0.0
24 *        0.000    .085    0.0
25 *        0.000    .075    0.0
26 *        0.000    .056     .3
27 *        0.000    .062    0.0
28 *        0.000    .066    0.0
29 *        0.000    .066    0.0
30 *        0.000    .060    0.0
31 *        0.000    .049    0.0
```



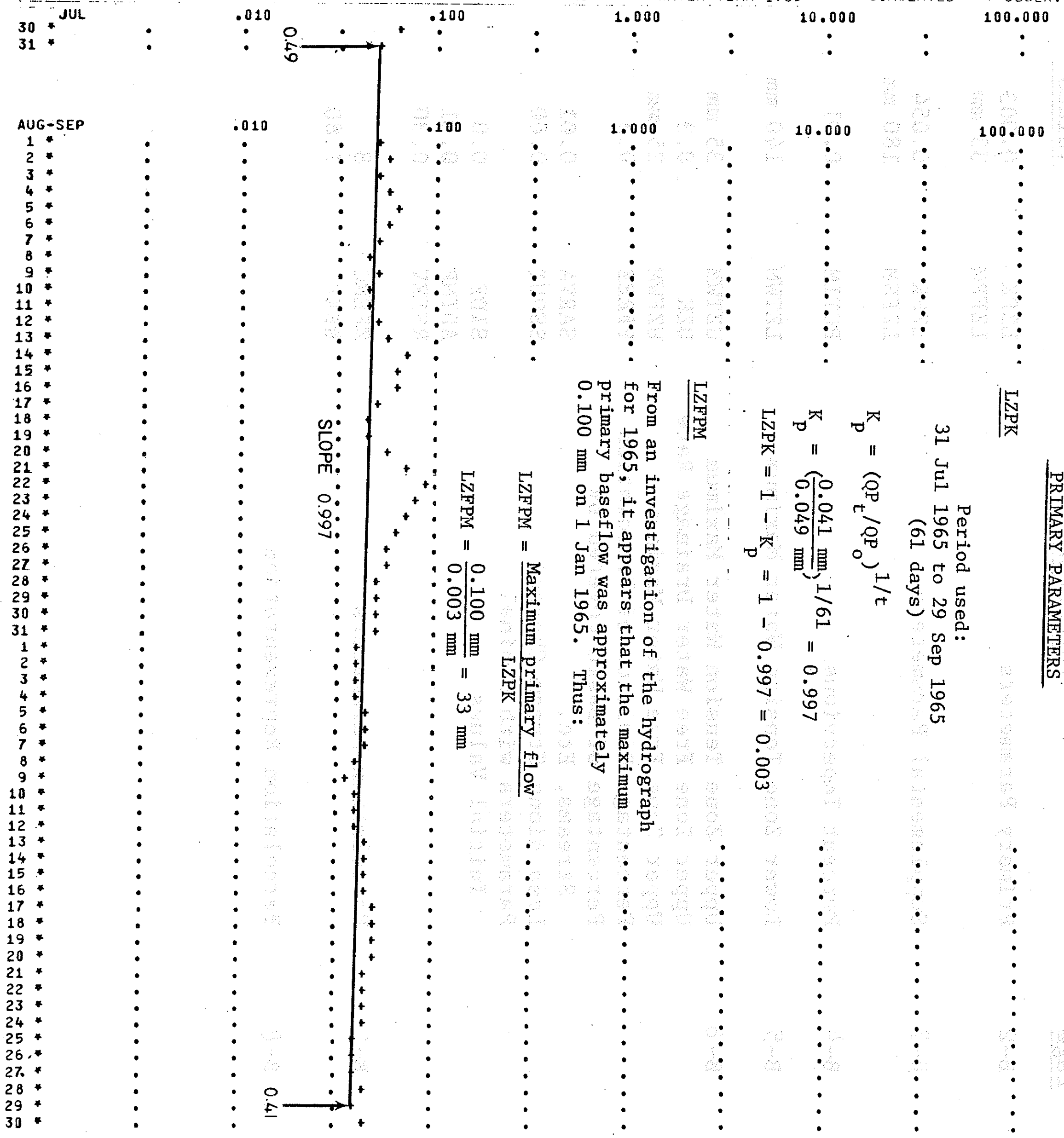
```
AUG-SEP      SIM.    OBS.  RAIN+MELT
 1 *        0.000    .049     .3
 2 *        0.000    .055     .3
 3 *        0.000    .051     .3
 4 *        0.000    .056    0.0
 5 *        0.000    .060    0.0
 6 *        0.000    .058    0.0
 7 *        0.000    .049     .3
 8 *        0.000    .047    1.5
 9 *        0.000    .049    0.0
10 *        0.000    .043     .3
11 *        0.000    .045    4.3
12 *        0.000    .053    5.1
13 *        0.000    .058    0.0
14 *        0.000    .070    0.0
15 *        0.000    .062    0.0
16 *        0.000    .060    0.0
17 *        0.000    .053    0.0
18 *        0.000    .045    0.0
19 *        0.000    .045    9.9
20 *        0.000    .055     .5
21 *        0.000    .073    0.0
22 *        0.000    .085    0.0
23 *        0.000    .081     .3
24 *        0.000    .068    0.0
25 *        0.000    .066    0.0
26 *        0.000    .056    0.0
27 *        0.000    .056    0.0
28 *        0.000    .049    0.0
29 *        0.000    .049    0.0
30 *        0.000    .049    0.0
31 *        0.000    .049    0.0
 1 *        0.000    .041    0.0
 2 *        0.000    .038    0.0
 3 *        0.000    .041    0.0
 4 *        0.000    .040    0.0
 5 *        0.000    .045    0.0
 6 *        0.000    .045    0.0
 7 *        0.000    .045    0.0
 8 *        0.000    .040    0.0
 9 *        0.000    .036    0.0
10 *        0.000    .040    0.0
11 *        0.000    .040    0.0
12 *        0.000    .041    0.0
13 *        0.000    .047    1.8
14 *        0.000    .047     .8
15 *        0.000    .045     .5
16 *        0.000    .047    0.0
17 *        0.000    .049    0.0
18 *        0.000    .053    0.0
19 *        0.000    .049    0.0
20 *        0.000    .049    0.0
21 *        0.000    .047    0.0
22 *        0.000    .047    0.0
23 *        0.000    .047    0.0
24 *        0.000    .043    0.0
25 *        0.000    .040    0.0
26 *        0.000    .041    0.0
27 *        0.000    .040    0.0
28 *        0.000    .043    0.0
29 *        0.000    .041    0.0
30 *        0.000    .043    0.0
```

APPENDIX B

INITIAL VALUES OF SOIL MOISTURE PARAMETERS
FOR
SOUTH YAMHILL RIVER NEAR WHITESON, OREGON, U.S.A.

Page	Parameters		Initial values
B-2	Primary Parameters	LZPK	0.003
		LZFPM	33 mm
B-3	Supplemental Parameters	LZSK	0.054
		LZFSM	180 mm
B-4	Percent Impervious	PCTIM	0.01
B-5	Lower Zone Tension Water Maximum	LZTWM	140 mm
B-6	Upper Zone Tension Water Maximum	UZTWM	35 mm
	Upper Zone Free Water Drainage Rate	UZK	0.3
	Upper Zone Free Water Maximum	UZFWM	25 mm
	Percentage Division of Percolation	PFREE	0.3
	Percentage of Basin Covered by Streams, Etc.	SARVA	0.01
	Loss Along Stream Channel	SSOUT	0.00
	Parameters with Nominal Initial Values	SIDE	0.0
		ADIMP	0.01
		RSERV	0.30
B-7	Percolation Parameters	ZPERC	8
		REXP	1.80
B-8	Percolation Representation		

SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1965   *=SIMULATED   +=OBSERVED



JUL	SIM.	OBS.	RAIN+MELT
30	0.000	.060	0.0
31	0.000	.049	0.0

AUG-SEP	SIM.	OBS.	RAIN+MELT
1	0.000	.049	.3
2	0.000	.055	.3
3	0.000	.051	.3
4	0.000	.056	0.0
5	0.000	.060	0.0
6	0.000	.058	0.0
7	0.000	.049	.3
8	0.000	.047	1.5
9	0.000	.049	0.0
10	0.000	.043	.3
11	0.000	.045	.3
12	0.000	.053	5.1
13	0.000	.058	0.0
14	0.000	.070	0.0
15	0.000	.062	0.0
16	0.000	.060	0.0
17	0.000	.053	0.0
18	0.000	.045	0.0
19	0.000	.045	9.9
20	0.000	.055	.5
21	0.000	.073	0.0
22	0.000	.085	0.0
23	0.000	.081	.3
24	0.000	.068	0.0
25	0.000	.066	0.0
26	0.000	.056	0.0
27	0.000	.056	0.0
28	0.000	.049	0.0
29	0.000	.049	0.0
30	0.000	.049	0.0
31	0.000	.049	0.0
1	0.000	.041	0.0
2	0.000	.038	0.0
3	0.000	.041	0.0
4	0.000	.040	0.0
5	0.000	.045	0.0
6	0.000	.045	0.0
7	0.000	.045	0.0
8	0.000	.040	0.0
9	0.000	.036	0.0
10	0.000	.040	0.0
11	0.000	.040	0.0
12	0.000	.041	0.0
13	0.000	.047	1.8
14	0.000	.047	.8
15	0.000	.045	.5
16	0.000	.047	0.0
17	0.000	.049	0.0
18	0.000	.053	0.0
19	0.000	.049	0.0
20	0.000	.049	0.0
21	0.000	.047	0.0
22	0.000	.047	0.0
23	0.000	.047	0.0
24	0.000	.043	0.0
25	0.000	.040	0.0
26	0.000	.041	0.0
27	0.000	.040	0.0
28	0.000	.043	0.0
29	0.000	.041	0.0
30	0.000	.043	0.0

PRIMARY PARAMETERS

LZPK

Period used:
31 Jul 1965 to 29 Sep 1965
(61 days)

$$K_p = (QP_t/QP_o)^{1/t}$$

$$K_p = \left(\frac{0.041\ \text{mm}}{0.049\ \text{mm}}\right)^{1/61} = 0.997$$

$$LZPK = 1 - K_p = 1 - 0.997 = 0.003$$

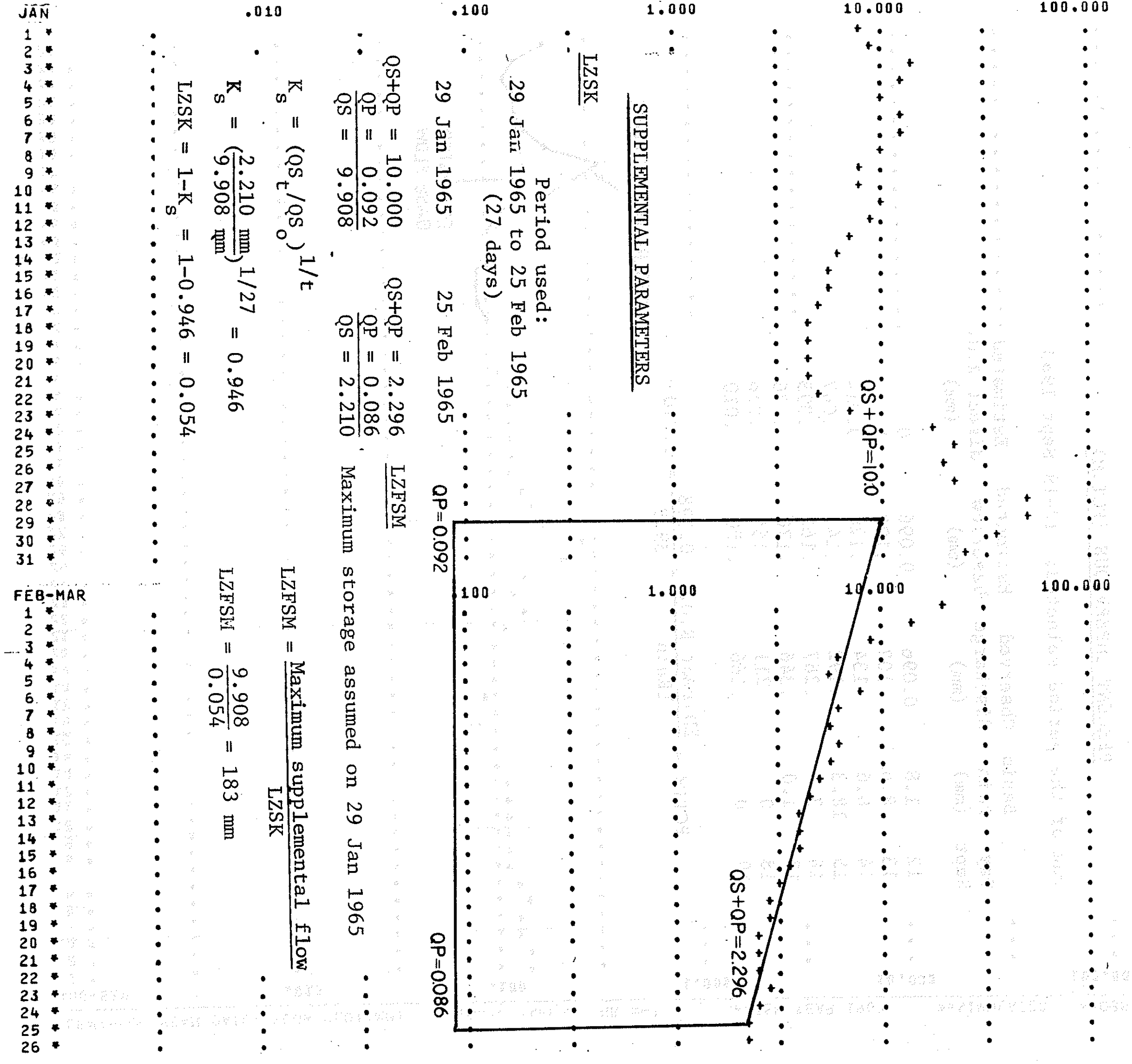
LZFPM

From an investigation of the hydrograph for 1965, it appears that the maximum primary baseflow was approximately 0.100 mm on 1 Jan 1965. Thus:

$$LZFPM = \frac{\text{Maximum primary flow}}{LZPK}$$

$$LZFPM = \frac{0.100\ \text{mm}}{0.003\ \text{mm}} = 33\ \text{mm}$$

SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1965   *=SIMULATED   +=OBSERVED



SUPPLEMENTAL PARAMETERS

LZSK

Period used:
29 Jan 1965 to 25 Feb 1965
(27 days)

29 Jan 1965	25 Feb 1965
QS+QP = 10.000	QS+QP = 2.296
QP = 0.092	QP = 0.086
QS = 9.908	QS = 2.210

$$K_s = (QS_t/QS_o)^{1/t}$$

$$K_s = \left(\frac{2.210 \text{ mm}}{9.908 \text{ mm}}\right)^{1/27} = 0.946$$

$$LZSK = 1-K_s = 1-0.946 = 0.054$$

LZFSM

Maximum storage assumed on 29 Jan 1965

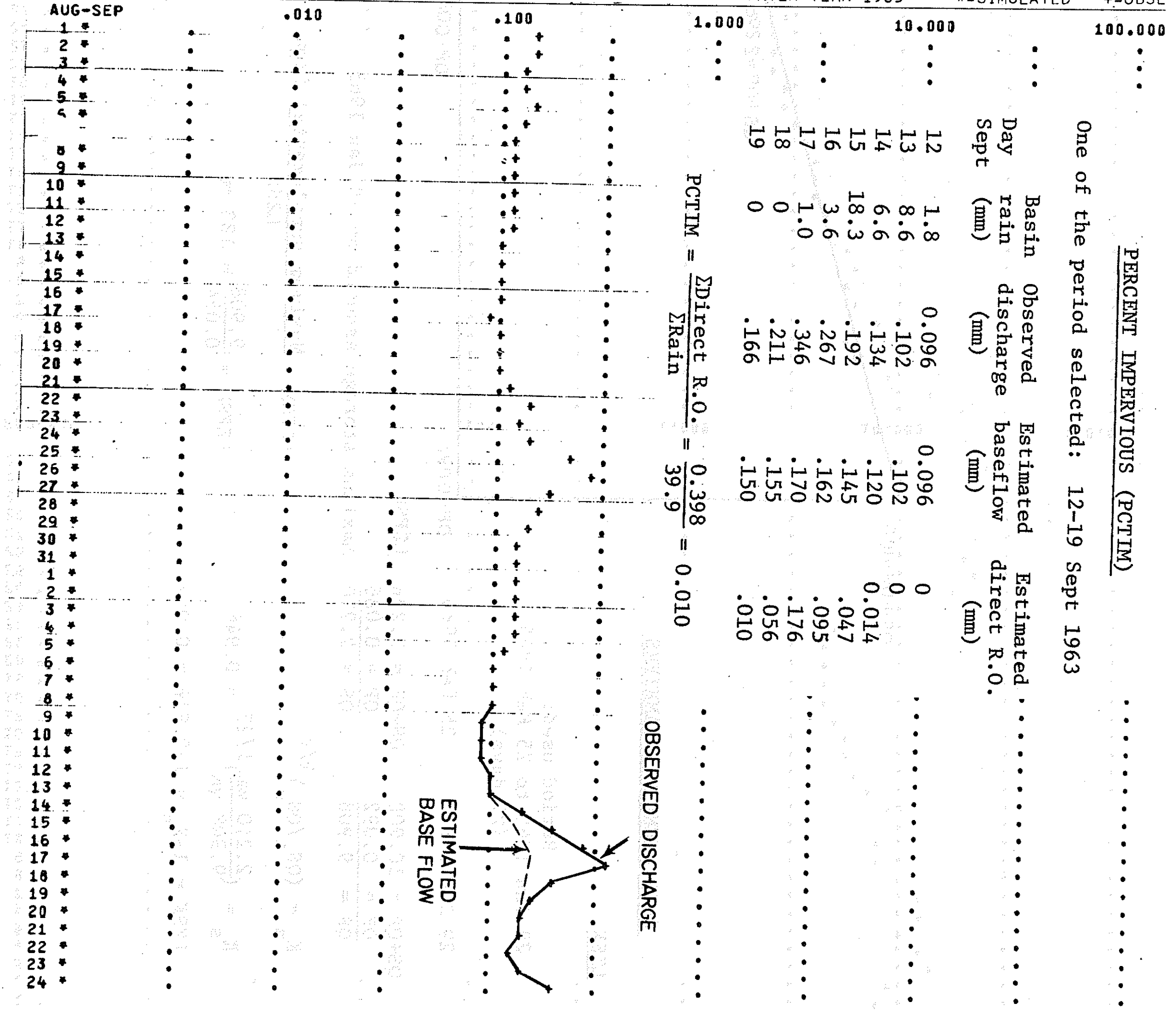
$$LZFSM = \frac{\text{Maximum supplemental flow}}{LZSK}$$

$$LZFSM = \frac{9.908}{0.054} = 183 \text{ mm}$$

```
JAN     SIM.    OBS.  RAIN+MELT
 1     0.000   7.697    7.9
 2     0.000   9.128   26.9
 3     0.000  13.701    9.1
 4     0.000  12.346    8.6
 5     0.000   9.956   21.8
 6     0.000  12.082   11.7
 7     0.000  12.910    3.3
 8     0.000  10.069    4.8
 9     0.000   8.017    6.3
10     0.000   7.641   13.7
11     0.000   9.448     .3
12     0.000   8.601     .3
13     0.000   7.227     .3
14     0.000   6.098    0.0
15     0.000   5.608    0.0
16     0.000   5.495    0.0
17     0.000   5.175    0.0
18     0.000   4.724    0.0
19     0.000   4.441     .8
20     0.000   4.366    3.6
21     0.000   4.686    5.8
22     0.000   5.119    4.1
23     0.000   6.794   69.6
24     0.000  17.446   18.3
25     0.000  21.831   20.6
26     0.000  21.078   17.0
27     0.000  21.455   75.9
28     0.000  49.496   51.1
29     0.000  52.319   15.0
30     0.000  35.381    6.3
31     0.000  25.783    0.0

FEB-MAR SIM.    OBS.  RAIN+MELT
 1     0.000  19.573     .3
 2     0.000  13.419    0.0
 3     0.000   8.714    1.0
 4     0.000   6.361     .3
 5     0.000   5.571   32.5
 6     0.000   7.773    1.8
 7     0.000   6.399     .3
 8     0.000   5.665   12.2
 9     0.000   6.436    0.0
10     0.000   5.646    1.3
11     0.000   5.025     .3
12     0.000   4.460     .8
13     0.000   4.046    3.0
14     0.000   3.802    8.6
15     0.000   3.839    1.5
16     0.000   3.501    0.0
17     0.000   3.181    0.0
18     0.000   2.955    0.0
19     0.000   2.767    0.0
20     0.000   2.578    0.0
21     0.000   2.447    7.1
22     0.000   2.635    7.9
23     0.000   2.804    1.5
24     0.000   2.503    0.0
25     0.000   2.296    0.0
26     0.000   2.183   29.0
```

SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1963   *=SIMULATED   +=OBSERVED



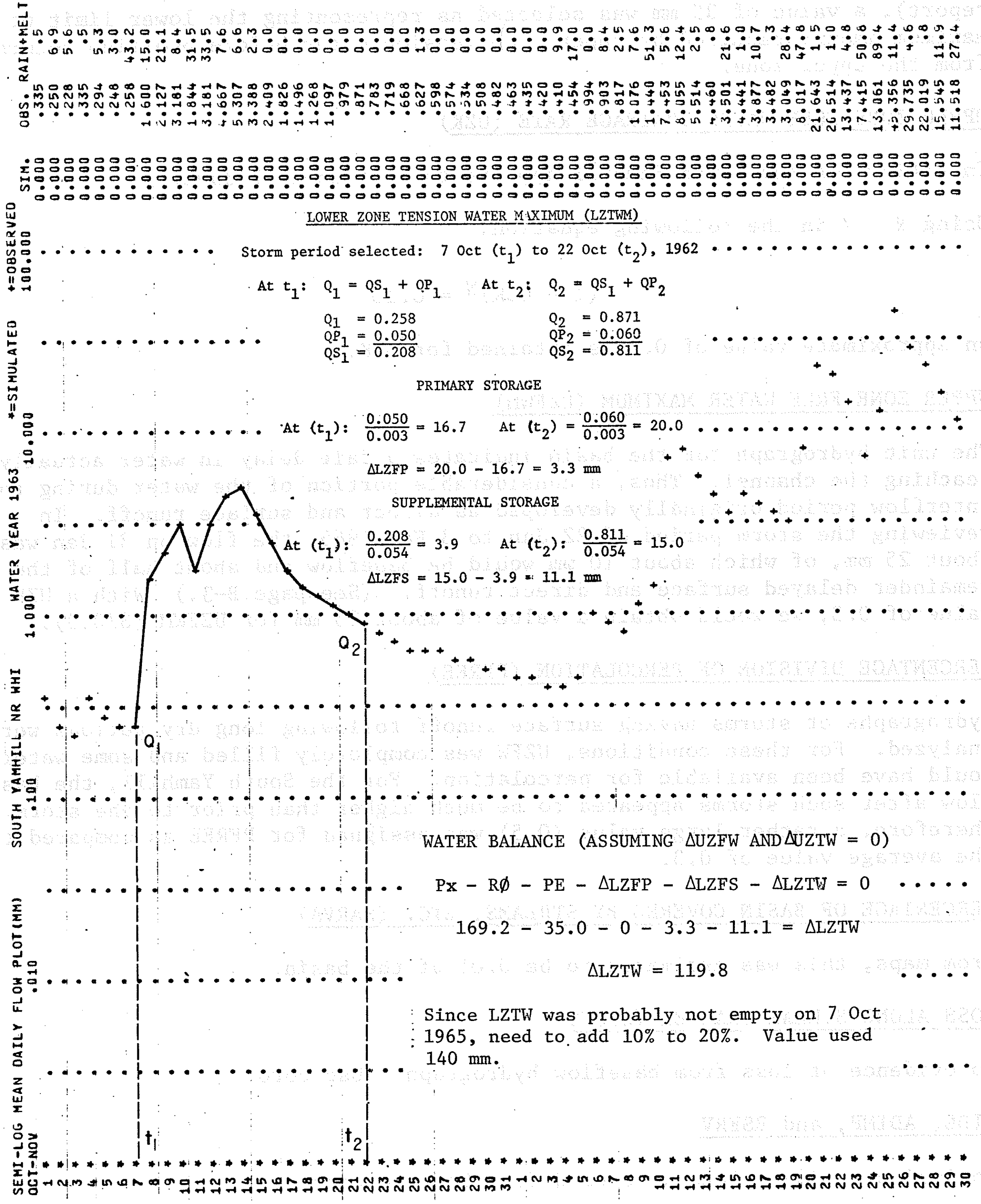
AUG-SEP	SIM.	OBS.	RAIN+MELT
1	0.000	.141	0.0
2	0.000	.136	0.0
3	0.000	.132	0.0
4	0.000	.130	0.0
5	0.000	.136	0.0
6	0.000	.126	0.0
	0.000	.113	0.0
8	0.000	.107	0.0
9	0.000	.111	0.0
10	0.000	.109	0.0
11	0.000	.109	.5
12	0.000	.111	0.0
13	0.000	.100	0.0
14	0.000	.105	0.0
15	0.000	.100	0.0
16	0.000	.098	0.0
17	0.000	.092	0.0
18	0.000	.096	2.3
19	0.000	.100	.5
20	0.000	.104	4.8
21	0.000	.117	1.3
22	0.000	.145	2.0
23	0.000	.130	7.6
24	0.000	.145	15.5
25	0.000	.224	.5
26	0.000	.288	0.0
27	0.000	.186	0.0
28	0.000	.151	0.0
29	0.000	.139	0.0
30	0.000	.126	0.0
31	0.000	.120	0.0
1	0.000	.126	.8
2	0.000	.132	0.0
3	0.000	.130	0.0
4	0.000	.120	0.0
5	0.000	.107	0.0
6	0.000	.104	0.0
7	0.000	.096	0.0
8	0.000	.100	0.0
9	0.000	.094	1.8
10	0.000	.092	1.3
11	0.000	.092	0.0
12	0.000	.096	1.8
13	0.000	.102	8.6
14	0.000	.134	6.6
15	0.000	.192	18.3
16	0.000	.267	3.6
17	0.000	.346	1.0
18	0.000	.211	0.0
19	0.000	.166	0.0
20	0.000	.149	0.0
21	0.000	.136	0.0
22	0.000	.128	13.0
23	0.000	.139	0.0
24	0.000	.201	0.0

PERCENT IMPERVIOUS (PCTIM)

One of the period selected: 12-19 Sept 1963

Day Sept	Basin rain (mm)	Observed discharge (mm)	Estimated baseflow (mm)	Estimated direct R.O. (mm)
12	1.8	0.096	0.096	0
13	8.6	.102	.102	0
14	6.6	.134	.120	0.014
15	18.3	.192	.145	.047
16	3.6	.267	.162	.095
17	1.0	.346	.170	.176
18	0	.211	.155	.056
19	0	.166	.150	.010

$$\text{PCTIM} = \frac{\Sigma\text{Direct R.O.}}{\Sigma\text{Rain}} = \frac{0.398}{39.9} = 0.010$$



```
OCT-NOV   SIM.    OBS.  RAIN+MELT
 1       0.000    .335     .5
 2       0.000    .250    6.9
 3       0.000    .228    5.6
 4       0.000    .335     .5
 5       0.000    .294    5.3
 6       0.000    .248    3.0
 7       0.000    .258   43.2
 8       0.000   1.600   15.0
 9       0.000   2.127   21.1
10       0.000   3.181    8.4
11       0.000   1.844   31.5
12       0.000   3.181   33.5
13       0.000   4.667    7.6
14       0.000   5.307    6.6
15       0.000   3.388    2.3
16       0.000   2.409    0.0
17       0.000   1.826    0.0
18       0.000   1.496    0.0
19       0.000   1.268    0.0
20       0.000   1.097    0.0
21       0.000    .979    0.0
22       0.000    .871    0.0
23       0.000    .783    0.0
24       0.000    .719    0.0
25       0.000    .668    0.0
26       0.000    .627    1.3
27       0.000    .598    0.0
28       0.000    .574    0.0
29       0.000    .534    0.0
30       0.000    .508    0.0
31       0.000    .482    0.0
 1       0.000    .463    0.0
 2       0.000    .435    0.0
 3       0.000    .420    0.0
 4       0.000    .410    9.9
 5       0.000    .454   17.0
 6       0.000    .994    0.0
 7       0.000    .903    8.4
 8       0.000    .817    2.5
 9       0.000   1.076    7.6
10       0.000   1.440   51.3
11       0.000   7.453    5.6
12       0.000   8.055   12.4
13       0.000   5.514    2.5
14       0.000   4.460     .8
15       0.000   3.501   21.6
16       0.000   4.441    1.0
17       0.000   3.877   10.7
18       0.000   3.482     .3
19       0.000   3.049   28.4
20       0.000   8.017   47.8
21       0.000  21.643    1.5
22       0.000  26.514    1.0
23       0.000  13.437    4.8
24       0.000   7.415   50.8
25       0.000  13.061   89.4
26       0.000  45.356   11.4
27       0.000  29.735    4.6
28       0.000  22.019     .8
29       0.000  15.545   11.9
30       0.000  11.518   27.4
```

<u>LOWER ZONE TENSION WATER MAXIMUM (LZTWM)</u>

Storm period selected: 7 Oct (t_1) to 22 Oct (t_2), 1962

At t_1: $Q_1 = QS_1 + QP_1$ At t_2: $Q_2 = QS_1 + QP_2$

$Q_1 = 0.258$
$QP_1 = 0.050$
$QS_1 = 0.208$

$Q_2 = 0.871$
$QP_2 = 0.060$
$QS_2 = 0.811$

PRIMARY STORAGE

At (t_1): $\frac{0.050}{0.003} = 16.7$ At (t_2) = $\frac{0.060}{0.003} = 20.0$

$\Delta LZFP = 20.0 - 16.7 = 3.3$ mm

SUPPLEMENTAL STORAGE

At (t_1): $\frac{0.208}{0.054} = 3.9$ At (t_2): $\frac{0.811}{0.054} = 15.0$

$\Delta LZFS = 15.0 - 3.9 = 11.1$ mm

WATER BALANCE (ASSUMING $\Delta UZFW$ AND $\Delta UZTW = 0$)

$Px - R\emptyset - PE - \Delta LZFP - \Delta LZFS - \Delta LZTW = 0$

$169.2 - 35.0 - 0 - 3.3 - 11.1 = \Delta LZTW$

$\Delta LZTW = 119.8$

Since LZTW was probably not empty on 7 Oct 1965, need to add 10% to 20%. Value used 140 mm.

UPPER ZONE TENSION WATER MAXIMUM (UZTWM)

From a review of small storms following dry periods (data listed in text of report), a value of 35 mm was selected as representing the lower limit of the maximum amount required by upper zone tension water before overflow occurs, from the upper zone.

UPPER ZONE FREE WATER DRAINAGE RATE (UZK)

Interflow for the South Yamhill appears to last about 7 days.

Using N = 7 in the following equation:

$$(1 - UZK)^N = 0.10$$

an approximate value of 0.3 is obtained for UZK.

UPPER ZONE FREE WATER MAXIMUM (UZFWM)

The unit hydrograph for the basin indicates a fair delay in water actually reaching the channel. Thus, a considerable portion of the water during the interflow period originally developed as direct and surface runoff. In reviewing the storm period of 22 Jan to 3 Feb 1965, the flow on 31 Jan was about 25 mm, of which about 10 mm would be baseflow and about half of the remainder delayed surface and direct runoff. (See page B-3.) With a UZK value of 0.3, we would obtain a value of about 25 mm for UZFWM (8/0.3).

PERCENTAGE DIVISION OF PERCOLATION (PFREE)

Hydrographs of storms having surface runoff following long dry periods were analyzed. For these conditions, UZFW was completely filled and some water could have been available for percolation. For the South Yamhill, the baseflow after such storms appeared to be much higher than prior to the storm. Therefore, a rather large value (0.5) was assigned for PFREE as compared to the average value of 0.3.

PERCENTAGE OF BASIN COVERED BY STREAMS, ETC. (SARVA)

From maps, this was estimated to be 0.01 of the basin.

LOSS ALONG STREAM CHANNEL (SSOUT)

No evidence of loss from baseflow hydrograph. Use zero.

SIDE, ADIMP, and RSERV

Nominal starting values were used for these parameters:

(SIDE = 0.0; ADIMP = 0.01; and RSERV = 0.30)

PERCOLATION PARAMETERS (ZPERC and REXP)

A daily maximum percolation rate curve (with upper zone storages UZTW and UZFW at maximum) was developed for the basin (fig. B-1). PBASE was computed as 9.819 mm from the equation:

$$\mathrm{PBASE} = \mathrm{LZFPM} * \mathrm{LZPK} + \mathrm{LZFSM} * \mathrm{LZSK}$$

Calculations of parameters used in this equation were developed on pages B-2 and B-3. Based on experience with other basins, a value of approximately 90 was selected for the maximum percolation rate (for the conditions as stated).

For completely dry lower zone conditions (lower zone 100% deficient), the maximum rate is defined as:

$$\text{Maximum rate} = (1 + \mathrm{ZPERC}) * \mathrm{PBASE}$$

$$90\ \mathrm{mm} = (1 + \mathrm{ZPERC}) * 9.819$$

$$\mathrm{ZPERC} = \frac{90 - 9.819}{9.819} = 8.17$$

A value of eight was selected for ZPERC and the nominal initial value of 1.80 was used for REXP.

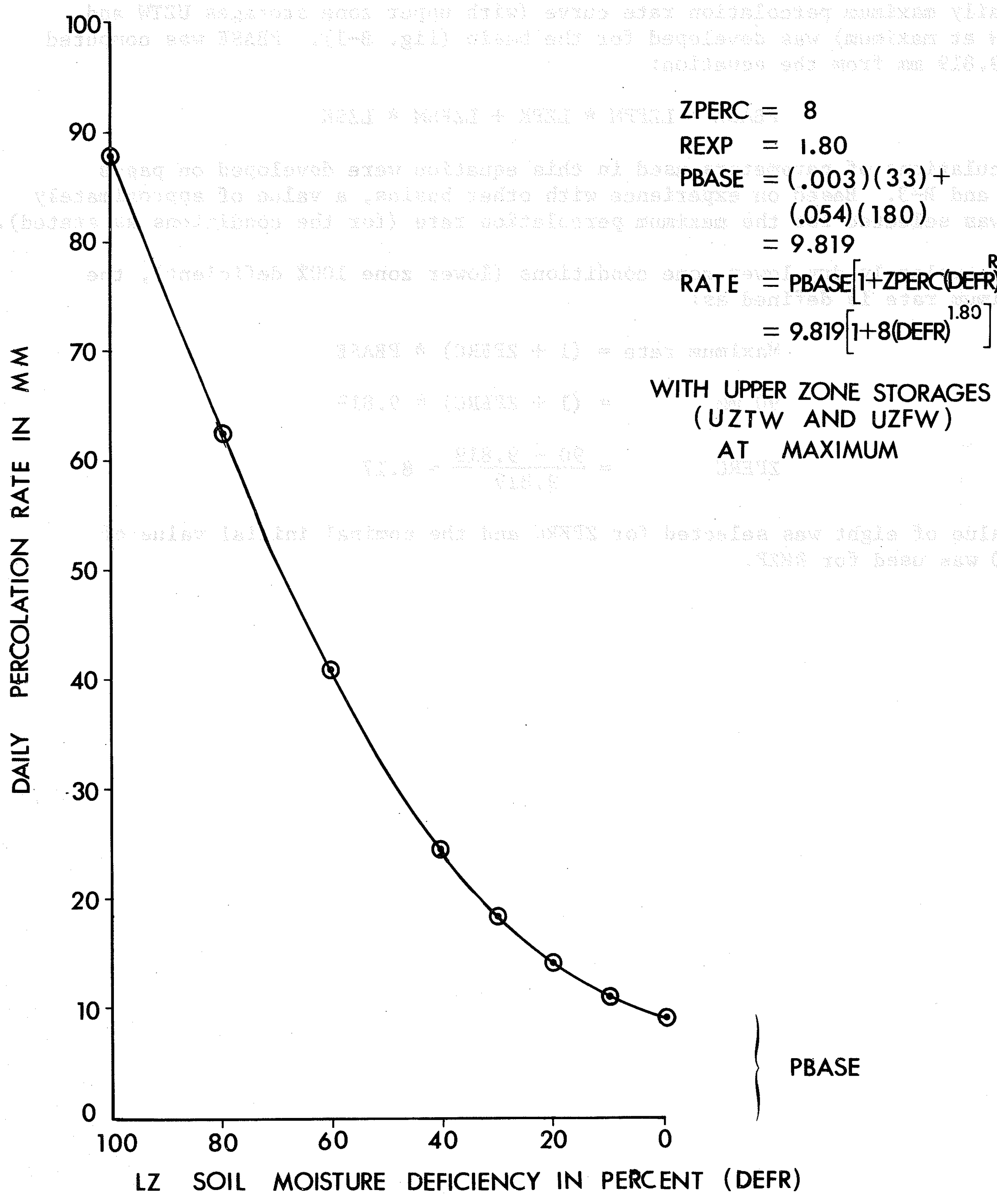


Figure B-1.--Percolation representation for South Yamhill.

APPENDIX C

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                         SOUTH YAMHILL NEAR WHITESON.OREGON

              RUN BEGINS OCT 1962     RUN ENDS SEPT 1967



SOIL-MOISTURE ACCOUNTING PARAMETERS -   SOUTH YAMHILL NEAR WHITESON.OREGON

U.S. NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM - MANUAL CALIBRATION PROGRAM

     CONTENT AND CAPACITY VALUES ARE IN MM.

                                 UPPER ZONE AND IMPERVIOUS AREA PARAMETERS

AREA NO.   AREA I.D.             AREA NAME    PX-ADJ  PE-ADJ   UZTWM   UZFWM    UZK   PCTIM   ADIMP   SARVA
   1   14194000      YAMHILL NR  MBP         1.000   1.000     35.     25.    .300   .010    .010    .010

                                 PERCOLATION AND LOWER ZONE PARAMETERS

AREA NO.    PBASE   ZPERC    REXP   LZTWM   LZFSM   LZFPM    LZSK    LZPK   PFREE   RSERV    SIDE
   1          9.8     8.0    1.80    140.    180.     33.   .0540   .0030    .50     .30     0.00

                         PE-ADJUSTMENT OR ET-DEMAND FOR THE 16TH OF EACH MONTH

AREA NO.                          1     2     3     4     5     6     7     8     9    10    11    12      I.D. OF PE DATA
   1   ET-DEMAND-MM/DAY          .5    .5   1.0   1.8   2.5   2.8   3.0   3.0   2.8   2.3   2.0   1.0

                                 INITIAL STORAGE CONTENTS

AREA NO.   UZTWC  UZFWC   LZTWC   LZFSC   LZFPC   ADIMC
   1         25.     0.     25.      0.      0.     25.



                 SOUTH YAMHILL NEAR WHITESON.OREGON

U.S. NATIONAL WEATHER SERVICE RIVER FORECAST SYSTEM - MANUAL CALIBRATION PROGRAM

                                 FLOW-POINT PARAMETERS

NO.      FLOW-POINT NAME        AREA-SQ KM     K   SSOUT OBSER COMPAR SIXIN  HISTOGRAMS
 1    SOUTH YAMHILL NR WHI        1300.00   3.01   0.00     0      1      0  TIME-DELAY .008 .033 .082 .142 .181 .173 .116 .081 .057 .044
                                                                                       .031 .023 .018 .011
                                                                             GAGE AREA   1    1    1    1    1    1    1    1    1    1
                                                                                         1    1    1    1         .
```

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                                   MULTIYEAR STATISTICAL SUMMARY

                         FLOWPOINT = SOUTH YAMHILL NR WHI     WATER YEARS 1963 TO 1967



                                      BIAS                   1ST MOMENT                             PERCENT                       BEST FIT LINE
                SIMULATED  OBSERVED  (SIM MEAN   PERCENT    (SIM)-1ST    MAXIMUM   STANDARD   STANDARD       CORREL.      OBS = A + B *SIM
  MONTH            MEAN       MEAN   -OBS MEAN)     BIAS   MOMENT(OBS)     ERROR      ERROR       ERROR       COEFF          A            B
 ..............................................................................................................................................

 OCTOBER           9.186      7.642      1.544     20.211      1.536    -14.613      3.975      52.021        .951        .055         .826
 NOVEMBER         56.895     61.096     -4.201     -6.876      -.794   -156.641     28.853      47.226        .941      -2.234        1.113
 DECEMBER        121.384    127.250     -5.866     -4.610       .380   -211.356     45.523      35.774        .962     -10.201        1.132
 JANUARY         156.830    166.336     -9.506     -5.715      -.678    233.231     50.943      30.627        .947      -6.176        1.100
 FEBRUARY         87.163     78.126      9.037     11.568      1.206   -155.589     26.791      34.293        .909     -46.835        1.434
 MARCH            85.714     80.944      4.771      5.894      -.249   -104.397     22.398      27.670        .960     -13.896        1.106
 APRIL            47.436     42.682      4.754     11.139       .590   -110.329     14.407      33.755        .929      -9.269        1.095
 MAY              19.681     19.187       .494      2.573       .122    -24.018      6.390      33.306        .963      -1.011        1.026
 JUNE              4.306      5.094      -.788    -15.471     -1.039      7.979      1.232      24.189        .792       3.265         .425
 JULY              1.320      2.069      -.749    -36.183       .066     -2.926       .740      35.753        .775        .622        1.096
 AUGUST             .749      1.092      -.344    -31.445       .491     -2.890       .705      64.559        .557       -.241        1.781
 SEPTEMBER          .908      1.143      -.236    -20.597      1.093      1.951       .539      47.155        .684        .466         .746
 ..............................................................................................................................................
 WATER YEAR       49.247     49.408      -.160      -.325     27.924    233.231     25.180      50.964        .964      -4.185        1.088
 ..............................................................................................................................................


 **NOTE...SUM OF (SIM-OBS)**2 =             1257419......ROOT MEAN OF SUM OF (SIM-OBS)**2 =     26.242...**



                 NUMBER                                                                      PERCENT                      BEST FIT LINE
       FLOW     OF CASES OBSERVED SIMULATED              PERCENT     MAXIMUM   STANDARD     STANDARD      CORREL.      OBS = A + B *SIM
    INTERVAL    OBSERVED   MEAN      MEAN       BIAS       BIAS        ERROR      ERROR        ERROR       COEFF          A            B
 ..............................................................................................................................................

     0 -     1    272      .740      .763       .023      3.103       1.951       .300       40.583        .409        .446         .385
     1 -     3    287     2.002     1.198      -.804    -40.170      -2.366       .448       22.371        .378       1.653         .292
     3 -     8    238     5.432     5.613       .181      3.329      11.050      1.317       24.253        .484       4.504         .165
     8 -    22    235    15.045    18.761      3.715     24.692      32.968      2.931       19.481        .639       9.316         .305
    22 -    50    277    35.955    47.867     11.912     33.131      37.841      4.934       13.722        .770      13.537         .468
    50 -    99    272    69.835    80.758     10.923     15.640      58.822     10.878       15.577        .641      31.933         .469
    99 -   179    133   130.000   121.537     -8.463     -6.510     102.832     18.555       14.273        .442      94.729         .290
   179 -   304     60   225.123   188.286    -36.837    -16.363     233.231     36.966       16.420        .230     198.646         .141
   304 -   489     33   371.122   306.406    -64.715    -17.438    -211.356     45.433       12.242        .432     298.827         .236
   ABOVE   489     19   663.954   570.085    -93.870    -14.138    -188.418     67.861       10.221        .910     164.806         .876
 ..............................................................................................................................................
   ABOVE    50    517   144.400   136.114     -8.286     -5.738     233.231     45.273       31.353        .943      -7.058        1.113
 ..............................................................................................................................................
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                         AREAL WATER YEAR SUMMARY     UNITS ARE MM.

                    AREA NUMBER  1      YAMHILL NR  MBP          WATER YEAR 1963



                                 SOIL MOISTURE ACCOUNTING VOLUMES

                                                                 BASEFLOW
MONTH   TOTAL-RO     IMPV-RO DIRECT-RO     SURF-RO INTERFLOW    CHANNEL NON-CHANNEL   RAIN+MELT  POTENTIAL-ET   ACTUAL-ET
OCT         56.5         1.9        .4         0.0      16.1       38.8         0.0       192.3        72.0        63.0
NOV        202.6         4.3       3.1        80.3      53.9       61.5         0.0       431.5        58.3        54.9
DEC        138.1         1.2        .9         0.0      27.9      108.3         0.0       123.4        33.2        32.8
JAN         79.8         1.2       1.0         8.0      14.7       55.1         0.0       115.1        17.4        17.3
FEB        168.8         1.7       1.6        23.5      42.1      100.0         0.0       174.0        15.4        15.3
MAR        144.9         2.3       2.0        17.9      45.0       78.1         0.0       227.1        31.9        31.7
APR        175.1         1.7       1.2         0.0      39.8      132.9         0.0       168.1        53.0        52.4
MAY        104.7         1.0        .8         0.0      20.8       82.9         0.0       104.9        76.7        70.2
JUNE        19.1          .4       0.0         0.0       0.0       19.5         0.0        37.8        83.6        60.4
JULY         5.0          .3       0.0         0.0       0.0        5.6         0.0        34.0        93.2        67.2
AUG          2.1          .4       0.0         0.0       0.0        2.7         0.0        35.1        93.3        47.3
SEPT         3.2          .6        .0         0.0        .2        3.2         0.0        56.6        82.9        57.6

TOTAL     1099.9        17.0      10.9       129.7     260.5      688.7         0.0      1700.0       710.9       570.2

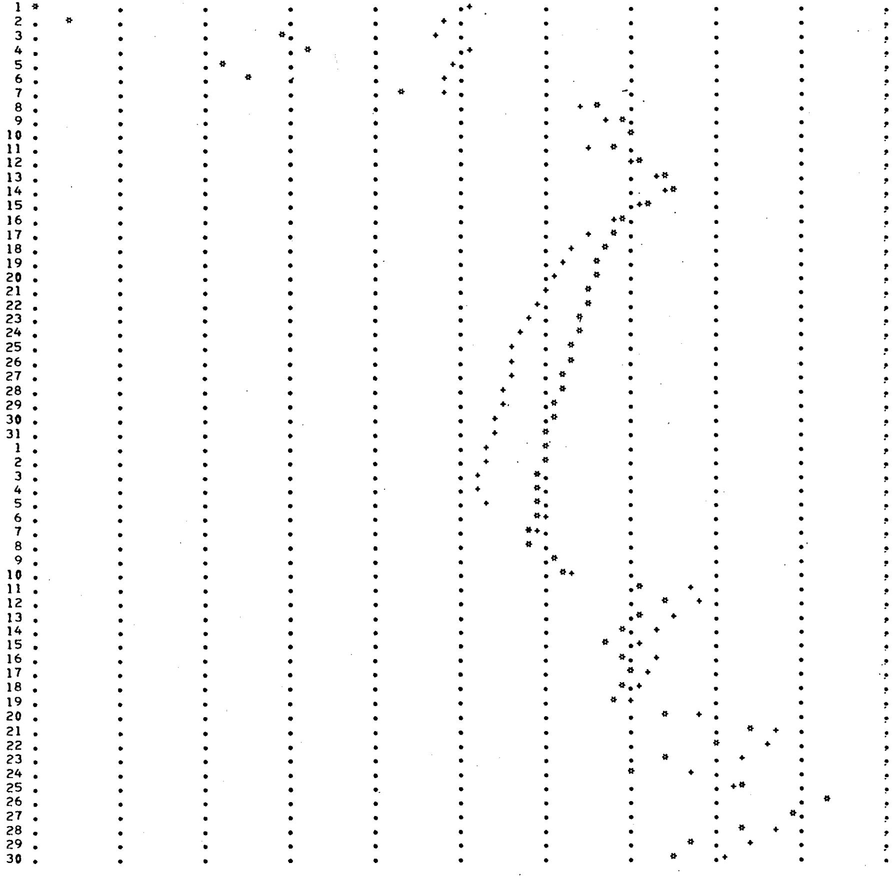


                              SOIL MOISTURE VARIABLES AT END OF MONTH

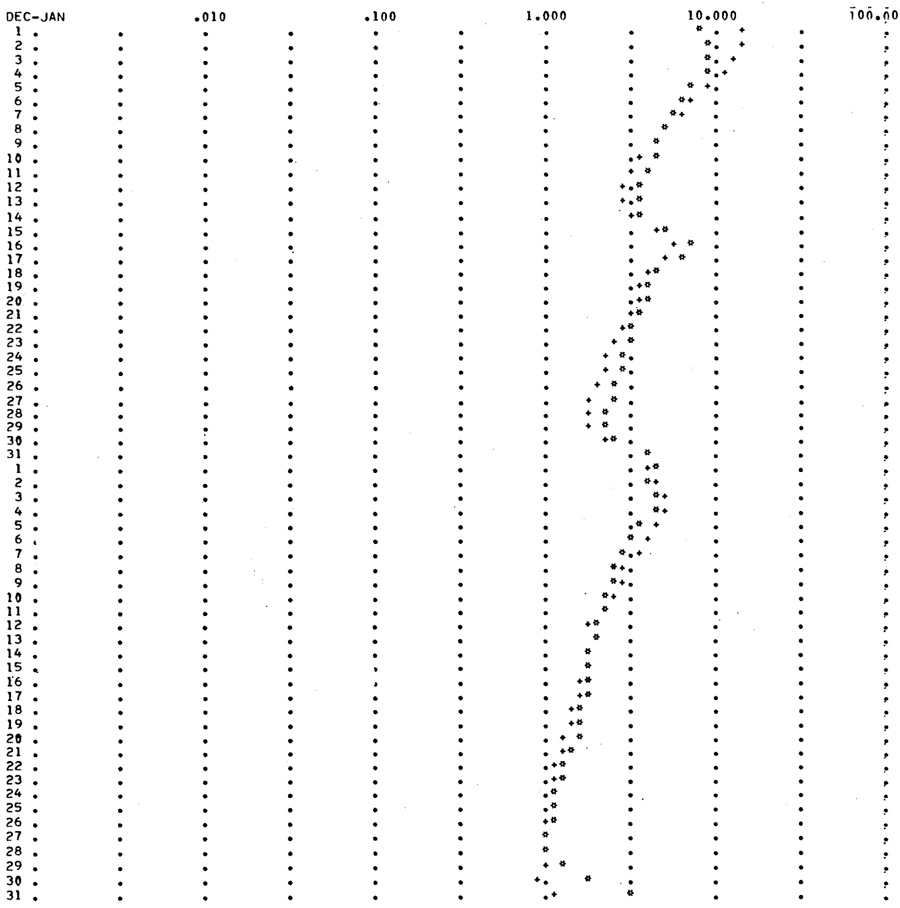
                 MONTH       UZTWC     UZFWC     LZTWC     LZFSC     LZFPC  LZDEFR      ADIMC      BALANCE
                  OCT          12.        0.        84.       17.       10.     .69       115.         -.00
                  NOV          35.       15.       140.       85.       26.     .29       173.         -.00
                  DEC          34.        4.       140.       46.       28.     .39       173.         -.00
                  JAN          35.       25.       140.       42.       28.     .40       174.         -.00
                  FEB          35.        3.       140.       52.       30.     .37       175.         -.00
                  MAR          35.        9.       140.       95.       32.     .24       174.         -.00
                  APR          32.        0.       138.       51.       31.     .38       169.         -.00
                  MAY           8.        0.       121.       21.       29.     .51       128.         -.00
                  JUNE         20.        0.        87.        4.       27.     .67       106.         -.00
                  JULY          7.        0.        67.        1.       24.     .74        73.         -.00
                  AUG          17.        0.        45.        0.       22.     .81        62.         -.00
                  SEPT         19.        0.        40.        1.       21.     .83        61.         -.00

                      LZDEFR IS THE LOWER ZONE SOIL MOISTURE DEFICIENCY RATIO.
```

SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1963   *=SIMULATED   +=OBSERVED



```
      SIM.     OBS.  RAIN+MELT
 1    0.000    .335    .5
 2     .002    .250   6.9
 3     .029    .228   5.6
 4     .040    .335    .5
 5     .013    .294   5.3
 6     .017    .248   3.0
 7     .144    .258  43.2
 8    1.887   1.600  15.0
 9    2.770   2.127  21.1
10    3.160   3.181   8.4
11    2.397   1.844  31.5
12    3.510   3.181  33.5
13    4.776   4.667   7.6
14    5.365   5.307   6.6
15    3.955   3.388   2.3
16    2.921   2.409   0.0
17    2.402   1.826   0.0
18    2.183   1.496   0.0
19    2.050   1.268   0.0
20    1.938   1.097   0.0
21    1.834    .979   0.0
22    1.735    .871   0.0
23    1.642    .783   0.0
24    1.554    .719   0.0
25    1.470    .668   0.0
26    1.393    .627   1.3
27    1.324    .598   0.0
28    1.248    .574   0.0
29    1.179    .534   0.0
30    1.115    .508   0.0
31    1.055    .482   0.0
 1     .999    .463   0.0
 2     .945    .435   0.0
 3     .894    .420   0.0
 4     .852    .410   9.9
 5     .860    .454  17.0
 6     .889    .994   0.0
 7     .778    .903   8.4
 8     .808    .817   2.5
 9    1.080   1.076   7.6
10    1.230   1.440  51.3
11    3.722   7.453   5.6
12    5.150   8.055  12.4
13    3.685   5.514   2.5
14    2.905   4.460    .8
15    2.179   3.501  21.6
16    2.768   4.441   1.0
17    3.159   3.877  10.7
18    2.745   3.482    .3
19    2.513   3.049  28.4
20    5.066   8.017  47.8
21   16.534  21.643   1.5
22   10.103  20.514   1.0
23    5.100  13.437   4.8
24    3.181   7.415  50.8
25   13.684  13.061  89.4
26   44.655  45.356  11.4
27   28.828  29.735   4.6
28   13.457  22.019    .8
29    6.793  15.545  11.9
30    5.822  11.518  27.4
```



```
      SIM.     OBS.  RAIN+MELT
 1    8.256  14.002   7.9
 2    8.783  13.343  16.3
 3    8.740  12.779   6.1
 4    8.679  11.405   2.0
 5    7.245   9.109   5.6
 6    6.048   7.453   0.0
 7    5.591   6.060    .8
 8    5.030   5.025    .3
 9    4.563   4.291    .3
10    4.220   3.726   0.0
11    3.963   3.293   0.0
12    3.742   2.936   4.3
13    3.559   2.729  11.4
14    3.687   3.086  16.3
15    5.098   4.498   9.7
16    6.861   5.627   2.0
17    6.031   4.837   0.0
18    4.721   4.103   2.0
19    3.940   3.708   3.6
20    3.780   3.482   0.0
21    3.586   3.105   0.0
22    3.294   2.823    .3
23    3.056   2.578   0.0
24    2.872   2.352   0.0
25    2.715   2.127   0.0
26    2.571   1.976   0.0
27    2.436   1.848    .5
28    2.311   1.769   1.5
29    2.202   1.754  12.4
30    2.426   2.183  14.0
31    3.958   4.027   6.3
 1    4.592   4.027   7.9
 2    4.156   4.272  12.7
 3    4.655   5.194   1.0
 4    4.622   5.157   0.0
 5    3.752   4.441   0.0
 6    3.112   3.802   0.0
 7    2.782   3.350   0.0
 8    2.595   2.955    .8
 9    2.457   2.710   3.6
10    2.345   2.560   0.0
11    2.217   2.164   0.0
12    2.091   1.728   0.0
13    1.977   1.976    .5
14    1.877   1.769   2.3
15    1.799   1.690    .8
16    1.762   1.622   1.3
17    1.688   1.545   1.3
18    1.634   1.491    .5
19    1.609   1.406   0.0
20    1.505   1.297   0.0
21    1.396   1.233   0.0
22    1.310   1.182   0.0
23    1.240   1.144   0.0
24    1.176   1.097    .3
25    1.118   1.063    .3
26    1.062   1.029   0.0
27    1.008    .984    .3
28     .966    .969  10.7
29    1.198    .971   0.0
30    1.685    .903  22.6
31    3.318   1.127  48.5
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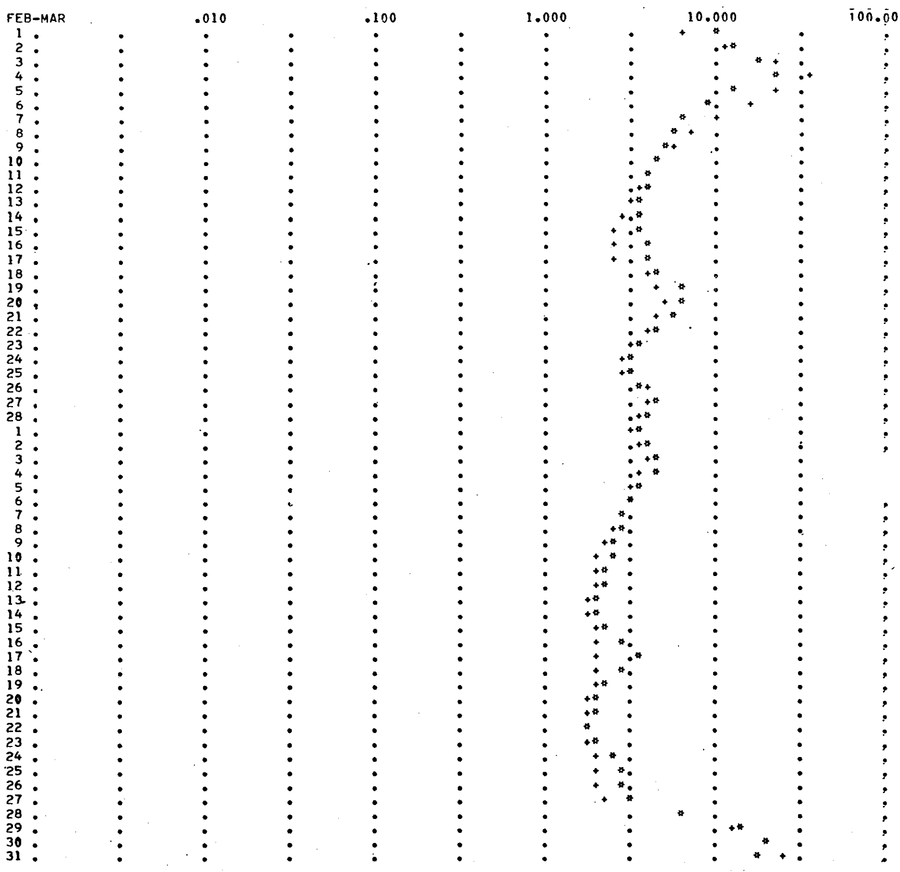
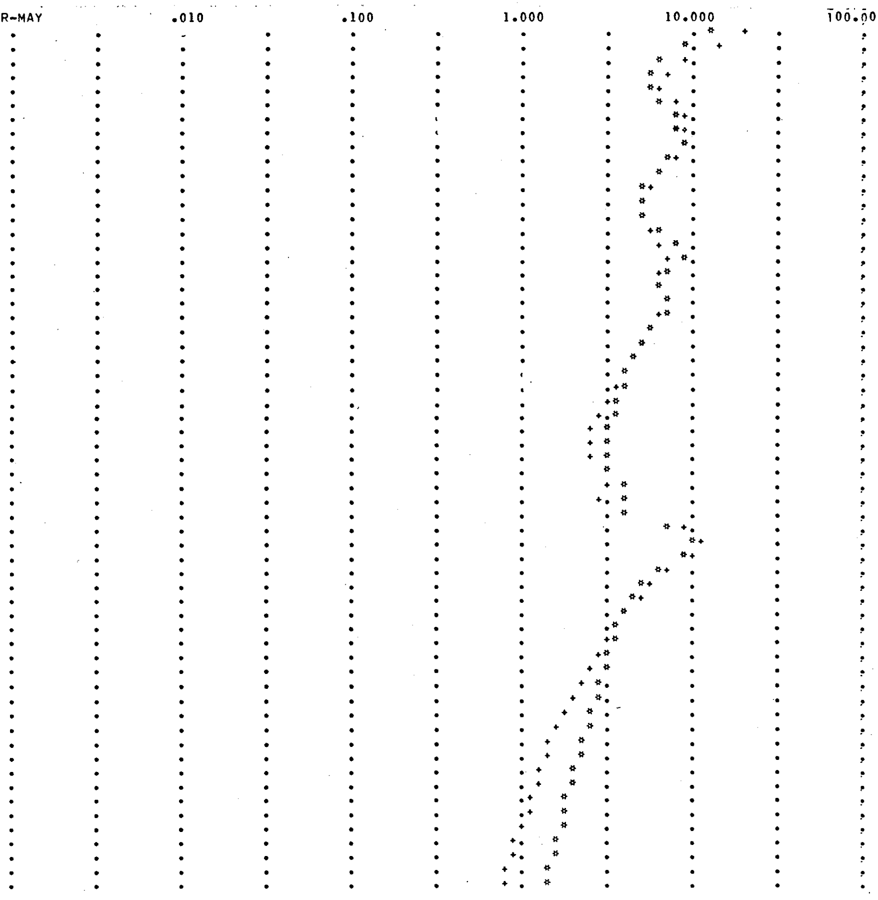
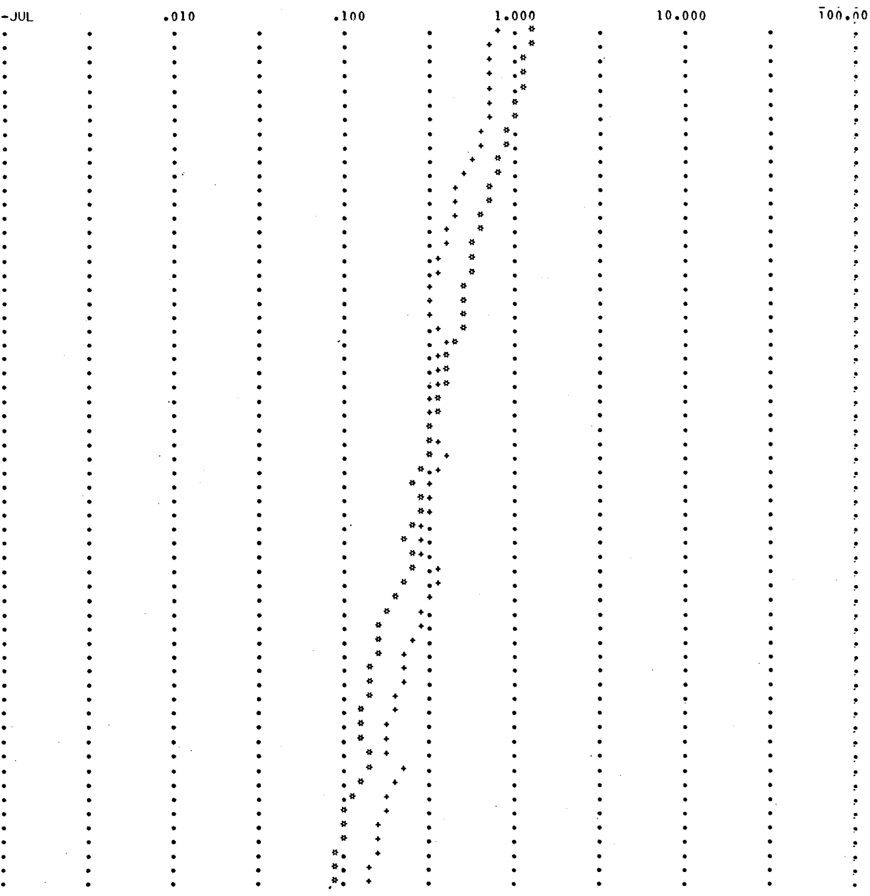


```
      SIM.     OBS.  RAIN+MELT
 1    9.460   6.361  13.2
 2   12.206  11.141  52.3
 3   18.507  22.207  16.0
 4   23.159  33.499  15.0
 5   13.021  22.584   0.0
 6    8.725  15.809   4.6
 7    6.602  10.087   0.0
 8    5.564   6.945    .3
 9    4.819   5.552   0.0
10    4.359   4.611   0.0
11    4.055   3.877   0.0
12    3.818   3.369   1.8
13    3.641   3.068   4.6
14    3.701   2.842   5.3
15    3.681   2.635   3.8
16    3.819   2.578   1.5
17    3.826   2.409  19.6
18    4.295   3.764   8.4
19    6.109   4.667   6.3
20    6.241   4.912   0.0
21    5.342   4.366    .3
22    4.268   3.802   0.0
23    3.662   3.331   0.0
24    3.342   2.974   0.0
25    3.143   2.748  15.0
26    3.579   3.915   3.6
27    4.559   3.933   0.0
28    4.052   3.463   4.6
 1    3.536   3.275   7.4
 2    3.786   3.519   9.7
 3    4.728   3.990   0.0
 4    4.433   3.613   0.0
 5    3.639   3.331   0.0
 6    3.125   3.030   0.0
 7    2.860   2.729   0.0
 8    2.684   2.465   0.0
 9    2.536   2.277   0.0
10    2.402   2.089   1.0
11    2.285   1.938   4.8
12    2.187   1.957   0.0
13    2.060   1.784    .8
14    1.984   1.735   8.9
15    2.311   1.920  11.2
16    2.948   2.051   3.0
17    3.420   2.089    .3
18    2.866   1.957   1.0
19    2.363   1.901   0.0
20    2.086   1.863   0.0
21    1.941   1.797   3.0
22    1.855   1.731   3.6
23    1.950   1.724  12.4
24    2.641   2.070    .5
25    2.888   1.995   6.1
26    2.736   1.957  15.5
27    3.328   2.296  31.7
28    6.062   6.267  36.1
29   13.564  13.193  37.1
30   18.982  20.514  25.9
31   18.125  24.278   7.1
```

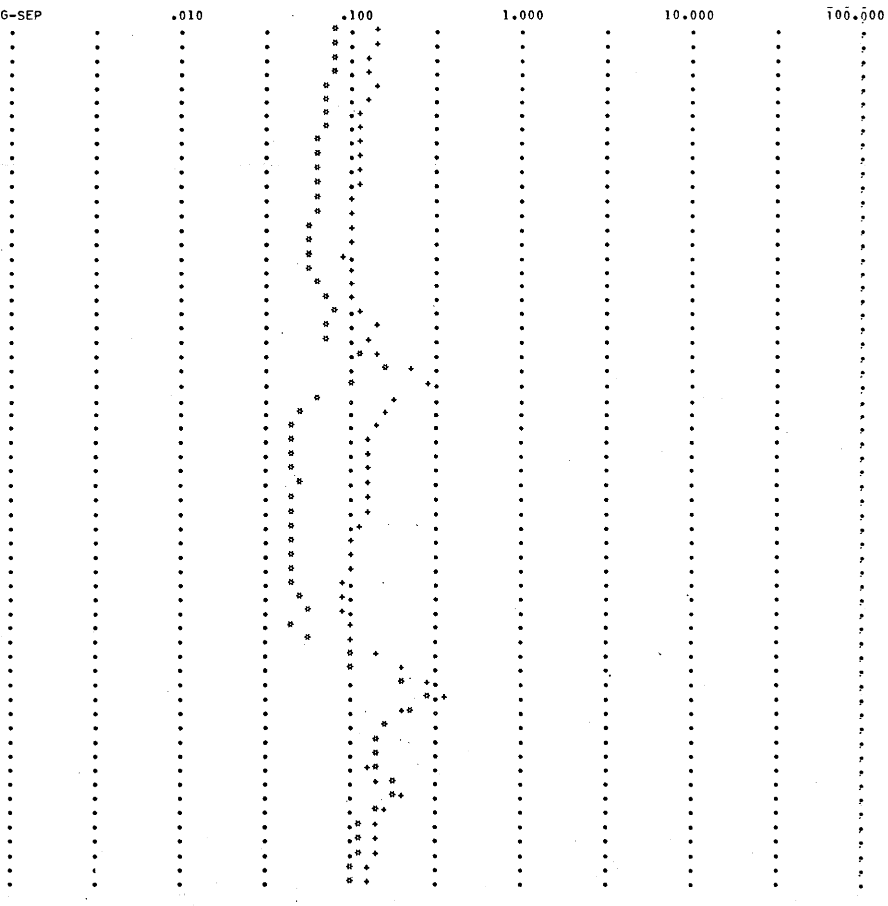
```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)     SOUTH YAMHILL NR WHI     WATER YEAR 1963     *=SIMULATED    +=OBSERVED
```



```
APR-MAY     SIM.     OBS.  RAIN+MELT
  1       12.616   19.949     0.0
  2        8.758   13.663      .8
  3        6.531    8.921     9.4
  4        5.868    7.453      .3
  5        5.793    6.625    18.3
  6        6.636    7.942    12.4
  7        8.187    8.958    15.0
  8        8.392    8.958     8.1
  9        8.544    9.015     2.5
 10        7.381    7.697      .5
 11        6.070    6.361     0.0
 12        5.207    5.420     6.9
 13        4.902    4.893     3.0
 14        4.985    4.931    22.4
 15        6.441    5.853    16.0
 16        7.936    6.531     9.4
 17        8.658    6.888     2.0
 18        7.456    6.323    11.7
 19        6.503    6.455    12.2
 20        7.300    7.001     3.0
 21        7.044    6.286     0.0
 22        5.921    5.477     0.0
 23        5.008    4.799     0.0
 24        4.485    4.272     3.8
 25        4.179    4.027     0.0
 26        3.923    3.576      .5
 27        3.700    3.162     0.0
 28        3.496    2.842     0.0
 29        3.317    2.635     5.1
 30        3.167    2.522     4.8
  1        3.031    2.484    13.5
  2        3.335    3.049     7.4
  3        4.026    3.237     1.3
  4        3.823    2.879    13.7
  5        3.892    4.046    41.1
  6        7.381    8.977    14.0
  7        9.802   10.916     4.6
  8        8.534    9.937      .8
  9        6.334    7.490     3.6
 10        4.922    5.834     1.8
 11        4.240    4.761      .5
 12        3.876    3.990      .3
 13        3.624    3.519     0.0
 14        3.417    3.086     0.0
 15        3.233    2.748     1.5
 16        3.068    2.428     0.0
 17        2.901    2.164     0.0
 18        2.745    1.957     0.0
 19        2.599    1.758     0.0
 20        2.462    1.592     0.0
 21        2.332    1.459      .3
 22        2.211    1.355      .5
 23        2.097    1.287     0.0
 24        1.984    1.199     0.0
 25        1.879    1.131     0.0
 26        1.780    1.071     0.0
 27        1.687     .992     0.0
 28        1.599     .939     0.0
 29        1.516     .879     0.0
 30        1.437     .834      .3
 31        1.363     .819     0.0
```



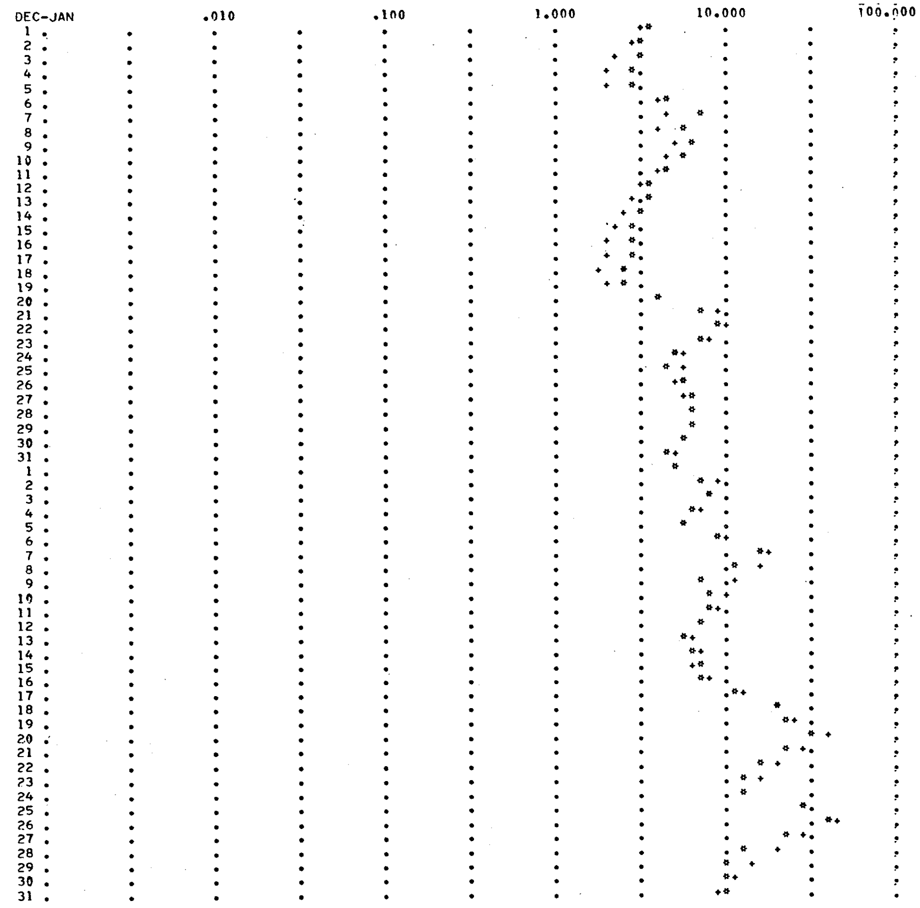
```
JUN-JUL     SIM.     OBS.  RAIN+MELT
  1        1.292     .762     0.0
  2        1.226     .728     2.0
  3        1.172     .723      .3
  4        1.112     .689     3.3
  5        1.068     .734     1.8
  6        1.013     .723     0.0
  7         .948     .674     0.0
  8         .894     .632      .8
  9         .851     .600      .3
 10         .808     .570     0.0
 11         .765     .512     0.0
 12         .725     .463     0.0
 13         .689     .450     0.0
 14         .654     .431     0.0
 15         .622     .408     0.0
 16         .591     .396     0.0
 17         .561     .361     0.0
 18         .534     .344     0.0
 19         .507     .318     0.0
 20         .483     .303     2.5
 21         .476     .309    11.4
 22         .499     .363      .5
 23         .466     .414      .3
 24         .411     .358     6.1
 25         .404     .361     0.0
 26         .387     .356     0.0
 27         .350     .316     2.5
 28         .340     .309     1.3
 29         .330     .324     2.0
 30         .316     .344     2.8
  1         .307     .380     0.0
  2         .279     .337     0.0
  3         .260     .305     6.9
  4         .277     .303     3.6
  5         .290     .329     0.0
  6         .242     .284     1.5
  7         .227     .271     3.8
  8         .240     .288     7.9
  9         .256     .344     1.0
 10         .222     .361     2.0
 11         .202     .326     0.0
 12         .178     .295     0.0
 13         .167     .269     0.0
 14         .159     .247     0.0
 15         .153     .231     0.0
 16         .147     .222     0.0
 17         .141     .215     0.0
 18         .136     .207     0.0
 19         .130     .199     0.0
 20         .126     .184     0.0
 21         .122     .188     5.3
 22         .143     .186     2.0
 23         .147     .215     0.0
 24         .119     .203     0.0
 25         .106     .181     0.0
 26         .101     .173     0.0
 27         .098     .166     0.0
 28         .095     .154     0.0
 29         .092     .152     0.0
 30         .089     .143     0.0
 31         .086     .141     0.0
```



```
AUG-SEP     SIM.     OBS.  RAIN+MELT
  1         .083     .141     0.0
  2         .081     .136     0.0
  3         .079     .132     0.0
  4         .076     .130     0.0
  5         .074     .136     0.0
  6         .072     .126     0.0
  7         .070     .113     0.0
  8         .069     .107     0.0
  9         .067     .111     0.0
 10         .065     .109     0.0
 11         .064     .109      .5
 12         .065     .111     0.0
 13         .062     .100     0.0
 14         .060     .105     0.0
 15         .058     .100     0.0
 16         .057     .098     0.0
 17         .056     .092     0.0
 18         .055     .096     2.3
 19         .066     .100      .5
 20         .069     .104     4.8
 21         .084     .117     1.3
 22         .069     .145     2.0
 23         .070     .130     7.6
 24         .110     .145    15.5
 25         .162     .224      .5
 26         .104     .288     0.0
 27         .062     .186     0.0
 28         .048     .151     0.0
 29         .047     .139     0.0
 30         .046     .126     0.0
 31         .046     .120     0.0
  1         .045     .126      .8
  2         .048     .132     0.0
  3         .047     .130     0.0
  4         .045     .120     0.0
  5         .044     .107     0.0
  6         .043     .104     0.0
  7         .043     .096     0.0
  8         .043     .100     0.0
  9         .042     .094     1.8
 10         .051     .092     1.3
 11         .058     .092     0.0
 12         .046     .096     1.8
 13         .058     .102     8.6
 14         .098     .134     6.6
 15         .100     .192    18.3
 16         .211     .267     3.6
 17         .282     .346     1.0
 18         .213     .211     0.0
 19         .163     .166     0.0
 20         .143     .149     0.0
 21         .136     .136     0.0
 22         .134     .128    13.0
 23         .185     .139     0.0
 24         .178     .201     0.0
 25         .135     .166     0.0
 26         .117     .141     0.0
 27         .111     .136     0.0
 28         .107     .139     0.0
 29         .103     .130     0.0
 30         .099     .120     0.0
```

```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)     SOUTH YAMHILL NR WHI     WATER YEAR 1964     *=SIMULATED     +=OBSERVED
```

```
OCT-NOV   SIM.    OBS.  RAIN+MELT
  1       .096    .119    0.0
  2       .092    .111    0.0
  3       .089    .109    0.0
  4       .087    .113    1.0
  5       .093    .113    2.5
  6       .098    .120    1.5
  7       .092    .126    0.0
  8       .083    .130    0.0
  9       .077    .124    1.0
 10       .078    .119    1.3
 11       .078    .117    2.5
 12       .090    .120     .5
 13       .082    .136    4.1
 14       .092    .137    1.0
 15       .080    .162    1.5
 16       .076    .143    0.0
 17       .064    .139    0.0
 18       .059    .128     .3
 19       .058    .124    0.0
 20       .063    .128    7.4
 21       .101    .136   16.5
 22       .351    .753   29.5
 23      1.776   2.748   16.0
 24      2.424   2.108   19.0
 25      2.447   3.011    3.6
 26      2.145   2.127    1.3
 27      1.529   1.364     .5
 28      1.317   1.029   11.7
 29      1.576   1.250    1.3
 30      1.476   1.046   11.4
 31      1.726   1.233    0.0
  1      1.512    .997   15.5
  2      1.645   1.319    2.3
  3      2.063   1.664   22.1
  4      2.339   2.221   11.2
  5      3.453   3.162    8.4
  6      3.063   2.691    9.1
  7      3.152   2.710   53.1
  8      6.197   8.845    9.1
  9      8.302   9.259     .8
 10      5.667   5.759   14.0
 11      4.700   5.063     .8
 12      3.692   3.764     .8
 13      2.939   2.936   19.0
 14      3.159   3.613   29.5
 15      5.723   7.001   13.2
 16      7.164   8.620   16.0
 17      6.596   8.356   13.0
 18      6.704   9.617    9.1
 19      5.947   8.488   11.9
 20      6.355   8.601    3.3
 21      5.569   6.888    5.3
 22      4.880   5.778   13.2
 23      5.093   6.022   17.3
 24      6.555   7.942    3.6
 25      6.559   7.377    3.0
 26      5.641   6.286    9.9
 27      5.113   5.721     .8
 28      5.024   5.006    0.0
 29      4.402   4.272    0.0
 30      3.875   3.651    0.0
```



```
DEC-JAN   SIM.    OBS.  RAIN+MELT
  1      3.535   3.124    0.0
  2      3.308   2.710    0.0
  3      3.122   2.352    1.3
  4      2.961   2.089    3.3
  5      2.848   1.957   36.1
  6      4.219   3.764    6.1
  7      6.712   4.366    1.8
  8      5.853   3.877   18.5
  9      6.034   5.063     .3
 10      5.631   4.554     .3
 11      4.505   3.858    0.0
 12      3.757   3.275    0.0
 13      3.381   2.842    0.0
 14      3.155   2.522    0.0
 15      2.976   2.277    1.0
 16      2.822   2.089     .5
 17      2.675   1.976     .8
 18      2.535   1.784    7.6
 19      2.546   1.901   24.1
 20      3.985   4.122   29.2
 21      7.044   8.544    8.1
 22      8.735  10.445    2.3
 23      6.948   8.017    1.3
 24      5.104   5.947   12.4
 25      4.555   5.401    2.0
 26      5.404   5.194   15.2
 27      6.008   5.684   13.7
 28      6.409   6.305     .5
 29      6.544   6.323     .5
 30      5.408   5.382    0.0
 31      4.566   4.743   11.4
  1      4.934   5.063   28.2
  2      6.884   9.391    1.0
  3      8.036   8.394    5.8
  4      6.614   6.794    1.5
  5      5.826   5.947   27.9
  6      8.684  10.125   24.4
  7     16.277  17.503     .5
  8     10.665  15.112    8.6
  9      7.372  11.028   14.5
 10      7.633  10.050    6.9
 11      8.160   8.921    0.0
 12      7.092   7.377     .3
 13      5.858   6.286   16.5
 14      6.344   7.001    2.3
 15      6.937   6.342   12.4
 16      7.198   8.017   24.9
 17     11.318  12.233   45.7
 18     20.778  20.702   24.1
 19     21.256  25.971   51.8
 20     31.632  41.404   16.0
 21     22.637  27.289   10.2
 22     15.232  20.514   12.2
 23     12.280  16.147    7.1
 24     12.188  12.685   58.2
 25     27.363  28.983   43.4
 26     39.201  43.098    1.0
 27     22.461  27.477    5.6
 28     13.000  20.137    6.6
 29      9.757  14.454   12.7
 30     10.333  11.330    1.5
 31      9.773   9.071   10.9
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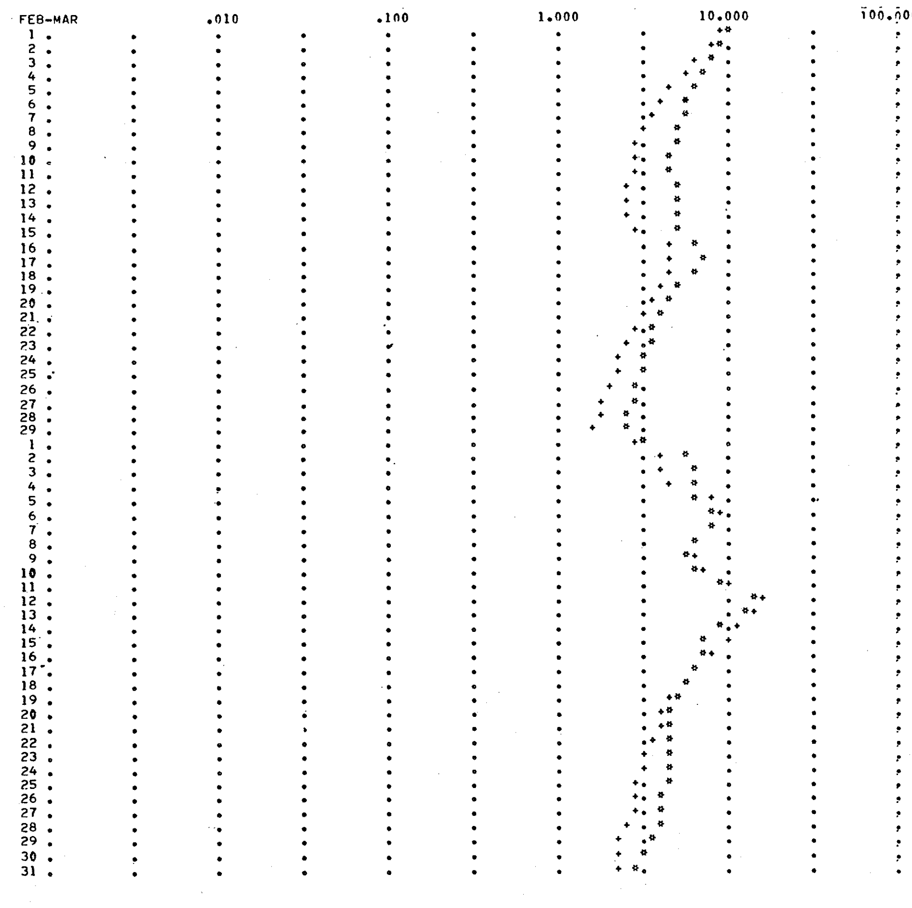

```
FEB-MAR   SIM.    OBS.  RAIN+MELT
  1      9.457   8.732    3.6
  2      9.090   7.509    0.0
  3      7.938   6.267    0.0
  4      6.852   5.420    1.5
  5      6.146   4.705    0.0
  6      5.676   4.103    0.0
  7      5.320   3.632    0.0
  8      5.017   3.275    0.0
  9      4.743   2.936    0.0
 10      4.504   2.710   10.9
 11      4.710   2.936     .3
 12      5.078   2.635    6.9
 13      4.901   2.635    2.0
 14      5.056   2.541    5.1
 15      4.931   2.861   18.8
 16      6.309   4.667    6.3
 17      6.918   4.649    1.8
 18      6.186   4.366    0.0
 19      5.073   3.952    0.0
 20      4.327   3.538    0.0
 21      3.905   3.162    0.0
 22      3.638   2.842    0.0
 23      3.427   2.560    0.0
 24      3.241   2.352    0.0
 25      3.069   2.145    0.0
 26      2.907   1.995    0.0
 27      2.755   1.848     .5
 28      2.614   1.724    2.3
 29      2.496   1.656   24.6
  1      3.203   2.823   12.4
  2      5.698   3.764    8.6
  3      6.449   4.046    8.6
  4      6.001   4.479   21.3
  5      6.593   8.074   15.7
  6      8.116   9.259    4.1
  7      7.735   7.942     .5
  8      6.133   6.342    9.9
  9      5.450   6.135   14.0
 10      6.331   6.907   15.0
 11      8.510   9.711   33.8
 12     13.931  15.301    9.9
 13     12.126  14.924    1.0
 14      9.135  11.028    8.6
 15      7.324   9.523    2.8
 16      6.863   7.773     .3
 17      6.027   6.211    3.3
 18      5.384   5.382     .8
 19      4.955   4.611    0.0
 20      4.561   4.046    7.6
 21      4.465   3.933    2.5
 22      4.699   3.651    1.8
 23      4.556   3.275    7.4
 24      4.366   3.086    0.0
 25      4.399   2.785    3.6
 26      4.068   2.710    3.6
 27      4.045   2.710    0.0
 28      3.775   2.484    0.0
 29      3.411   2.334    0.0
 30      3.133   2.240    0.0
 31      2.937   2.164    2.0
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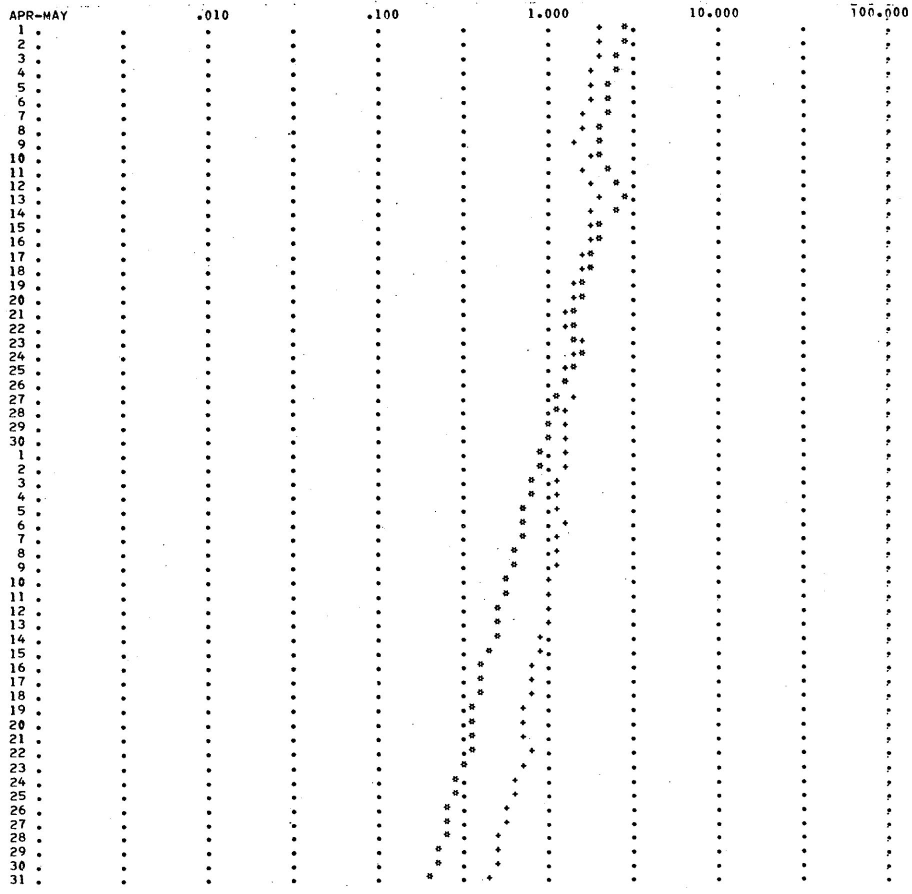
```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)     SOUTH YAMHILL NR WHI     WATER YEAR 1964     *=SIMULATED    +=OBSERVED
```



```
 DAY    SIM.    OBS. RAIN+MELT
  1    2.786   2.108   4.3
  2    2.663   2.070   3.8
  3    2.561   1.957   0.0
  4    2.432   1.780   3.0
  5    2.304   1.765   2.3
  6    2.299   1.731    .5
  7    2.182   1.596   0.0
  8    2.011   1.509   0.0
  9    1.889   1.474  10.2
 10    2.058   1.724   2.5
 11    2.157   1.652   7.6
 12    2.474   1.848   5.8
 13    2.696   1.957   0.0
 14    2.484   1.856   0.0
 15    2.099   1.746   4.1
 16    1.887   1.720   3.3
 17    1.847   1.649   0.0
 18    1.788   1.513   0.0
 19    1.644   1.417   0.0
 20    1.526   1.334   0.0
 21    1.436   1.304   1.3
 22    1.379   1.314  11.7
 23    1.440   1.562   1.0
 24    1.524   1.410   0.0
 25    1.375   1.325    .3
 26    1.229   1.284   4.3
 27    1.150   1.398   0.0
 28    1.068   1.331   0.0
 29    1.006   1.263    .5
 30     .956   1.216   5.6
  1     .931   1.250   1.3
  2     .888   1.257   1.3
  3     .830   1.182   0.0
  4     .779   1.131    .8
  5     .747   1.110   7.6
  6     .745   1.267   0.0
  7     .685   1.144   3.0
  8     .652   1.124   0.0
  9     .605   1.060    .3
 10     .572   1.024   1.5
 11     .550   1.003   0.0
 12     .521    .962   3.3
 13     .509    .994   0.0
 14     .474    .933   0.0
 15     .445    .879   0.0
 16     .421    .813    .5
 17     .403    .779    .3
 18     .386    .757   0.0
 19     .365    .717    .8
 20     .358    .694   6.6
 21     .369    .745   1.0
 22     .342    .757   1.3
 23     .316    .708   0.0
 24     .291    .666   0.0
 25     .275    .623   0.0
 26     .262    .570   0.0
 27     .250    .544   0.0
 28     .239    .514   0.0
 29     .229    .516   0.0
 30     .219    .499   0.0
 31     .209    .470   0.0
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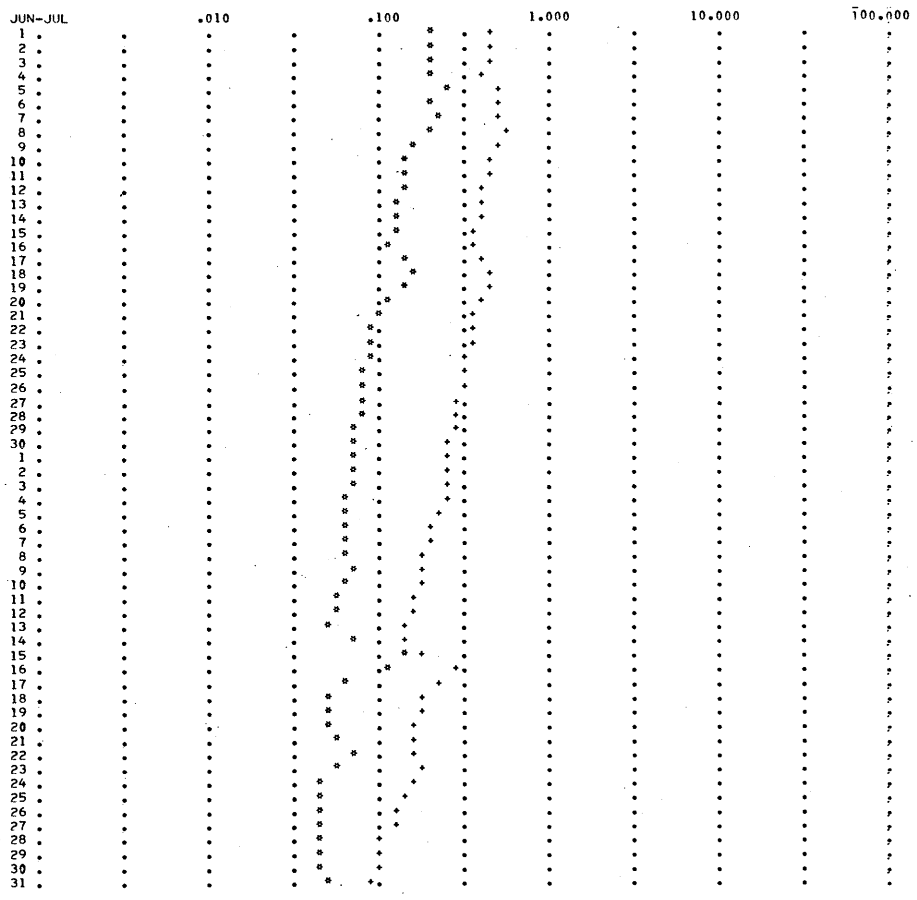

```
 DAY    SIM.    OBS. RAIN+MELT
  1     .201    .450    .8
  2     .197    .437    .8
  3     .191    .423   1.8
  4     .197    .420  10.9
  5     .243    .527   1.3
  6     .203    .474   8.1
  7     .215    .519   2.8
  8     .191    .544    .3
  9     .161    .506   0.0
 10     .142    .461    .3
 11     .137    .425   1.0
 12     .135    .416    .3
 13     .127    .397   0.0
 14     .124    .380   2.0
 15     .127    .361   0.0
 16     .117    .358   8.9
 17     .149    .390   3.0
 18     .154    .446   2.0
 19     .135    .437    .3
 20     .107    .399   0.0
 21     .096    .373   0.0
 22     .091    .350   0.0
 23     .088    .339   0.0
 24     .085    .320   0.0
 25     .083    .311   0.0
 26     .080    .301    .3
 27     .079    .292    .3
 28     .078    .292   0.0
 29     .075    .282   0.0
 30     .072    .263   0.0
  1     .070    .254   0.0
  2     .068    .245    .5
  3     .069    .263   0.0
  4     .066    .245   0.0
  5     .063    .226    .3
  6     .063    .207   0.0
  7     .061    .207   0.0
  8     .061    .188   2.8
  9     .073    .173   0.0
 10     .063    .177   0.0
 11     .057    .162   0.0
 12     .053    .151   0.0
 13     .053    .143   1.0
 14     .069    .137  13.2
 15     .135    .194   3.8
 16     .108    .284    .3
 17     .066    .216   0.0
 18     .051    .184   0.0
 19     .048    .171   0.0
 20     .048    .166   2.0
 21     .058    .154   2.5
 22     .068    .164   0.0
 23     .054    .171   0.0
 24     .047    .158   0.0
 25     .045    .143   0.0
 26     .044    .132   0.0
 27     .044    .122   0.0
 28     .043    .105   0.0
 29     .043    .104   0.0
 30     .043    .098    .8
 31     .049    .094   3.8
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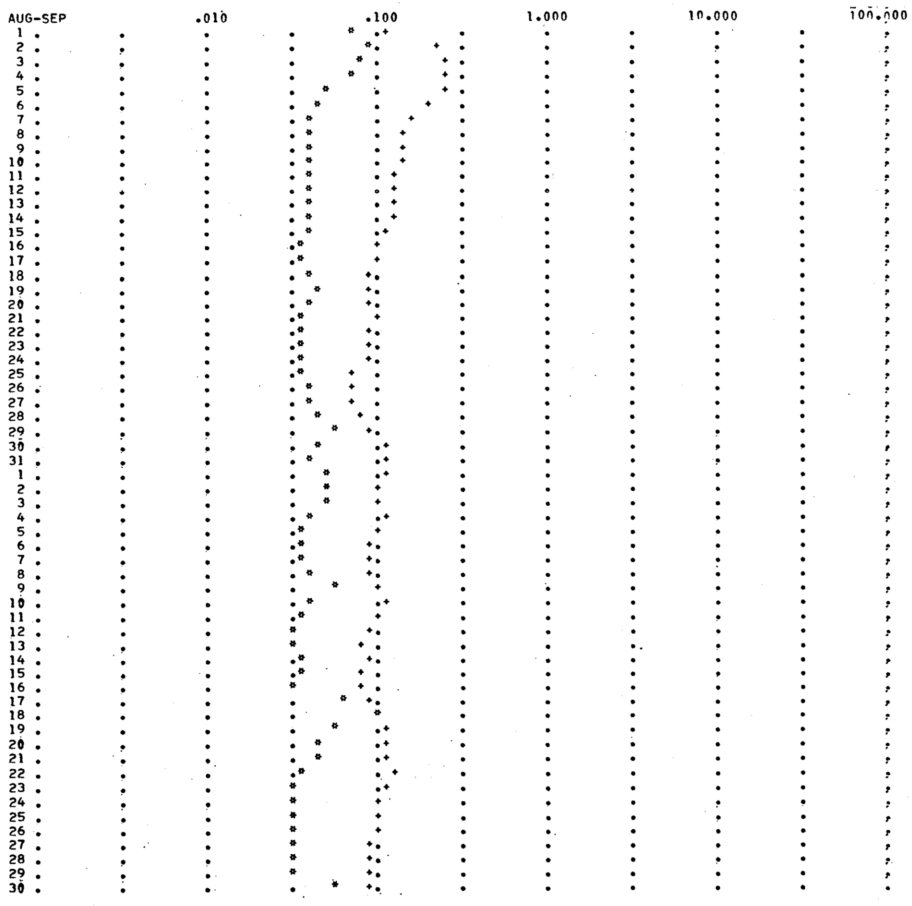
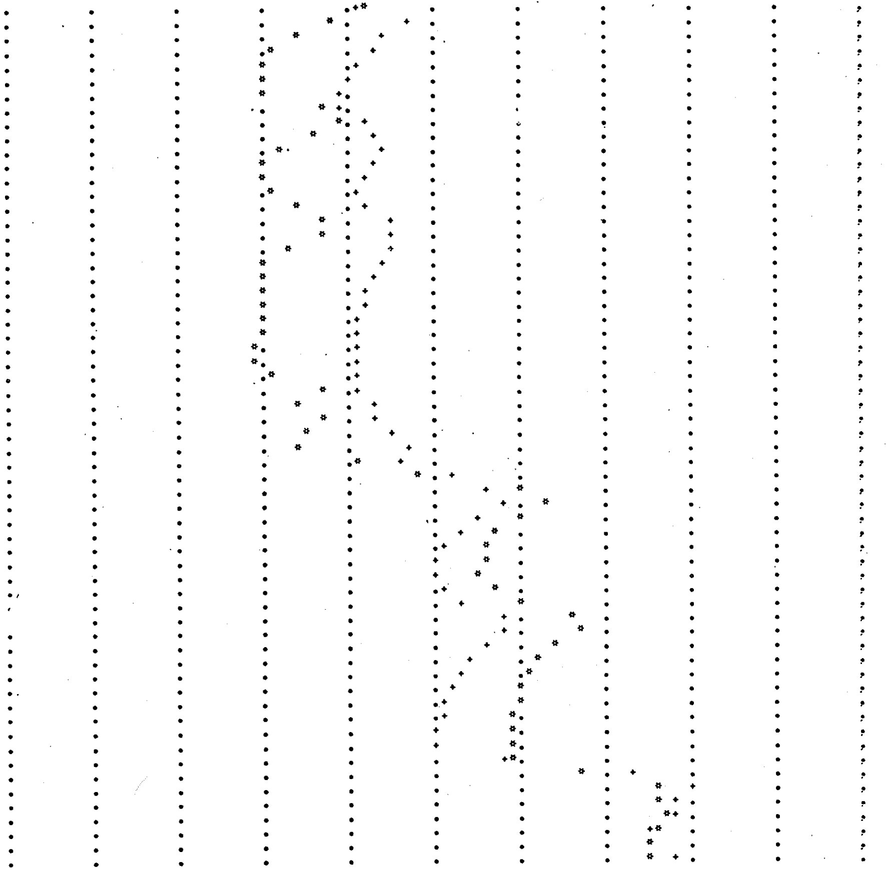
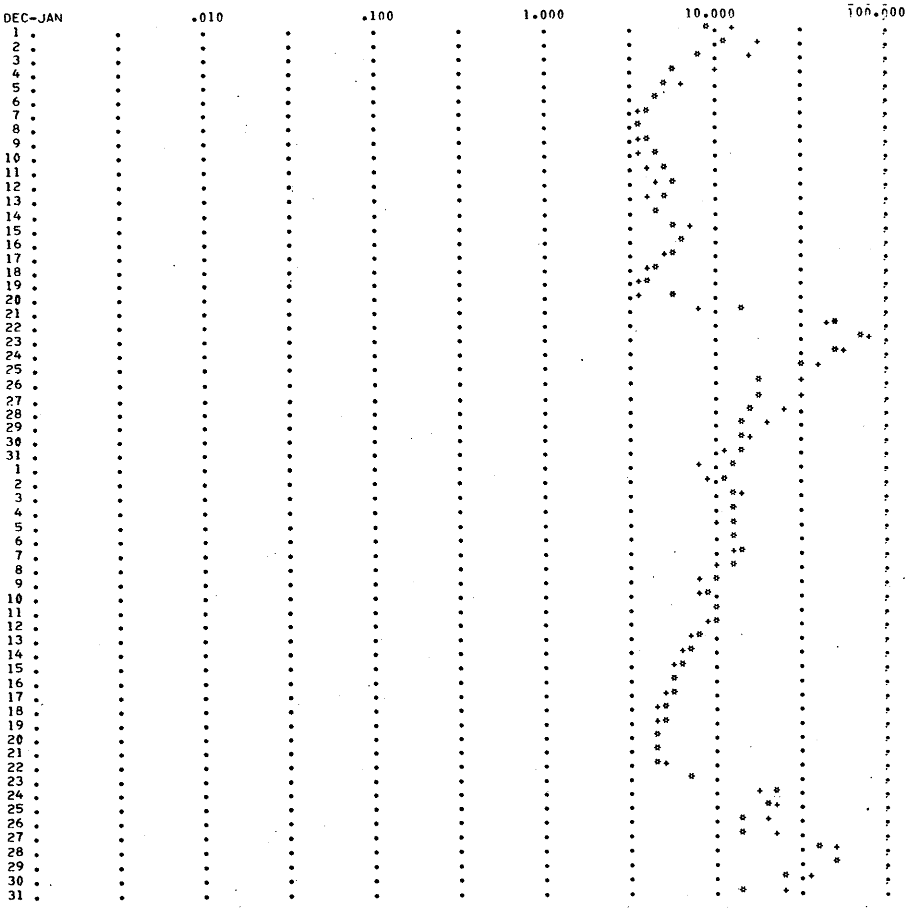


```
 DAY    SIM.    OBS. RAIN+MELT
  1     .070    .109   6.3
  2     .093    .231   3.8
  3     .081    .256   3.0
  4     .071    .263   0.0
  5     .051    .243   0.0
  6     .042    .199   0.0
  7     .040    .166   0.0
  8     .040    .145   0.0
  9     .039    .139    .3
 10     .039    .134   0.0
 11     .039    .126   0.0
 12     .038    .120    .3
 13     .038    .122   0.0
 14     .038    .120   0.0
 15     .038    .107   0.0
 16     .037    .102   0.0
 17     .037    .096    .3
 18     .039    .090   1.3
 19     .044    .087   0.0
 20     .039    .094   0.0
 21     .037    .096   0.0
 22     .036    .090   0.0
 23     .036    .088   0.0
 24     .036    .087   0.0
 25     .036    .072   1.0
 26     .038    .072    .3
 27     .040    .073   1.5
 28     .046    .083   2.5
 29     .054    .094    .5
 30     .043    .117   1.0
 31     .040    .117   3.8
  1     .050    .113   0.0
  2     .052    .105   2.3
  3     .052    .102   0.0
  4     .040    .107   0.0
  5     .036    .102   0.0
  6     .034    .092   0.0
  7     .034    .090    .5
  8     .039    .094   3.3
  9     .054    .105   0.0
 10     .041    .117   0.0
 11     .035    .100   0.0
 12     .033    .090   0.0
 13     .033    .083   0.0
 14     .034    .085    .3
 15     .034    .081   0.0
 16     .033    .083   4.3
 17     .063    .092   8.6
 18     .104    .098   0.0
 19     .056    .117   1.8
 20     .045    .107   1.0
 21     .043    .117   0.0
 22     .036    .128    .3
 23     .033    .113   0.0
 24     .032    .104   0.0
 25     .032    .098    .3
 26     .032    .105   0.0
 27     .032    .088   0.0
 28     .032    .088   0.0
 29     .033    .085   3.0
 30     .056    .090  14.2
```

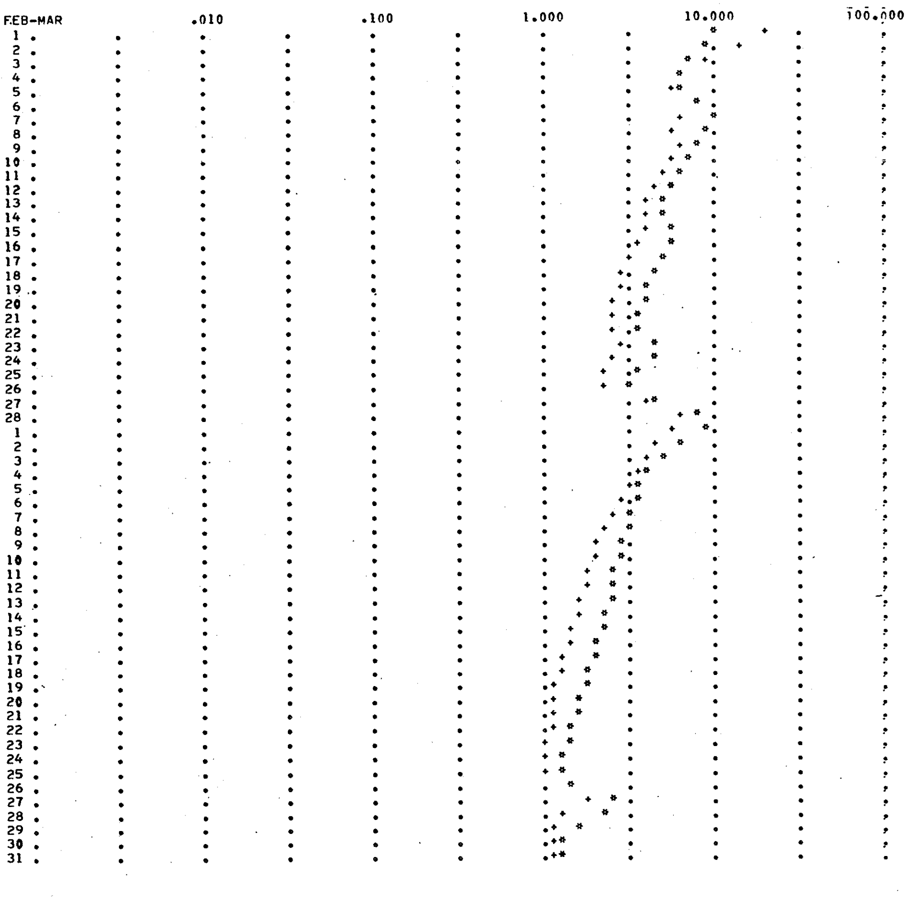
SEMI-LOG MEAN DAILY FLOW PLOT(MM) SOUTH YAMHILL NR WHI WATER YEAR 1965 *=SIMULATED +=OBSERVED



OCT-NOV	SIM.	OBS.	RAIN+MELT
1	.121	.115	.5
2	.077	.218	1.3
3	.050	.151	0.0
4	.035	.136	0.0
5	.032	.117	0.0
6	.031	.098	0.0
7	.032	.090	6.6
8	.069	.094	4.3
9	.087	.122	2.8
10	.062	.149	.3
11	.040	.158	0.0
12	.033	.139	0.0
13	.031	.122	.5
14	.034	.117	3.3
15	.050	.124	5.6
16	.071	.169	3.3
17	.068	.171	0.0
18	.043	.173	0.0
19	.033	.158	0.0
20	.030	.137	0.0
21	.030	.130	0.0
22	.030	.122	0.0
23	.030	.117	0.0
24	.030	.113	0.0
25	.030	.111	0.0
26	.030	.111	0.0
27	.036	.109	7.1
28	.068	.117	0.0
29	.052	.139	6.1
30	.069	.147	2.0
31	.057	.183	.3
1	.050	.226	14.7
2	.117	.209	2.5
3	.263	.378	20.3
4	1.007	.640	13.5
5	1.357	.828	0.0
6	1.017	.587	0.0
7	.732	.435	.8
8	.631	.361	2.0
9	.603	.324	2.8
10	.588	.301	11.7
11	.694	.344	6.1
12	1.031	.469	27.2
13	2.057	.802	4.8
14	2.341	.794	0.0
15	1.612	.610	.3
16	1.226	.491	0.0
17	1.090	.439	0.0
18	1.028	.397	0.0
19	.975	.363	0.0
20	.924	.339	0.0
21	.876	.322	.3
22	.845	.316	16.3
23	.932	.798	31.7
24	2.330	4.705	39.1
25	6.072	10.313	26.7
26	5.992	8.187	23.4
27	6.807	7.679	15.2
28	6.372	5.947	10.7
29	5.646	5.740	13.2
30	5.712	7.810	46.7

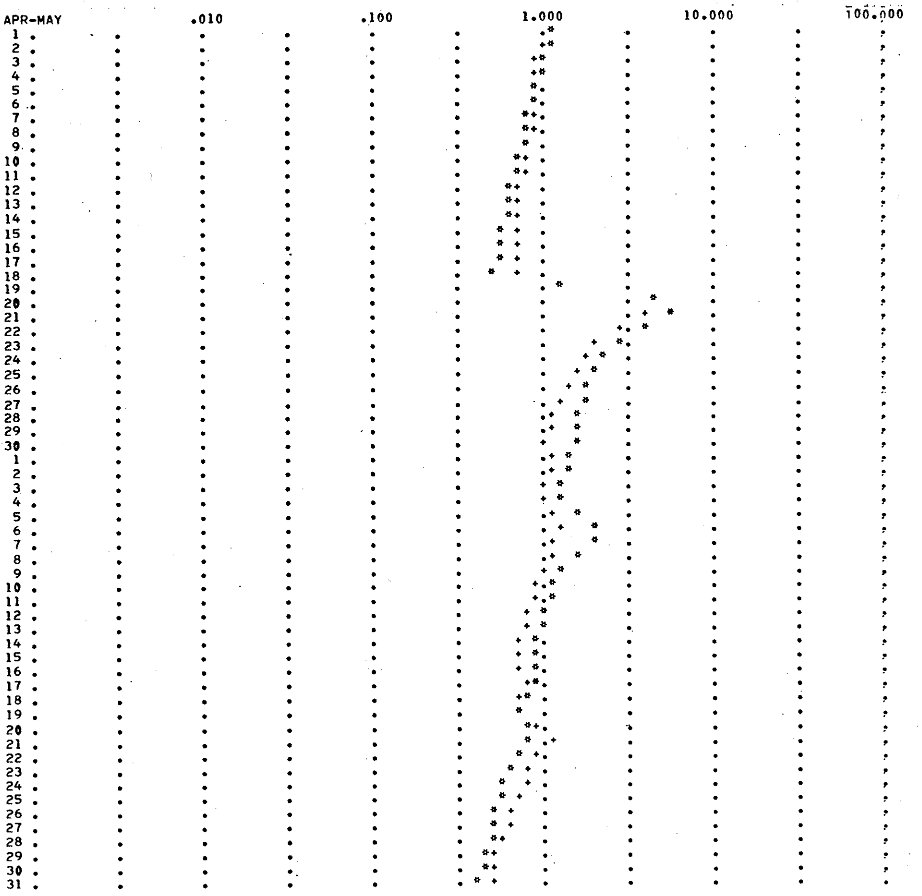


DEC-JAN	SIM.	OBS.	RAIN+MELT
1	9.240	13.268	19.3
2	10.862	17.446	4.8
3	8.408	15.225	.5
4	5.908	9.673	8.9
5	4.773	6.229	0.0
6	4.521	4.667	1.0
7	3.960	3.745	6.1
8	3.657	3.388	6.3
9	4.012	3.388	7.9
10	4.313	3.632	10.7
11	5.009	4.140	6.6
12	5.434	4.291	5.1
13	4.923	4.197	1.3
14	4.507	4.272	19.3
15	5.393	6.775	6.9
16	6.231	6.418	0.0
17	5.368	4.893	0.0
18	4.310	3.764	3.6
19	3.890	3.576	27.7
20	5.745	3.576	24.6
21	14.852	8.017	97.3
22	50.813	46.673	93.2
23	70.473	82.996	46.0
24	50.520	56.272	26.2
25	31.931	41.968	13.2
26	18.323	32.370	31.0
27	17.560	30.112	17.3
28	15.326	24.842	16.5
29	14.143	19.573	18.0
30	13.754	14.981	11.4
31	13.676	10.652	2.8
1	12.376	7.697	7.9
2	10.666	9.128	26.9
3	11.956	13.701	9.1
4	12.773	12.346	8.6
5	12.218	9.956	21.8
6	12.622	12.082	11.7
7	13.414	12.910	3.3
8	11.919	10.069	4.8
9	10.129	8.017	6.3
10	9.199	7.641	13.7
11	9.824	9.448	.3
12	9.544	8.601	.3
13	8.105	7.227	.3
14	6.944	6.098	0.0
15	6.233	5.608	0.0
16	5.772	5.495	0.0
17	5.416	5.175	0.0
18	5.110	4.724	0.0
19	4.831	4.441	.8
20	4.577	4.366	3.6
21	4.365	4.686	5.8
22	4.414	5.119	4.1
23	6.750	6.794	69.6
24	22.155	17.446	18.3
25	19.337	21.831	20.6
26	14.802	21.078	17.0
27	14.750	21.455	75.9
28	40.034	49.496	51.1
29	50.645	52.319	15.0
30	26.015	35.381	6.3
31	14.798	25.783	0.0



FEB-MAR	SIM.	OBS.	RAIN+MELT
1	10.448	19.573	.3
2	8.416	13.419	0.0
3	7.135	8.714	1.0
4	6.396	6.361	.3
5	6.065	5.571	32.5
6	8.250	7.773	1.8
7	9.953	6.399	.3
8	8.502	5.665	12.2
9	7.861	6.436	0.0
10	7.429	5.646	1.3
11	6.432	5.025	.3
12	5.657	4.460	.8
13	5.147	4.046	3.0
14	5.019	3.862	8.6
15	5.513	3.839	1.5
16	5.550	3.501	0.0
17	4.966	3.181	0.0
18	4.408	2.955	0.0
19	4.037	2.767	0.0
20	3.776	2.578	0.0
21	3.565	2.447	7.1
22	3.621	2.635	7.9
23	4.421	2.804	1.5
24	4.297	2.503	0.0
25	3.758	2.296	0.0
26	3.321	2.193	29.0
27	4.525	4.065	23.4
28	8.342	6.493	.8
1	8.432	5.759	.3
2	6.358	4.724	0.0
3	4.815	3.952	0.0
4	4.093	3.406	0.0
5	3.741	2.992	0.0
6	3.504	2.691	0.0
7	3.307	2.465	0.0
8	3.129	2.258	0.0
9	2.964	2.089	0.0
10	2.808	1.957	0.0
11	2.660	1.816	0.0
12	2.520	1.701	0.0
13	2.388	1.588	0.0
14	2.263	1.509	0.0
15	2.145	1.438	0.0
16	2.033	1.363	1.0
17	1.932	1.310	0.0
18	1.830	1.242	0.0
19	1.733	1.176	0.0
20	1.642	1.129	0.0
21	1.557	1.097	0.0
22	1.476	1.065	.3
23	1.402	1.033	0.0
24	1.329	.999	0.0
25	1.265	.982	19.3
26	1.471	1.468	10.7
27	2.449	1.741	0.0
28	2.129	1.316	3.6
29	1.612	1.188	0.0
30	1.326	1.114	0.0
31	1.204	1.065	2.5

SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1965   *=SIMULATED   +=OBSERVED



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APR-MAY   SIM.    OBS.  RAIN+MELT
  1      1.137   1.060     .8
  2      1.084    .996    0.0
  3      1.018    .941    0.0
  4       .962    .941    0.0
  5       .913    .903     .3
  6       .868    .866    1.0
  7       .829    .866     .5
  8       .788    .866    1.5
  9       .755    .828    2.3
 10       .728    .828    2.8
 11       .693    .753    0.0
 12       .649    .715    0.0
 13       .612    .689    5.8
 14       .608    .711    0.0
 15       .568    .689    1.5
 16       .542    .672    4.8
 17       .533    .728    1.3
 18       .503    .715   15.5
 19      1.204   1.323   33.3
 20      4.580   4.441   11.9
 21      5.539   4.009    0.0
 22      4.143   2.691    0.0
 23      2.817   2.089    1.3
 24      2.229   1.795     .5
 25      1.999   1.602    0.0
 26      1.863   1.428    0.0
 27      1.759   1.295    0.0
 28      1.666   1.188     .3
 29      1.580   1.095    0.0
 30      1.504   1.033    5.6
  1      1.459   1.063    8.4
  2      1.407   1.142    1.3
  3      1.306   1.028    2.8
  4      1.249    .969    9.9
  5      1.516   1.092    8.9
  6      2.097   1.302    0.0
  7      1.930   1.171    0.0
  8      1.516   1.073    0.0
  9      1.278   1.001    0.0
 10      1.171    .932    0.0
 11      1.103    .866    0.0
 12      1.046    .815    0.0
 13       .992    .764    0.0
 14       .941    .723    0.0
 15       .892    .693    2.5
 16       .864    .708    5.8
 17       .848    .821     .3
 18       .782    .700     .3
 19       .740    .672   14.7
 20       .771    .856    3.3
 21       .791   1.084     .3
 22       .710    .886    1.5
 23       .639    .796     .3
 24       .588    .751    0.0
 25       .553    .694    0.0
 26       .524    .638    0.0
 27       .498    .597    0.0
 28       .473    .555    0.0
 29       .450    .518    0.0
 30       .428    .499    0.0
 31       .408    .491    0.0
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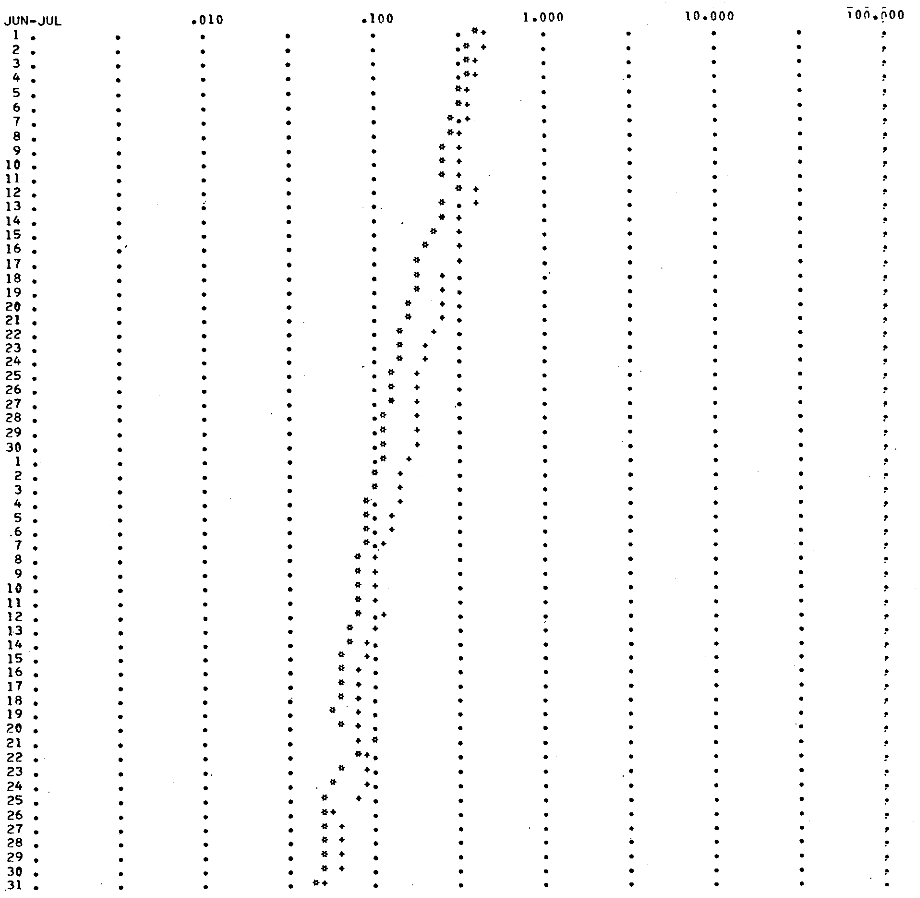

```
JUN-JUL   SIM.    OBS.  RAIN+MELT
  1       .388    .470    0.0
  2       .370    .440    0.0
  3       .352    .407    0.0
  4       .335    .380    0.0
  5       .320    .365    0.0
  6       .305    .358    0.0
  7       .290    .339    0.0
  8       .277    .320     .3
  9       .266    .320    0.0
 10       .253    .320     .3
 11       .266    .301   16.0
 12       .326    .420     .8
 13       .259    .376    3.0
 14       .242    .320    3.8
 15       .236    .320    0.0
 16       .203    .320    0.0
 17       .186    .301    0.0
 18       .176    .263     .3
 19       .170    .263    0.0
 20       .163    .245    0.0
 21       .156    .245    0.0
 22       .149    .226    0.0
 23       .143    .207    0.0
 24       .137    .207    0.0
 25       .132    .188    0.0
 26       .127    .188    0.0
 27       .122    .188    0.0
 28       .117    .188    0.0
 29       .113    .179    0.0
 30       .109    .169     .5
  1       .107    .160    0.0
  2       .104    .141    0.0
  3       .098    .141    0.0
  4       .094    .141    0.0
  5       .091    .122    0.0
  6       .088    .122    0.0
  7       .085    .113    0.0
  8       .082    .104    0.0
  9       .080    .104    0.0
 10       .078    .104    1.0
 11       .081    .104     .3
 12       .076    .113    0.0
 13       .072    .105    0.0
 14       .069    .094    0.0
 15       .066    .094    0.0
 16       .064    .075    0.0
 17       .063    .075    0.0
 18       .061    .075    0.0
 19       .059    .075    0.0
 20       .067    .075    7.9
 21       .101    .075     .5
 22       .078    .085    0.0
 23       .061    .094    0.0
 24       .053    .085    0.0
 25       .052    .075    0.0
 26       .051    .056     .3
 27       .051    .062    0.0
 28       .050    .066    0.0
 29       .048    .066    0.0
 30       .048    .060    0.0
 31       .047    .049    0.0
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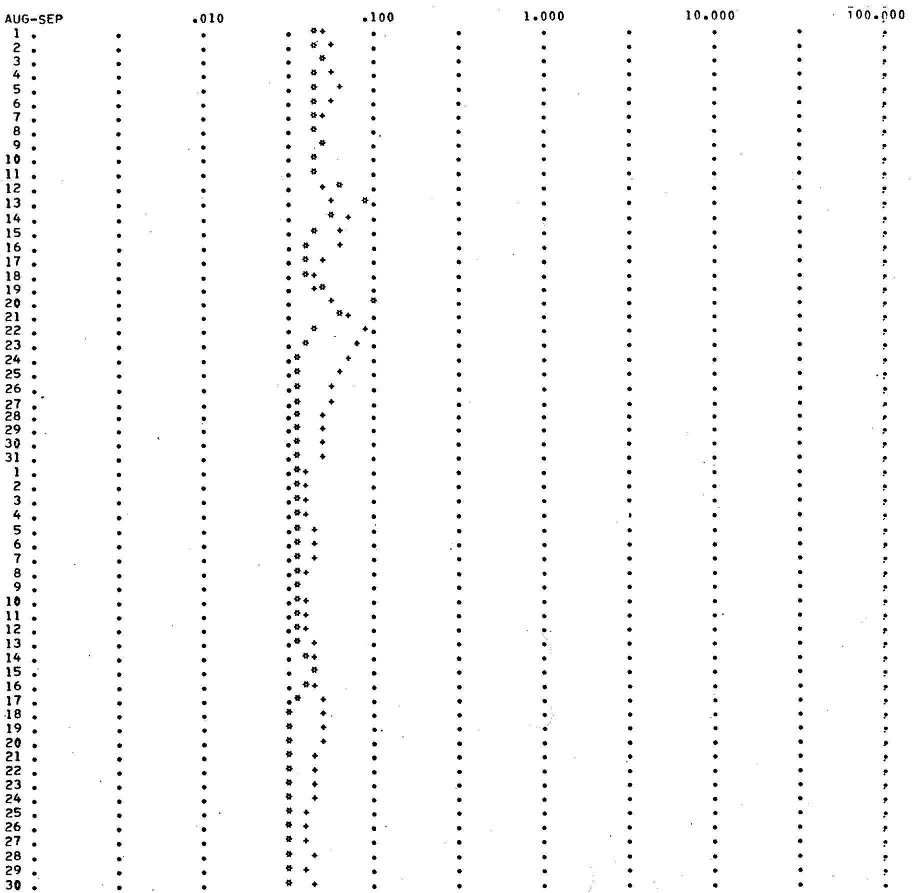

```
AUG-SEP   SIM.    OBS.  RAIN+MELT
  1       .046    .049     .3
  2       .047    .055     .3
  3       .048    .051     .3
  4       .047    .056    0.0
  5       .045    .060    0.0
  6       .044    .058    0.0
  7       .043    .049     .3
  8       .045    .047    1.5
  9       .052    .049    0.0
 10       .046    .043     .3
 11       .043    .045    4.3
 12       .065    .053    5.1
 13       .089    .058    0.0
 14       .055    .070    0.0
 15       .043    .062    0.0
 16       .039    .060    0.0
 17       .039    .053    0.0
 18       .039    .045    0.0
 19       .053    .045    9.9
 20       .096    .055     .5
 21       .062    .073    0.0
 22       .044    .085    0.0
 23       .038    .081     .3
 24       .037    .068    0.0
 25       .037    .066    0.0
 26       .037    .056    0.0
 27       .036    .056    0.0
 28       .036    .049    0.0
 29       .036    .049    0.0
 30       .036    .049    0.0
 31       .036    .049    0.0
  1       .035    .041    0.0
  2       .035    .038    0.0
  3       .035    .041    0.0
  4       .035    .040    0.0
  5       .035    .045    0.0
  6       .035    .045    0.0
  7       .034    .045    0.0
  8       .034    .040    0.0
  9       .034    .036    0.0
 10       .034    .040    0.0
 11       .034    .040    0.0
 12       .034    .041    0.0
 13       .034    .047    1.8
 14       .041    .047     .8
 15       .043    .045     .5
 16       .039    .047    0.0
 17       .034    .049    0.0
 18       .033    .053    0.0
 19       .033    .049    0.0
 20       .033    .049    0.0
 21       .033    .047    0.0
 22       .032    .047    0.0
 23       .032    .047    0.0
 24       .032    .043    0.0
 25       .032    .040    0.0
 26       .032    .041    0.0
 27       .032    .040    0.0
 28       .032    .043    0.0
 29       .032    .041    0.0
 30       .032    .043    0.0
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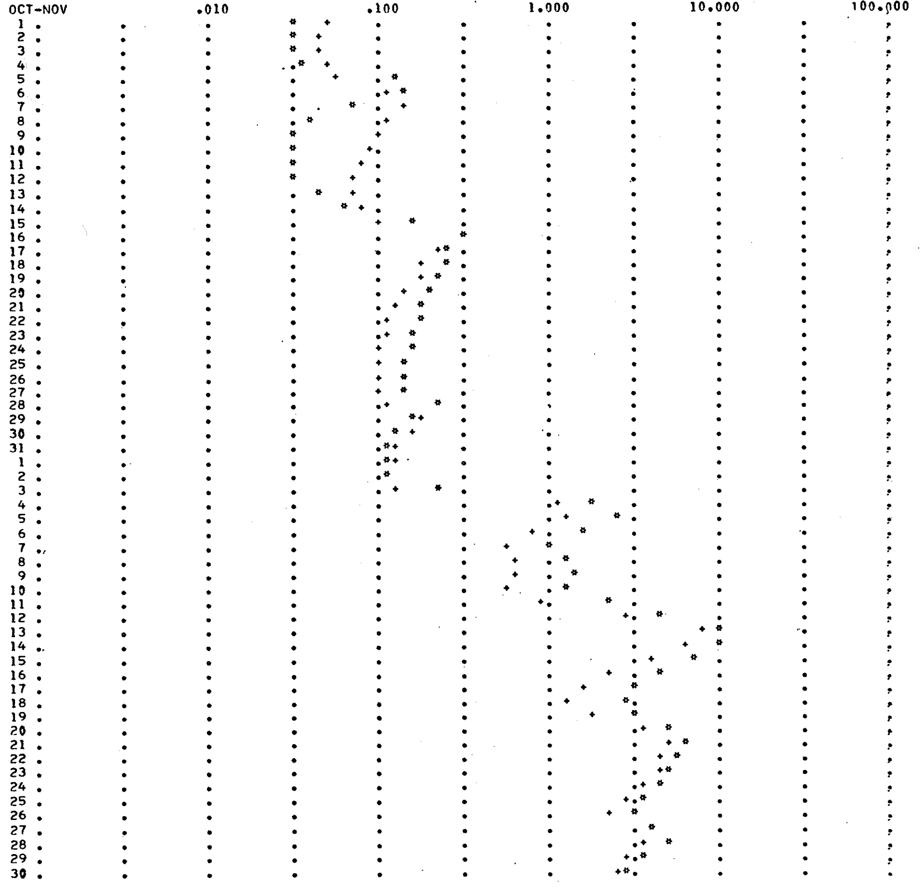
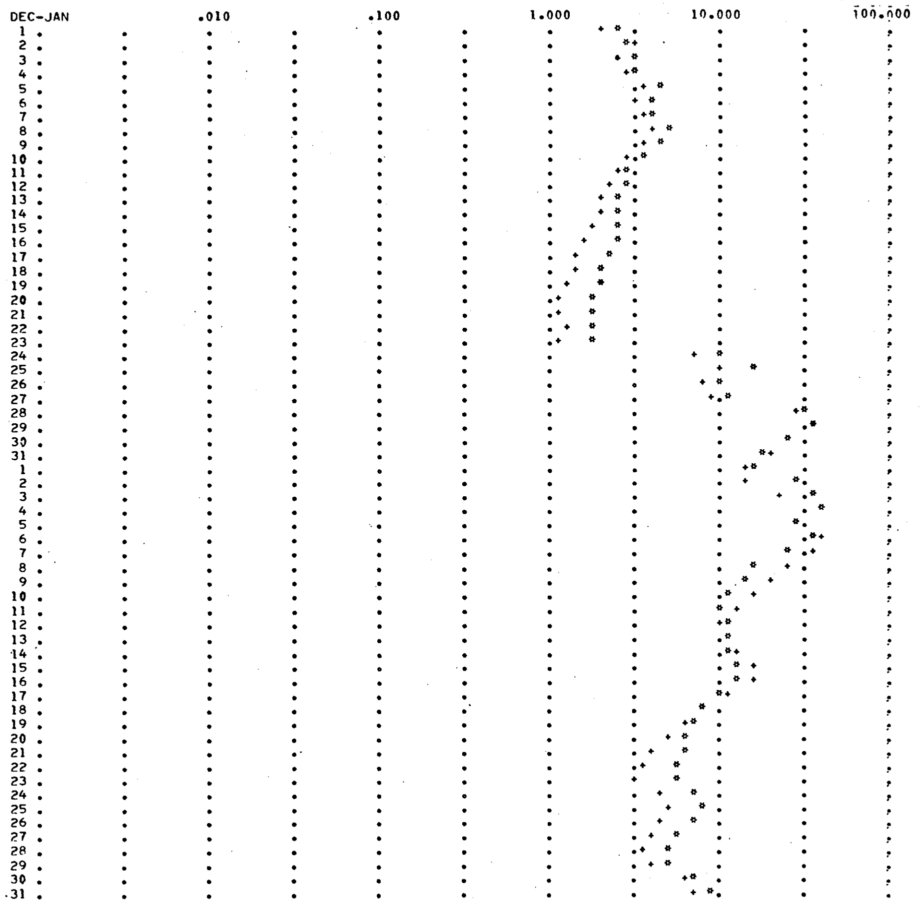
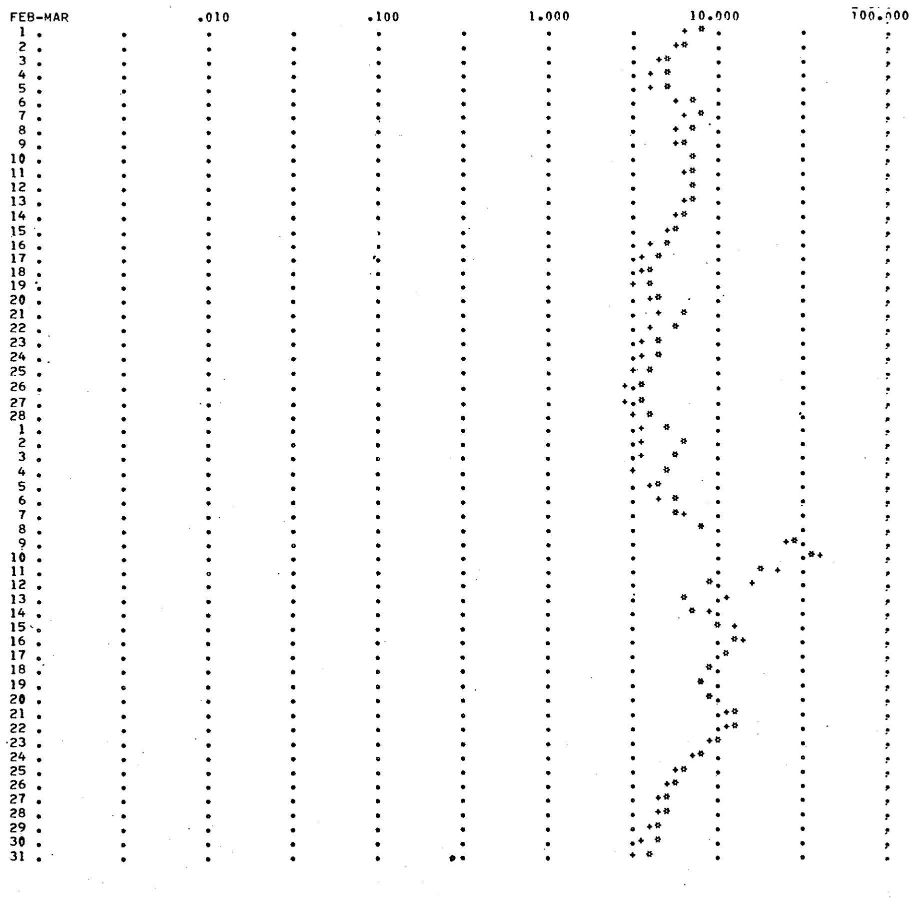
SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1966   *=SIMULATED   +=OBSERVED



```
OCT-NOV    SIM.     OBS.  RAIN+MELT
  1        .032     .049     0.0
  2        .032     .047     0.0
  3        .031     .045     0.0
  4        .035     .053    16.5
  5        .124     .058     8.4
  6        .143     .113     1.5
  7        .072     .145      .3
  8        .039     .109     0.0
  9        .032     .098     0.0
 10        .031     .087     0.0
 11        .031     .075     0.0
 12        .031     .070     3.8
 13        .046     .070      .3
 14        .065     .079    18.0
 15        .155     .104     8.1
 16        .299     .316     0.0
 17        .248     .230     4.8
 18        .253     .173     1.0
 19        .219     .173      .3
 20        .198     .143     0.0
 21        .181     .128     0.0
 22        .171     .109     0.0
 23        .163     .109     0.0
 24        .155     .104     0.0
 25        .149     .102     0.0
 26        .142     .096     0.0
 27        .145     .096    14.7
 28        .214     .107     0.0
 29        .167     .169      .3
 30        .132     .152     0.0
 31        .115     .124     0.0
  1        .109     .120      .3
  2        .109     .111     5.8
  3        .227     .124    41.1
  4       1.778    1.090    10.7
  5       2.493    1.282      .3
  6       1.507     .764     5.6
  7       1.057     .542    11.2
  8       1.211     .612     3.0
  9       1.390     .666      .5
 10       1.250     .563    26.9
 11       2.188     .886    33.5
 12       4.691    2.898    56.9
 13       9.951    7.566    26.2
 14       9.884    6.248     2.8
 15       7.072    3.820     0.0
 16       4.392    2.371      .3
 17       3.270    1.538     5.1
 18       2.894    1.252    21.1
 19       3.342    1.795     9.9
 20       5.180    3.425    21.6
 21       6.465    5.270     6.1
 22       5.865    4.554    11.9
 23       5.224    4.630     4.6
 24       4.237    3.538     3.3
 25       3.712    2.898     1.8
 26       3.274    2.334    21.3
 27       4.165    3.877      .8
 28       4.811    3.613     0.0
 29       3.756    2.936      .8
 30       2.972    2.428     1.3
```

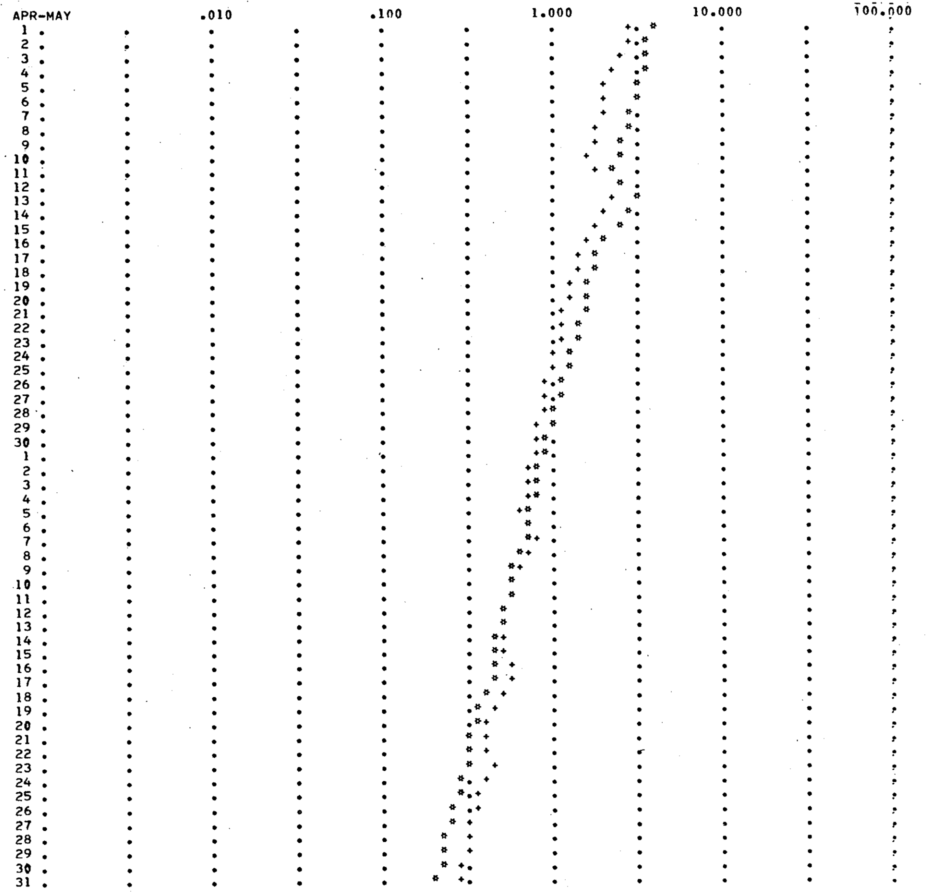


```
DEC-JAN    SIM.     OBS.  RAIN+MELT
  1       2.612    2.108    14.2
  2       2.872    3.199      .3
  3       3.255    2.654    11.9
  4       3.272    2.898     8.6
  5       4.424    3.576      .8
  6       3.986    3.199    13.2
  7       4.205    3.708    11.2
  8       4.797    4.084     0.0
  9       4.258    3.519      .5
 10       3.442    2.917      .5
 11       2.962    2.503     2.5
 12       2.729    2.315      .3
 13       2.564    2.070     6.1
 14       2.558    1.938      .3
 15       2.647    1.763     0.0
 16       2.434    1.634     0.0
 17       2.222    1.485     0.0
 18       2.067    1.378     0.0
 19       1.950    1.272     0.0
 20       1.847    1.180     5.3
 21       1.772    1.174     2.0
 22       1.701    1.242     1.3
 23       1.752    1.133    59.2
 24      10.548    6.926    15.7
 25      16.703   10.351     9.4
 26       9.989    7.848    36.6
 27      11.872    8.883    71.9
 28      33.483   27.101    36.8
 29      34.910   35.005    33.5
 30      23.840   25.407    16.8
 31      17.695   19.573    13.7
  1      15.272   14.153    55.6
  2      28.995   13.494    40.1
  3      35.010   22.207    56.6
  4      40.833   39.145     7.9
  5      29.061   27.101    56.9
  6      33.533   41.404    12.4
  7      24.562   34.440    10.2
  8      16.423   24.654    10.7
  9      13.471   20.137      .3
 10      11.672   16.053    14.7
 11      10.518   12.139     6.9
 12      10.936   10.520    12.2
 13      10.821   11.047    14.7
 14      11.195   12.722    19.0
 15      12.573   15.771      .3
 16      12.216   15.018      .3
 17       9.992   11.443      .3
 18       8.152    8.130      .3
 19       7.071    6.060     0.0
 20       6.434    4.912     0.0
 21       5.990    4.159     5.1
 22       5.706    3.670     0.0
 23       5.709    3.312    17.8
 24       6.688    4.234     6.1
 25       7.931    4.818     0.0
 26       7.118    4.423     0.0
 27       5.897    3.877      .8
 28       5.110    3.538     9.4
 29       5.070    3.839    18.3
 30       7.179    6.173    13.0
 31       8.710    7.453      .5
```

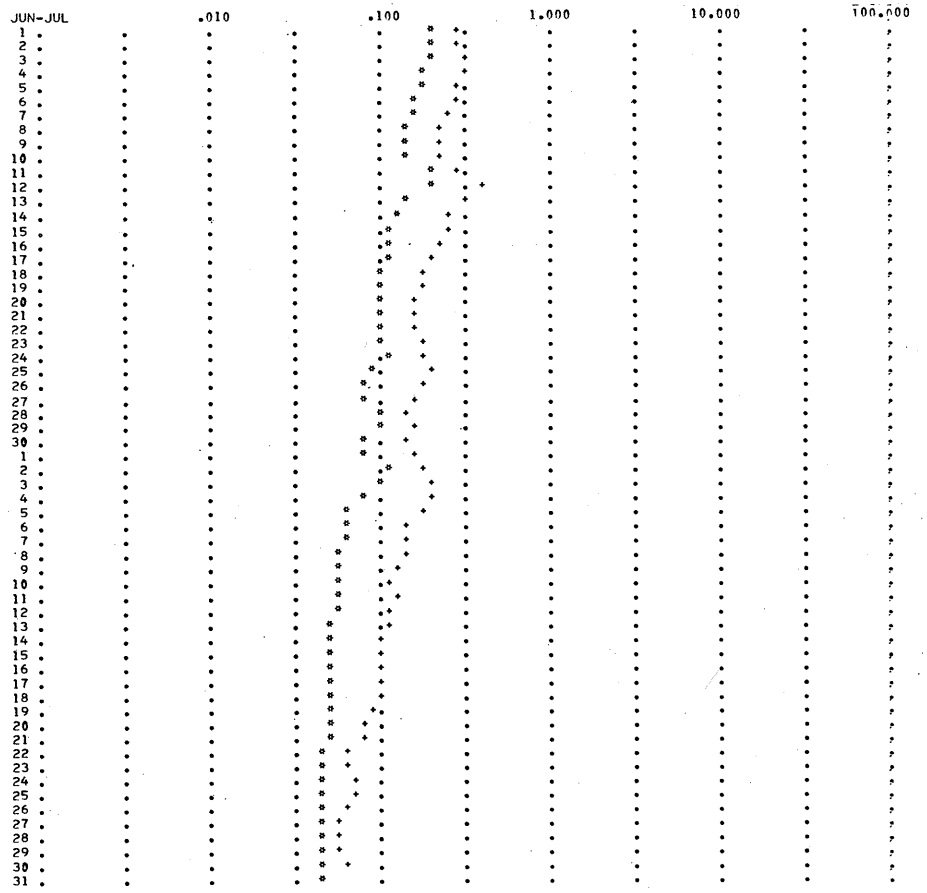


```
FEB-MAR    SIM.     OBS.  RAIN+MELT
  1       7.961    6.493      .3
  2       6.298    5.326     0.0
  3       5.207    4.498     3.0
  4       4.755    4.046     7.9
  5       5.070    4.065    20.6
  6       6.762    5.909     5.6
  7       7.782    6.361     1.3
  8       6.905    5.684     7.6
  9       6.099    5.382    16.5
 10       6.818    6.813     0.0
 11       7.228    6.436    15.7
 12       6.950    6.926     2.3
 13       7.325    6.116      .3
 14       6.224    5.382     4.6
 15       5.481    4.874     0.0
 16       4.982    4.216     0.0
 17       4.486    3.726     0.0
 18       4.114    3.350     0.0
 19       3.856    3.030    18.5
 20       4.404    3.820     4.6
 21       6.030    4.408     0.0
 22       5.430    3.896     4.1
 23       4.571    3.576     3.6
 24       4.430    3.388     0.0
 25       4.084    3.011      .3
 26       3.654    2.785     5.3
 27       3.448    2.729     6.1
 28       3.871    3.162    13.0
  1       4.770    3.406    10.7
  2       6.020    3.425     4.8
  3       5.787    3.388     0.0
  4       4.857    3.162    10.4
  5       4.417    3.877     5.6
  6       5.329    4.705    18.8
  7       5.934    6.098    11.7
  8       8.196    7.754    67.6
  9      28.369   26.348    35.8
 10      35.611   39.710     0.0
 11      17.143   22.019     0.0
 12       8.588   15.526     8.1
 13       6.220   10.746    11.4
 14       7.237    9.391    30.5
 15       9.840   12.233    19.3
 16      11.909   13.626     5.6
 17      11.052   11.612     2.8
 18       8.952    9.090    10.2
 19       7.848    7.942    19.0
 20       8.899    8.544    29.2
 21      12.738   10.803     3.0
 22      13.110   10.671     0.0
 23      10.014    8.469     0.0
 24       7.597    6.775     0.0
 25       6.348    5.759     0.0
 26       5.697    5.157     0.0
 27       5.278    4.686     0.0
 28       4.956    4.291     0.0
 29       4.677    3.896     0.0
 30       4.423    3.538     1.0
 31       4.192    3.293     0.0
```

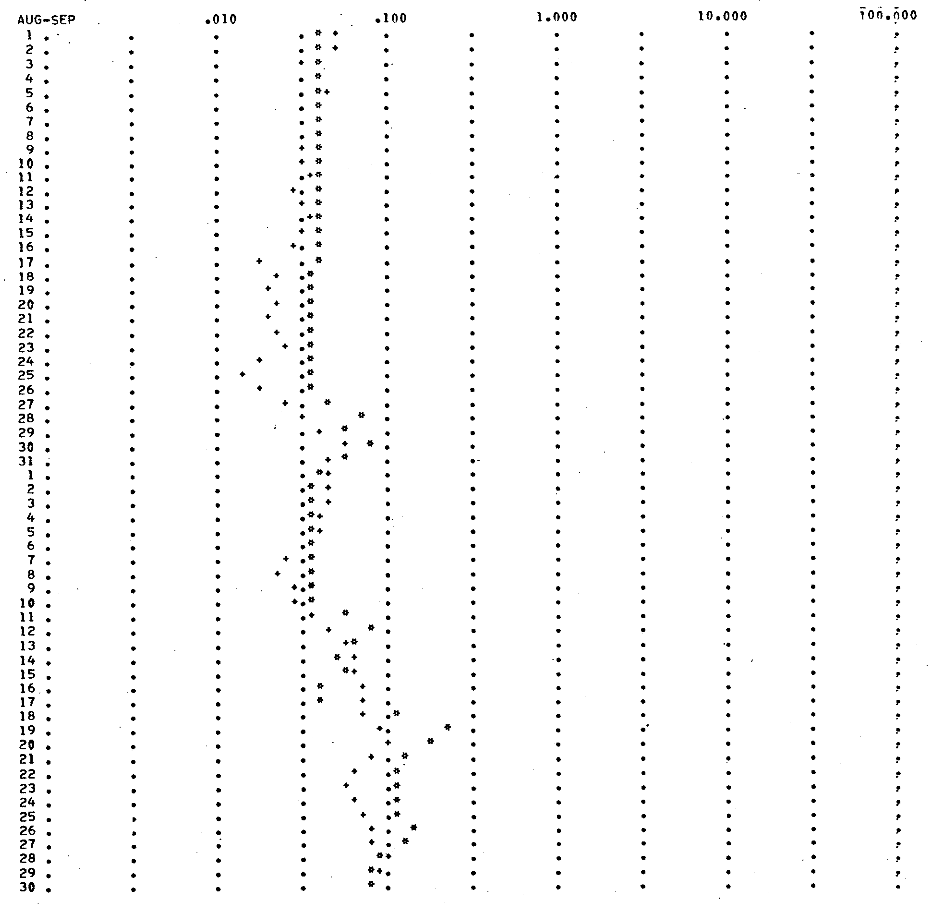
SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1966   *=SIMULATED   +=OBSERVED



APR-MAY	SIM.	OBS.	RAIN+MELT
1	3.967	2.974	.3
2	3.756	2.710	.5
3	3.559	2.465	0.0
4	3.368	2.258	0.0
5	3.189	2.108	0.0
6	3.020	2.014	0.0
7	2.860	1.920	0.0
8	2.709	1.826	0.0
9	2.573	1.743	4.1
10	2.459	1.671	11.2
11	2.370	1.743	4.8
12	2.372	2.616	11.7
13	3.084	2.258	0.0
14	2.939	1.920	2.8
15	2.401	1.758	.3
16	2.047	1.611	0.0
17	1.876	1.487	0.0
18	1.764	1.379	0.0
19	1.670	1.291	0.0
20	1.584	1.218	2.3
21	1.514	1.188	.5
22	1.432	1.142	.3
23	1.353	1.088	0.0
24	1.280	1.033	0.0
25	1.213	.986	.3
26	1.155	.943	1.8
27	1.103	.943	0.0
28	1.040	.890	.3
29	.985	.836	0.0
30	.934	.809	0.0
1	.886	.775	0.0
2	.841	.749	0.0
3	.798	.723	0.0
4	.758	.693	0.0
5	.720	.647	11.4
6	.733	.700	7.1
7	.745	.757	0.0
8	.651	.678	0.0
9	.594	.612	.3
10	.559	.559	0.0
11	.531	.534	0.0
12	.507	.525	2.8
13	.497	.508	0.0
14	.466	.499	1.0
15	.446	.512	6.3
16	.455	.542	3.0
17	.432	.548	0.0
18	.386	.480	0.0
19	.359	.440	.8
20	.344	.412	0.0
21	.330	.393	3.3
22	.331	.407	1.5
23	.316	.423	0.0
24	.289	.384	0.0
25	.271	.359	0.0
26	.258	.335	.3
27	.248	.322	0.0
28	.237	.309	0.0
29	.226	.311	0.0
30	.216	.290	0.0
31	.208	.271	2.3

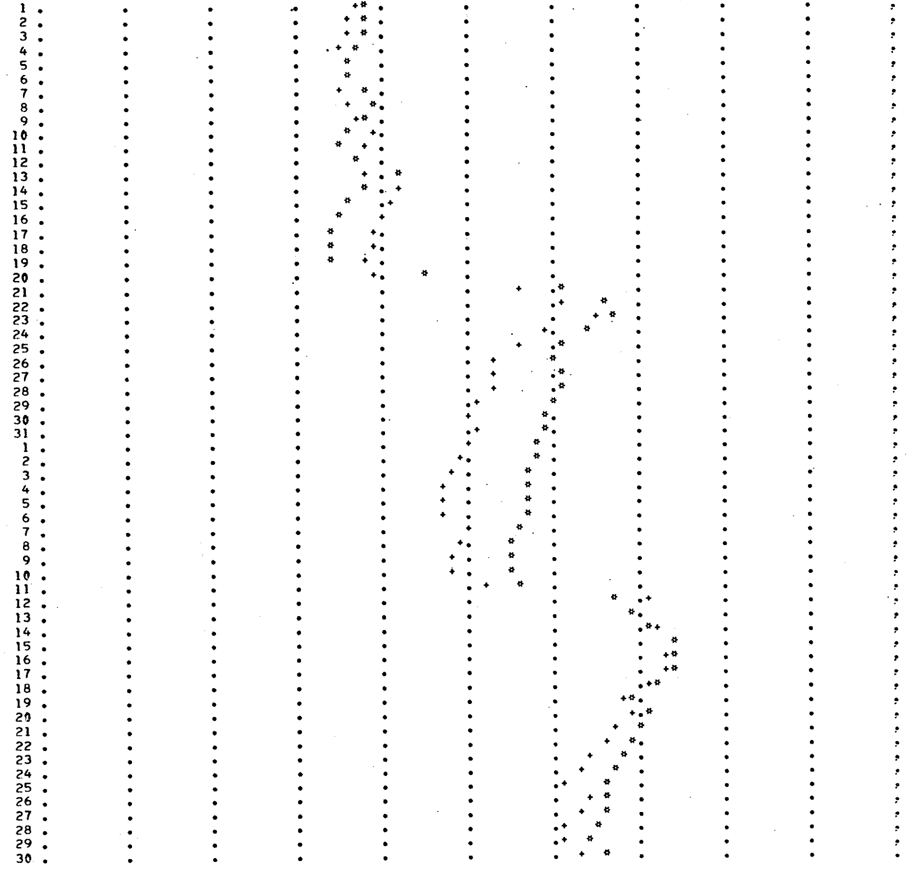


JUN-JUL	SIM.	OBS.	RAIN+MELT
1	.211	.286	.5
2	.199	.292	2.0
3	.194	.303	.3
4	.185	.311	0.0
5	.171	.292	0.0
6	.161	.273	0.0
7	.155	.260	0.0
8	.149	.237	0.0
9	.143	.230	.3
10	.146	.230	10.7
11	.191	.267	4.8
12	.193	.393	0.0
13	.144	.331	0.0
14	.122	.265	0.0
15	.114	.239	0.0
16	.110	.215	0.0
17	.107	.190	0.0
18	.103	.183	0.0
19	.100	.175	.3
20	.098	.162	0.0
21	.095	.164	2.0
22	.101	.166	.8
23	.102	.188	4.3
24	.115	.186	0.0
25	.094	.199	0.0
26	.083	.171	0.0
27	.079	.156	4.1
28	.096	.141	2.3
29	.105	.164	0.0
30	.081	.149	0.0
1	.083	.151	7.9
2	.117	.173	2.8
3	.099	.199	0.0
4	.076	.209	0.0
5	.065	.173	0.0
6	.062	.137	0.0
7	.060	.134	0.0
8	.059	.145	0.0
9	.057	.130	.3
10	.057	.119	0.0
11	.056	.122	0.0
12	.054	.111	0.0
13	.053	.109	0.0
14	.052	.104	0.0
15	.051	.105	0.0
16	.050	.098	0.0
17	.049	.104	0.0
18	.049	.098	0.0
19	.049	.087	.3
20	.049	.081	0.0
21	.047	.077	0.0
22	.047	.066	0.0
23	.046	.064	0.0
24	.045	.072	.5
25	.046	.073	0.0
26	.046	.060	0.0
27	.044	.058	0.0
28	.044	.055	0.0
29	.043	.056	0.0
30	.043	.060	0.0
31	.043	.045	0.0



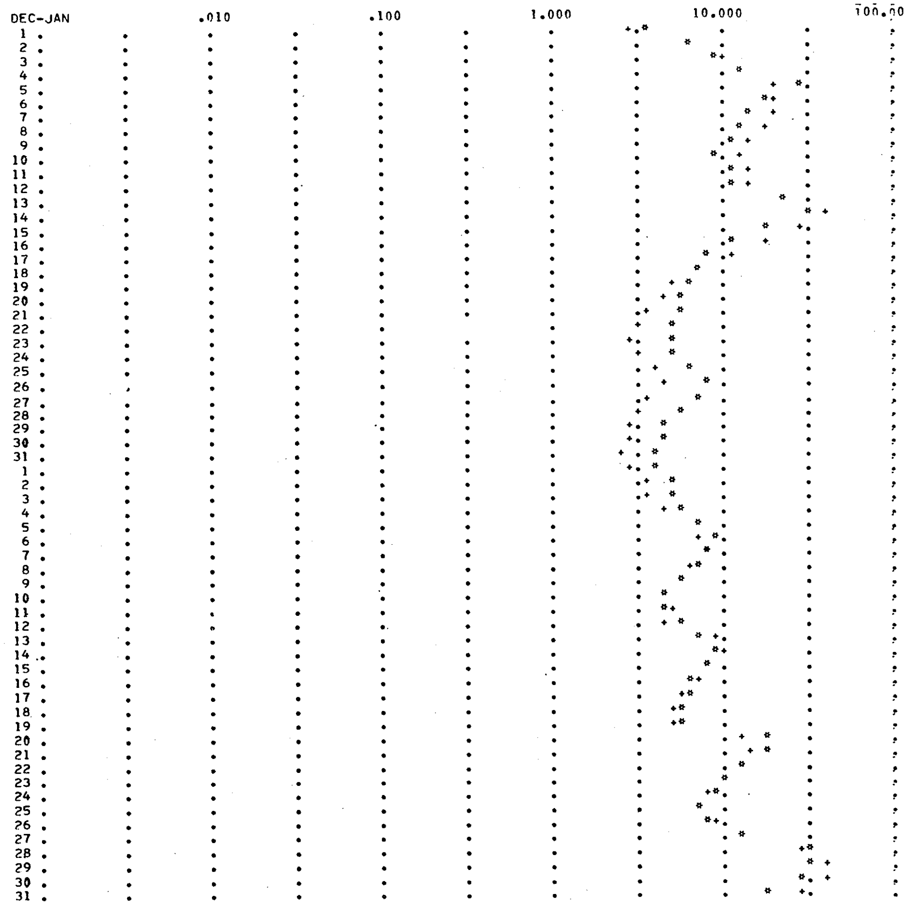
AUG-SEP	SIM.	OBS.	RAIN+MELT
1	.042	.051	0.0
2	.042	.049	0.0
3	.041	.032	0.0
4	.041	.041	0.0
5	.041	.043	0.0
6	.041	.041	0.0
7	.040	.038	0.0
8	.040	.038	.3
9	.040	.032	0.0
10	.039	.032	0.0
11	.039	.034	0.0
12	.039	.028	0.0
13	.039	.030	.3
14	.038	.034	0.0
15	.038	.030	0.0
16	.038	.028	0.0
17	.038	.018	0.0
18	.037	.023	0.0
19	.037	.021	0.0
20	.037	.023	0.0
21	.037	.021	0.0
22	.037	.023	0.0
23	.037	.024	0.0
24	.036	.018	0.0
25	.036	.015	0.0
26	.036	.018	.5
27	.043	.024	6.3
28	.075	.030	0.0
29	.056	.041	7.6
30	.079	.055	0.0
31	.058	.045	0.0
1	.041	.045	0.0
2	.035	.045	0.0
3	.035	.043	0.0
4	.035	.038	0.0
5	.035	.041	.3
6	.034	.034	0.0
7	.034	.026	0.0
8	.034	.023	0.0
9	.034	.028	0.0
10	.034	.028	6.6
11	.059	.036	1.3
12	.078	.045	3.8
13	.067	.058	2.0
14	.051	.066	2.5
15	.054	.066	0.0
16	.041	.070	.8
17	.040	.070	18.0
18	.118	.073	7.9
19	.218	.088	0.0
20	.172	.102	0.0
21	.125	.081	0.0
22	.108	.066	3.3
23	.119	.055	.3
24	.113	.062	2.0
25	.115	.070	9.1
26	.141	.081	.3
27	.124	.081	0.0
28	.094	.104	0.0
29	.082	.088	0.0
30	.078	.077	0.0

```
SEMI-LOG MEAN DAILY FLOW PLOT(MM)    SOUTH YAMHILL NR WHI     WATER YEAR 1967    *=SIMULATED   +=OBSERVED
OCT-NOV                   .010          .100          1.000         10.000          100.000
```



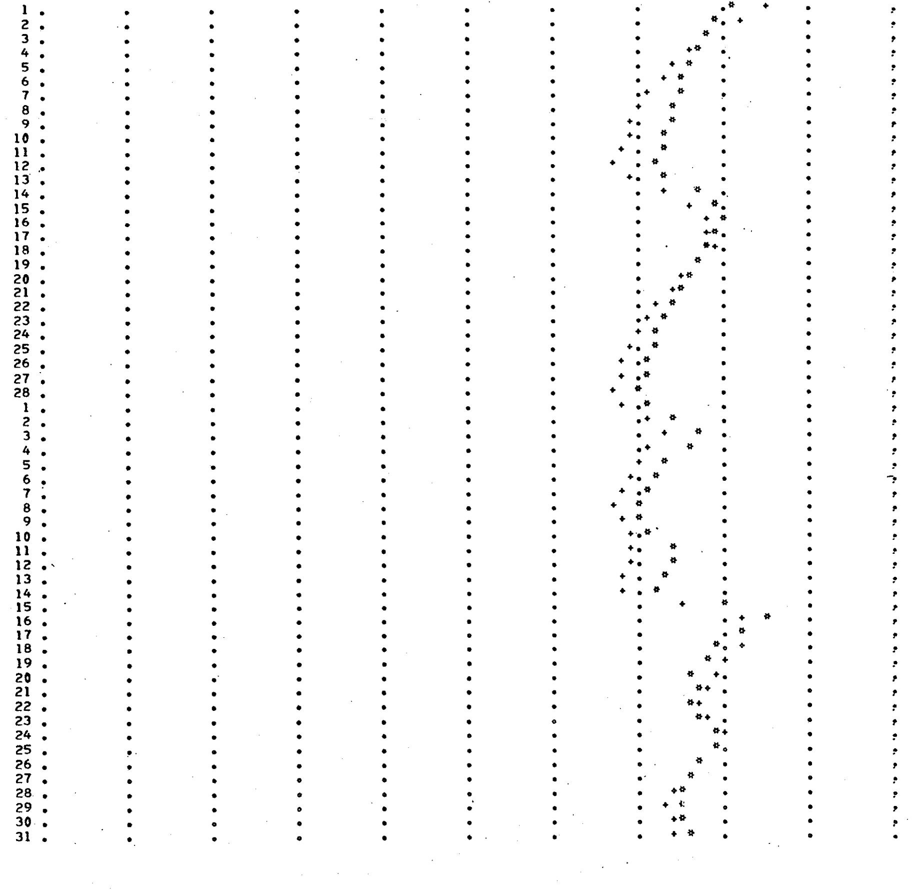
```
DAY     SIM.     OBS.  RAIN+MELT
  1     .076     .068     1.3
  2     .079     .062      .5
  3     .080     .062     0.0
  4     .071     .058     0.0
  5     .067     .064      .3
  6     .066     .060     3.0
  7     .079     .055     2.8
  8     .094     .064     1.8
  9     .079     .072     0.0
 10     .063     .088     0.0
 11     .057     .077     0.0
 12     .067     .073    11.9
 13     .121     .077     0.0
 14     .082     .122     1.0
 15     .062     .119     0.0
 16     .054     .100     0.0
 17     .050     .094      .3
 18     .048     .085     0.0
 19     .048     .081    16.0
 20     .187     .090    25.7
 21    1.132     .638    23.1
 22    1.887    1.174     7.6
 23    2.252    1.724     2.0
 24    1.547     .937     0.0
 25    1.153     .604      .3
 26    1.010     .457    13.0
 27    1.170     .467     0.0
 28    1.149     .431     0.0
 29     .997     .350     6.9
 30     .944     .324     0.0
 31     .912     .348     0.0
  1     .840     .299     0.0
  2     .786     .271     0.0
  3     .743     .254     0.0
  4     .704     .237     0.0
  5     .672     .224     7.6
  6     .674     .230      .8
  7     .632     .316     1.3
  8     .586     .271     0.0
  9     .550     .245     6.1
 10     .548     .243     4.6
 11     .639     .401    39.1
 12    2.190    3.350     1.5
 13    2.946    2.955    32.5
 14    3.540    3.971    27.4
 15    5.037    5.138    14.2
 16    5.060    4.611    14.2
 17    4.766    4.573     3.8
 18    3.799    3.350      .5
 19    2.978    2.465    16.3
 20    3.478    2.672     3.0
 21    3.286    2.240     3.6
 22    2.817    1.976     0.0
 23    2.433    1.598     0.0
 24    2.173    1.353     0.0
 25    2.021    1.184     9.7
 26    2.011    1.521      .3
 27    1.966    1.342     0.0
 28    1.797    1.188     0.0
 29    1.667    1.075    16.8
 30    1.993    1.494    20.3
```

```
DEC-JAN                   .010          .100          1.000         10.000          100.000
```



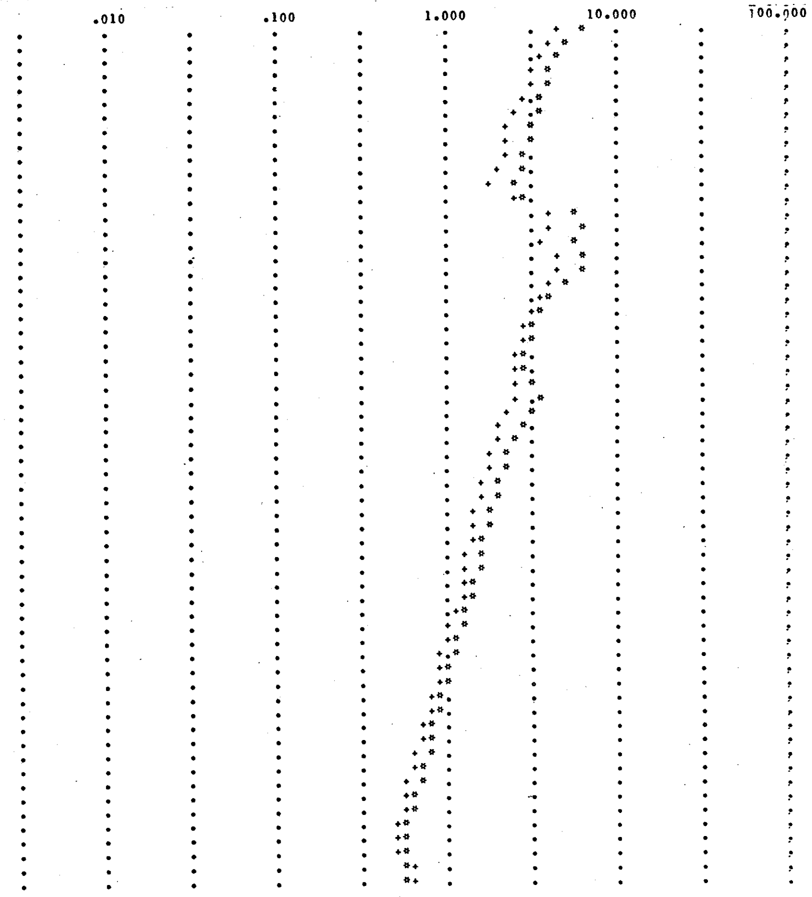
```
DAY     SIM.     OBS.  RAIN+MELT
  1    3.705    2.974    27.4
  2    6.106    6.625    28.2
  3    8.908   10.558    30.7
  4   13.060   12.120    59.9
  5   26.888   19.573    20.1
  6   17.316   21.078    31.5
  7   14.861   19.949    15.5
  8   13.237   18.109     2.8
  9   10.731   14.021    25.7
 10    9.408   12.346    11.2
 11   11.117   14.416    13.2
 12   11.233   13.964    50.8
 13   21.564   21.266    36.3
 14   31.144   40.651      .5
 15   18.701   28.042      .3
 16   11.123   18.425      .3
 17    7.855   11.292     0.0
 18    6.715    6.704     0.0
 19    6.084    4.987     6.6
 20    5.721    4.272      .5
 21    5.542    3.613     0.0
 22    5.220    3.105     0.0
 23    4.896    2.748    12.2
 24    5.206    3.068    16.8
 25    6.556    3.990     5.3
 26    7.762    4.272     0.0
 27    6.746    3.632      .3
 28    5.458    3.124      .8
 29    4.683    2.861     3.6
 30    4.339    2.804     1.0
 31    4.111    2.522     7.1
  1    4.164    2.823     5.3
  2    4.867    3.369     5.6
  3    4.949    3.576    12.4
  4    5.657    4.724    22.4
  5    7.373    6.888     7.4
  6    8.495    7.264    10.9
  7    8.222    7.622     0.0
  8    6.781    6.436     0.0
  9    5.389    5.401     0.0
 10    4.602    4.592    13.7
 11    4.628    4.743      .3
 12    5.425    4.611    31.5
 13    6.885    8.929     7.4
 14    9.225   10.219     0.0
 15    7.891    8.262     8.1
 16    6.558    6.850     3.0
 17    6.195    5.853     0.0
 18    5.433    4.968     0.0
 19    5.467    4.743    62.0
 20   18.021   12.346    15.5
 21   17.989   14.454     6.6
 22   12.524   12.685    10.7
 23    9.513   10.238     5.1
 24    8.509    8.375     2.3
 25    7.320    7.114    19.6
 26 [illegible].998    8.962    25.1
 27 1[illegible].395   13.212    67.1
 28 3[illegible].736   29.171    22.6
 29   30.888   40.463    34.8
 30   29.329   39.145     0.0
 31   17.198   27.665     0.0
```

```
FEB-MAR                   .010          .100          1.000         10.000          100.000
```

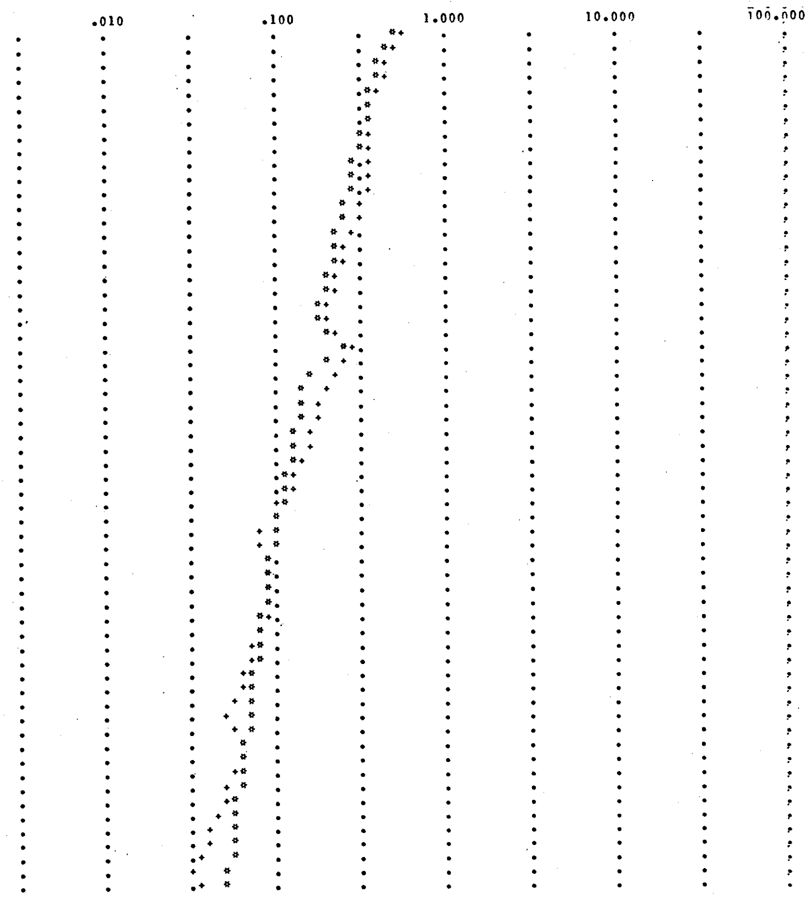


```
DAY     SIM.     OBS.  RAIN+MELT
  1   10.952   18.745     8.1
  2    8.591   12.496      .5
  3    7.804    8.224     0.0
  4    6.884    6.116     1.0
  5    6.176    5.044     0.0
  6    5.685    4.272     0.0
  7    5.321    3.726     0.0
  8    5.016    3.293     0.0
  9    4.742    2.936     1.3
 10    4.494    2.672     0.0
 11    4.260    2.465     3.6
 12    4.148    2.352     2.5
 13    4.370    2.842    25.7
 14    6.714    4.310    18.5
 15    8.421    6.041    17.0
 16    9.812    7.848     9.1
 17    9.264    8.243     6.3
 18    8.378    8.525     4.6
 19    7.441    7.396     0.0
 20    6.335    5.872     0.0
 21    5.370    4.893     0.0
 22    4.775    4.197     0.0
 23    4.408    3.689     0.0
 24    4.138    3.293     0.0
 25    3.909    2.955     2.0
 26    3.707    2.635     0.0
 27    3.504    2.390     0.0
 28    3.330    2.221    13.7
  1    3.721    2.597    12.7
  2    4.989    3.350    13.5
  3    6.711    4.329     0.0
  4    6.007    3.613     0.0
  5    4.647    3.105     0.0
  6    3.827    2.767     0.0
  7    3.444    2.522     0.0
  8    3.214    2.352     6.1
  9    3.104    2.409    13.5
 10    3.757    2.748     6.9
 11    5.030    2.823     5.6
 12    5.021    2.804      .5
 13    4.323    2.616     6.1
 14    3.955    2.654    41.9
 15    9.800    5.891    25.9
 16   17.911   12.271    11.2
 17   12.096   12.816    12.7
 18    9.262   11.913     2.3
 19    7.644   10.389     9.1
 20    6.538    8.507     4.8
 21    6.722    8.375     1.3
 22    6.071    7.114    19.0
 23    6.724    7.660    20.1
 24    8.705    9.561     5.3
 25    8.841    8.902     3.3
 26    7.412    7.321     1.0
 27    6.176    6.004      .5
 28    5.334    5.081    10.4
 29    5.419    4.724     6.9
 30    5.934    4.874    11.9
 31    6.451    5.194      .3
```

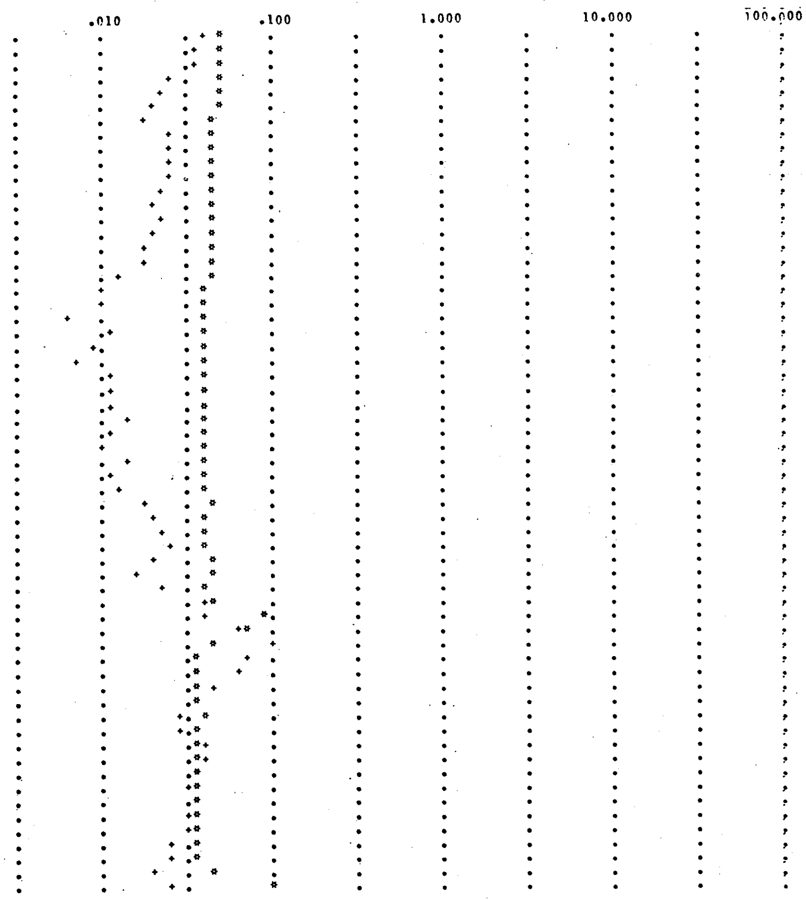
SEMI-LOG MEAN DAILY FLOW PLOT(MM)   SOUTH YAMHILL NR WHI   WATER YEAR 1967   *=SIMULATED   +=OBSERVED



APR-MAY	SIM.	OBS.	RAIN+MELT
1	6.216	4.724	0.0
2	5.235	4.178	0.0
3	4.514	3.670	.3
4	4.097	3.312	3.6
5	3.840	3.086	2.3
6	3.620	2.861	.3
7	3.415	2.597	.5
8	3.228	2.371	.8
9	3.061	2.240	3.3
10	2.913	2.145	.3
11	2.746	1.976	0.0
12	2.597	1.829	14.2
13	2.968	2.447	21.3
14	5.381	3.820	15.5
15	6.538	3.915	1.3
16	5.929	3.613	22.4
17	6.233	4.667	.8
18	6.024	4.253	2.3
19	4.782	4.009	2.3
20	3.931	3.576	.3
21	3.517	3.191	2.5
22	3.280	2.936	2.3
23	3.085	2.842	0.0
24	2.910	2.560	0.0
25	2.777	2.428	13.7
26	3.106	2.616	3.3
27	3.461	2.484	2.0
28	3.175	2.258	1.3
29	2.800	2.089	3.0
30	2.524	1.995	1.3
1	2.337	1.867	0.0
2	2.189	1.762	.5
3	2.070	1.664	.3
4	1.959	1.570	0.0
5	1.855	1.487	0.0
6	1.757	1.410	0.0
7	1.665	1.349	0.0
8	1.578	1.295	0.0
9	1.500	1.255	3.8
10	1.442	1.231	4.1
11	1.377	1.197	1.0
12	1.296	1.075	0.0
13	1.215	1.018	0.0
14	1.147	.975	0.0
15	1.087	.941	0.0
16	1.031	.915	0.0
17	.978	.871	0.0
18	.928	.830	0.0
19	.881	.760	0.0
20	.836	.710	0.0
21	.794	.676	0.0
22	.754	.640	0.0
23	.716	.612	0.0
24	.680	.565	0.0
25	.646	.553	0.0
26	.614	.533	0.0
27	.584	.506	0.0
28	.557	.512	3.6
29	.553	.527	8.9
30	.562	.612	6.6
31	.544	.640	0.0



JUN-JUL	SIM.	OBS.	RAIN+MELT
1	.484	.542	1.3
2	.444	.504	0.0
3	.417	.463	0.0
4	.393	.429	0.0
5	.374	.403	0.0
6	.356	.371	0.0
7	.339	.358	0.0
8	.323	.359	0.0
9	.308	.352	0.0
10	.294	.346	0.0
11	.281	.348	1.3
12	.275	.352	0.0
13	.260	.333	0.0
14	.246	.311	0.0
15	.234	.286	0.0
16	.224	.265	0.0
17	.214	.245	0.0
18	.205	.231	0.0
19	.196	.222	0.0
20	.188	.198	0.0
21	.180	.192	.8
22	.193	.228	14.5
23	.254	.280	0.0
24	.194	.265	0.0
25	.161	.220	0.0
26	.147	.201	0.0
27	.141	.194	.3
28	.137	.171	0.0
29	.131	.166	0.0
30	.126	.151	0.0
1	.121	.137	0.0
2	.116	.130	0.0
3	.112	.120	0.0
4	.108	.098	0.0
5	.105	.098	0.0
6	.101	.093	0.0
7	.098	.077	0.0
8	.094	.085	0.0
9	.091	.087	0.0
10	.088	.087	0.0
11	.086	.092	0.0
12	.083	.085	0.0
13	.080	.075	0.0
14	.078	.072	0.0
15	.076	.068	0.0
16	.074	.064	0.0
17	.072	.062	0.0
18	.070	.056	0.0
19	.068	.053	.3
20	.067	.056	0.0
21	.065	.066	0.0
22	.063	.064	0.0
23	.061	.058	0.0
24	.060	.051	0.0
25	.059	.049	0.0
26	.057	.047	0.0
27	.056	.040	0.0
28	.055	.038	0.0
29	.054	.036	0.0
30	.053	.032	0.0
31	.052	.034	0.0



AUG-SEP	SIM.	OBS.	RAIN+MELT
1	.051	.040	0.0
2	.050	.034	0.0
3	.050	.034	0.0
4	.049	.026	0.0
5	.048	.023	0.0
6	.048	.021	0.0
7	.047	.019	0.0
8	.047	.024	0.0
9	.046	.024	0.0
10	.046	.024	0.0
11	.045	.026	0.0
12	.045	.023	0.0
13	.044	.021	0.0
14	.044	.023	0.0
15	.043	.021	0.0
16	.043	.018	0.0
17	.043	.018	0.0
18	.042	.013	0.0
19	.042	.010	0.0
20	.042	.010	0.0
21	.041	.007	.3
22	.041	.011	0.0
23	.041	.009	0.0
24	.040	.007	0.0
25	.040	.011	0.0
26	.040	.011	0.0
27	.040	.011	0.0
28	.039	.014	0.0
29	.039	.011	0.0
30	.039	.010	0.0
31	.039	.014	0.0
1	.038	.011	.3
2	.040	.013	1.0
3	.044	.017	0.0
4	.040	.021	0.0
5	.038	.023	0.0
6	.038	.024	1.0
7	.042	.021	1.3
8	.044	.015	0.0
9	.040	.023	.3
10	.044	.040	8.1
11	.085	.040	2.0
12	.069	.060	0.0
13	.046	.102	0.0
14	.037	.073	0.0
15	.036	.066	0.0
16	.036	.047	0.0
17	.036	.036	.5
18	.039	.028	.5
19	.037	.028	0.0
20	.036	.040	0.0
21	.035	.040	0.0
22	.035	.036	0.0
23	.035	.032	0.0
24	.035	.036	0.0
25	.035	.032	0.0
26	.035	.032	0.0
27	.035	.024	0.0
28	.034	.024	0.0
29	.043	.021	11.2
30	.102	.026	4.3

APPENDIX D

LISTING OF THE NWSRFS SOIL MOISTURE ACCOUNTING SUBROUTINE

```
      SUBROUTINE LAND(ID1,IP1,ID2,IP2,MOSM,ICOUNT,IRG)
C
C
C***********************************************************************
C
C
C      NWSRFS SOIL MOISTURE ACCOUNTING PROCEDURE
C      BASED ON SOIL MOISTURE ACCOUNTING IN THE SACRAMENTO MODEL
C
C
C***********************************************************************
C
C
C      LAND VARIABLES
C
      REAL LZTWC,LZFPC,LZFSC,LZTWC1,LZFPC1,LZFSC1,LZTWM,LZFPM,LZFSM,LZPK
     1,LZSK
C
      DIMENSION MOSM(8,2),EPDIST(4)
C
C GENERAL PROGRAM VARIABLES
C
      INTEGER ROUTE,SNOW,SNOWA,YRIN,YR1,STORE,YEAR,PLT6HR,SAVEFW,COMPAR,
     1PTEST,PLOT,CTEST,SIXIN,OBSER,STDA,STP6,YR2,STAT,PEG
      REAL INFRO
C
      COMMON /G/ MONTH,MOIN,LAST,ROUTE,NGAGES,SNOW,SNOWA(12),YRIN,NPEGS,
     1YR1,NPTS,STORE,BASIN(20),YEAR,SSF(3,12),SOF(3,12),PLT6HR,SAVEFW,
     2COMPAR(3),PTEST,PLOT(3),LINEP,INFRO(20),PLOTMX(3),CTEST,FSFLOW(3),
     3PEG(5),STAT,YR2,AREA(6),SIXIN(3),OBSER(3),STDA(2,10),STP6(2,10),
     4IYEAR1(3),IPT,METRIC(3),NQ24,NQ6,NPTSUP,IQ24IN(3),IQ6IN(3)
C
C  SOIL MOISTURE ACCOUNTING VARIABLES.
C
      COMMON/SOIL/BAL(5),PL(5,18),VL(5,6),SL(5,10),E(5,12,31)
C
C TIME SERIES IDENTIFICATIONS AND DESCRIPTIONS.
C
      COMMON /TSID/ AID(5,3),ANAME(5,5),PEID(3,3),FPNAME(3,5),FPID(3,3),
     1Q24ID(3,3),Q6ID(3,3),UPFWID(3,3),PXID(5,3)
C
C BASIC DATA ARRAYS
C
      COMMON /BD/ PX(5,4,31),TA(5,4,31),PE(3,31),RO(5,4,31),OFW6(3,4,31)
     1,SFW6(3,4,31),UFW6(3,4,31),OFW24(3,31)
C
C SNOW AND LAND COMMON BLOCK
C
      COMMON/SL/COVER(5,31),EFC(5),PXADJ(5),NTAG,NWEG
      DATA EPDIST/0.0,0.33,0.67,0.0/
C
C***********************************************************************
C
C
      IPRINT=0
      IF((MONTH.EQ.MOSM(ICOUNT,1)).AND.(YEAR.EQ.MOSM(ICOUNT,2)))IPRINT=1
      IF(IPRINT.EQ.0) GO TO 200
C
      PRINT 900,MONTH,YEAR,(ANAME(IRG,I),I=1,5)
  900 FORMAT(1H1,33HSIX-HOUR SOIL MOISTURE OUTPUT FOR,1X,I2,1H/,I4,2X,5A
     14,20X,39HUNITS OF ALL QUANTITIES ARE MILLIMETERS)
C
      PRINT 902
  902 FORMAT(1H ,5X,19HPERC IS PERCOLATION,5X,31HBASEFW IS THE CHANNEL C
     1OMPONENT,5X,67HTOTAL-RO IS CHANNEL INFLOW MINUS ET FROM THE AREA D
     2EFINED BY SARVA.)
C
      PRINT 901
  901 FORMAT(1H ,3HDAY,1X,2HPD,2X,5HUZTWC,2X,5HUZFWC,2X,5HLZTWC,2X,5HLZF
     1SC,2X,5HLZFPC,2X,5HADIMC,4X,4HPERC,1X,7HIMPV-RO,2X,6HDIRECT,2X,6HS
     2UR-RO,1X,7HINTERFW,2X,6HBASEFW,1X,8HTOTAL-RO,1X,7HET-DEMD,1X,6HACT
     3-ET,2X,9HRAIN+MELT)
C
```

```
C..........................................................................
C
  200 SROT=0.0
      SIMPVT=0.0
      SRODT=0.0
      SROST=0.0
      SINTFT=0.0
      SGWFT=0.0
      SRECHT=0.0
      SETT=0.0
      SPRT=0.0
      SPET=0.0
C
C     INTIAL VALUES OF VARIABLES
C
      UZTWC=VL(IRG,1)
      UZFWC=VL(IRG,2)
      LZTWC=VL(IRG,3)
      LZFPC=VL(IRG,5)
      LZFSC=VL(IRG,4)
      ADIMC=VL(IRG,6)
      UZTWC1=UZTWC
      UZFWC1=UZFWC
C
      LZTWC1=LZTWC
      LZFPC1=LZFPC
      LZFSC1=LZFSC
C
      ADIMC1=ADIMC
C
C     INITIAL VALUES OF PARAMETERS
C
      PPADJ=PL(IRG,1)
      PEADJ=PL(IRG,2)
      UZTWM=PL(IRG,3)
      UZFWM=PL(IRG,4)
      UZK=PL(IRG,5)
      ZPERC=PL(IRG,9)
      REXP=PL(IRG,10)
      PCTIM=PL(IRG,6)
      ADIMP=PL(IRG,7)
      SARVA=PL(IRG,8)
      LZTWM=PL(IRG,11)
      LZFPM=PL(IRG,13)
      LZFSM=PL(IRG,12)
      LZPK=PL(IRG,15)
      LZSK=PL(IRG,14)
      PFREE=PL(IRG,16)
      RSERV=PL(IRG,17)
      SIDE=PL(IRG,18)
C
      WATSF=SARVA
      SARRA=0.0
C
      IF(SARVA.LE.PCTIM) GO TO 201
      WATSF=PCTIM
      SARRA=SARVA-PCTIM
C
  201 IGPE=PEG(IRG)
      EFCT=EFC(IRG)
      SAVED=RSERV*(LZFPM+LZFSM)
      PAREA=1.0-PCTIM-ADIMP
      IP6=IP1
      IDA=ID1
      GO TO 204
C
C************************************************************************
C
```

```
C
C     BEGINNING OF 6 HOUR AND DAY LOOP
C
C***********************************************************************
C
  205 IF(IP6.NE.1) GO TO 210
  204 IF(IGPE.GT.0) GO TO 206
C
C     NO PE INPUT, THUS PE IS OBTAIN FROM MEAN SEASONAL CURVE.
C
      EP=E(IRG,MONTH,IDA)
      GO TO 207
C
C     DAILY PE TIME SERIES IS AVAILABLE
C
  206 EP=PE(IGPE,IDA)
      EP=EP*E(IRG,MONTH,IDA)
  207 EP=EP*PEADJ
      SPET=SPET+EP
C
      IF(SNOW.EQ.1) EP=EFCT*EP+(1.0-EFCT)*(1.0-COVER(IRG,IDA))*EP
  210 IF((SNOW.EQ.1).AND.(SNOWA(MONTH).EQ.1)) GO TO 219
      PX6 = PX(IRG,IP6,IDA)*PPADJ
      GO TO 215
C
C     IF SNOW IS BEING CONSIDERED, PXADJ HAS ALREADY BEEN APPLIED
C
  219 PX6 = PX(IRG,IP6,IDA)
  215 SPRT=SPRT+PX6
C
C     PX6 IS THE SIX HOUR RAINFALL OR SNOW COVER OUTFLOW
C
C***********************************************************************
C
C
C     EDMND IS SIX-HOUR EVAPORATION DEMAND
C
      EDMND=EP*EPDIST(IP6)
C
C.......................................................................
C
      E1=EDMND*(UZTWC/UZTWM)
      RED=EDMND-E1
C
C     RED IS RESIDUAL EVAP DEMAND
C
      UZTWC=UZTWC-E1
      E2=0.0
      IF(UZTWC.GE.0.) GO TO 220
C
C     E1 CAN NOT EXCEED UZTWC
C
      E1=E1+UZTWC
      UZTWC=0.0
      RED=EDMND-E1
      IF(UZFWC.GE.RED) GO TO 221
C
C.......................................................................
C
C     E2 IS EVAP FROM UZFWC.
C
      E2=UZFWC
      UZFWC=0.0
      RED=RED-E2
      GO TO 225
C
  221 E2=RED
      UZFWC=UZFWC-E2
      RED=0.0
C
  220 IF((UZTWC/UZTWM).GE.(UZFWC/UZFWM)) GO TO 225
C
```

```
C.......................................................................
C
C     UPPER ZONE FREE WATER RATIO EXCEEDS UPPER ZONE
C     TENSION WATER RATIO, THUS TRANSFER FREE WATER TO TENSION
C
      UZRAT=(UZTWC+UZFWC)/(UZTWM+UZFWM)
      UZTWC=UZTWM*UZRAT
      UZFWC=UZFWM*UZRAT
C
C.......................................................................
C
C     COMPUTE ET FROM ADIMP AREA.-E5
C
  225 E5=E1+(RED+E2)*((ADIMC-E1-UZTWC)/(UZTWM+LZTWM))
C
C.......................................................................
C
C     COMPUTE ET FROM LZTWC (E3)
C
      E3=RED*(LZTWC/(UZTWM+LZTWM))
      LZTWC=LZTWC-E3
      IF(LZTWC.GE.0.0) GO TO 226
C
C     E3 CAN NOT EXCEED LZTWC
C
      E3=E3+LZTWC
      LZTWC=0.0
C
C.......................................................................
C
  226 RATLZT=LZTWC/LZTWM
      RATLZ=(LZTWC+LZFPC+LZFSC-SAVED)/(LZTWM+LZFPM+LZFSM-SAVED)
      IF(RATLZT.GE.RATLZ) GO TO 230
C
C     RESUPPLY LOWER ZONE TENSION WATER FROM LOWER
C     ZONE FREE WATER IF MORE WATER AVAILABLE THERE.
C
      DEL=(RATLZ-RATLZT)*LZTWM
C
C     TRANSFER FROM LZFSC TO LZTWC.
C
      LZTWC=LZTWC+DEL
      LZFSC=LZFSC-DEL
      IF(LZFSC.GE.0.0) GO TO 230
C
C     IF TRANSFER EXCEEDS LZFSC THEN REMAINDER COMES FROM LZFPC
C
      LZFPC=LZFPC+LZFSC
      LZFSC=0.0
C
C.......................................................................
C
  230 ROIMP=PX6*PCTIM
C
C      ROIMP IS RUNOFF FROM THE MINIMUM IMPERVIOUS AREA.
C
      SIMPVT=SIMPVT+ROIMP
C
C      ADJUST ADIMC,ADDITIONAL IMPERVIOUS AREA STORAGE, FOR EVAPORATION.
C
      ADIMC=ADIMC-E5
      IF(ADIMC.GE.0.0) GO TO 231
C
C.......................................................................
C
C     E5 CAN NOT EXCEED ADIMC.
C
      E5=E5+ADIMC
      ADIMC=0.0
  231 E5=E5*ADIMP
C
C     E5 IS ET FROM THE AREA ADIMP.
C
      PAV=PX6+UZTWC-UZTWM
C
C     PAV IS THE PERIOD AVAILABLE MOISTURE IN EXCESS
C     OF UZTW REQUIREMENTS.
```

```
      IF(PAV.GE.0.0) GO TO 232
C
C     ALL MOISTURE HELD IN UZTW--NO EXCESS.
C
      UZTWC=UZTWC+PX6
      PAV=0.0
      GO TO 233
C
C      MOISTURE AVAILABLE IN EXCESS OF UZTW STORAGE.
C
  232 UZTWC=UZTWM
  233 ADIMC=ADIMC+PX6-PAV
C
C
C*************************************************************
C
      SBF=0.0
      SSUR=0.0
      SIF=0.0
      SPERC=0.0
      SDRO=0.0
C
      NINC=1.0+0.2*(UZFWC+PAV)
C
C     NINC=NUMBER OF TIME INCREMENTS THAT THE SIX
C     HOUR PERIOD IS DIVIDED INTO FOR FURTHER
C     SOIL-MOISTURE ACCOUNTING.  NO ONE PERIOD
C     WILL EXCEED 5.0 MILLIMETERS OF UZFWC+PAV
C
      DINC=(1.0/NINC)*0.25
C
C     DINC=LENGTH OF EACH INCREMENT IN DAYS.
C
      PINC=PAV/NINC
C
C     PINC=AMOUNT OF AVAILABLE MOISTURE FOR EACH INCREMENT.
C      COMPUTE FREE WATER DEPLETION FRACTIONS FOR
C     THE TIME INTERVAL BEING USED-BASIC DEPLETIONS
C      ARE FOR ONE DAY
C
      DUZ=1.0-((1.0-UZK)**DINC)
      DLZP=1.0-((1.0-LZPK)**DINC)
      DLZS=1.0-((1.0-LZSK)**DINC)
C
C
C.............................................................
C
C
      DO 240 IC=1,NINC
C
      PAV=PINC
      ADSUR=0.0
      RATIO=(ADIMC-UZTWC)/LZTWM
      ADDRO=PINC*(RATIO**2)
      SDRO=SDRO+ADDRO*ADIMP
C
C     ADDRO IS THE AMOUNT OF DIRECT RUNOFF FROM
C     THE AREA ADIMP-SDRO IS THE SIX HOUR SUMMATION
C     COMPUTE BASEFLOW AND KEEP TRACK OF SIX-HOUR SUM.
C
      BF=LZFPC*DLZP
      LZFPC=LZFPC-BF
C
      IF (LZFPC.GT.0.0001) GO TO 234
C
      BF=BF+LZFPC
      LZFPC=0.0
C
  234 SBF=SBF+BF
      BF=LZFSC*DLZS
      LZFSC=LZFSC-BF
C
      IF(LZFSC.GT.0.0001) GO TO 235
C
```

```
      BF=BF+LZFSC
      LZFSC=0.0
C
  235 SBF=SBF+BF
C
C.....................................................................
C
C        COMPUTE PERCOLATION-IF NO WATER AVAILABLE THEN SKIP
C
      IF((PINC+UZFWC).GT.0.01) GO TO 251
C
      UZFWC=UZFWC+PINC
      GO TO 249
C
  251 PERCM=LZFPM*DLZP+LZFSM*DLZS
      PERC=PERCM*(UZFWC/UZFWM)
      DEFR=1.0-((LZTWC+LZFPC+LZFSC)/(LZTWM+LZFPM+LZFSM))
C
C     DEFR IS THE LOWER ZONE MOISTURE DEFICIENCY RATIO
C
      PERC=PERC*(1.0+ZPERC*(DEFR**REXP))
C
C     NOTE...PERCOLATION OCCURS FROM UZFWC BEFORE PAV IS ADDED.
C
      IF(PERC.LT.UZFWC) GO TO 241
C
C      PERCOLATION RATE EXCEEDS UZFWC.
C
      PERC=UZFWC
      UZFWC=0.0
      GO TO 247
C
C     PERCOLATION RATE IS LESS THAT UZFWC.
C
  241 UZFWC=UZFWC-PERC
C
C     CHECK TO SEE IF PERCOLATION EXCEEDS LOWER ZONE DEFICIENCY.
C
      CHECK=LZTWC+LZFPC+LZFSC+PERC-LZTWM-LZFPM-LZFSM
C
      IF(CHECK.LE.0.0) GO TO 242
      PERC=PERC-CHECK
      UZFWC=UZFWC+CHECK
  242 SPERC=SPERC+PERC
C
C     SPERC IS THE SIX HOUR SUMMATION OF PERC
C
C.....................................................................
C
C     COMPUTE INTERFLOW AND KEEP TRACK OF SIX HOUR SUM.
C     NOTE...PAV HAS NOT YET BEEN ADDED.
C
      DEL=UZFWC*DUZ
      SIF=SIF+DEL
      UZFWC=UZFWC-DEL
C
C.....................................................................
C
C     DISTRIBE PERCOLATED WATER INTO THE LOWER ZONES
C     TENSION WATER MUST BE FILLED FIRST EXCEPT FOR THE PFREE AREA.
C
  247 VPERC=PERC
      PERC=PERC*(1.0-PFREE)
C
      IF((PERC+LZTWC).GT.LZTWM) GO TO 243
      LZTWC=LZTWC+PERC
      PERC=0.0
      GO TO 244
C
  243 PERC=PERC+LZTWC-LZTWM
      LZTWC=LZTWM
C
C      DISTRIBUTE PERCOLATION IN EXCESS OF TENSION
C      REQUIREMENTS AMONG THE FREE WATER STORAGES.
```

```
  244 PERC=PERC+VPERC*PFREE
      IF(PERC.EQ.0.0) GO TO 245
      HPL=LZFPM/(LZFPM+LZFSM)
C
C     HRL IS THE RELATIVE SIZE OF THE PRIMARY STORAGE
C     AS COMPARED WITH TOTAL LOWER ZONE FREE WATER STORAGE.
C
      RATLP=LZFPC/LZFPM
      RATLS=LZFSC/LZFSM
C
C     RATLP AND RATLS ARE CONTENT TO CAPACITY RATIOS, OR
C     IN OTHER WORDS, THE RELATIVE FULLNESS OF EACH STORAGE
C
C
      PERCP=PERC*((HPL*2.0*(1.0-RATLP))/((1.0-RATLP)+(1.0-RATLS)))
      PERCS=PERC-PERCP
C
C     PERCP AND PERCS ARE THE AMOUNT OF THE EXCESS
C     PERCOLATION GOING TO PRIMARY AND SUPPLEMENTAL
C      STORGES,RESPECTIVELY.
C
      LZFSC=LZFSC+PERCS
C
      IF(LZFSC.LE.LZFSM) GO TO 246
      PERCS=PERCS-LZFSC+LZFSM
      LZFSC=LZFSM
C
  246 LZFPC=LZFPC+(PERC-PERCS)
C
C...............................................................
C
C      DISTRIBUTE PAV BETWEEN UZFWC AND SURFACE RUNOFF.
C
  245 IF(PAV.EQ.0.0) GO TO 249
C
C     CHECK IF PAV EXCEEDS UZFWM
C
      IF((PAV+UZFWC).GT.UZFWM) GO TO 248
C
C     NO SURFACE RUNOFF
C
      UZFWC=UZFWC+PAV
      GO TO 249
C
C...............................................................
C
C     COMPUTE SURFACE RUNOFF AND KEEP TRACK OF SIX HOUR SUM
C
  248 PAV=PAV+UZFWC-UZFWM
      UZFWC=UZFWM
      SSUR=SSUR+PAV*PAREA
      ADSUR=PAV*(1.0-ADDRO/PINC)
C
C     ADSUR IS THE AMOUNT OF SURFACE RUNOFF WHICH COMES
C     FROM THAT PORTION OF ADIMP WHICH IS NOT
C     CURRENTLY GENERATING DIRECT RUNOFF.  ADDRO/PINC
C     IS THE FRACTION OF ADIMP CURRENTLY GENERATING
C     DIRECT RUNOFF.
C
      SSUR=SSUR+ADSUR*ADIMP
  249 ADIMC=ADIMC+PINC-ADDRO-ADSUR
C
  240 CONTINUE
C
C..............................................................
C
C     END OF INCREMENTAL DO LOOP.
C
C
C*************************************************************************
C
```

```
C      COMPUTE SUMS AND ADJUST RUNOFF AMOUNTS BY THE AREA OVER
C      WHICH THEY ARE GENERATED.
C
       EUSED=E1+E2+E3
C
C      EUSED IS THE ET FROM PAREA WHICH IS 1.0-ADIMP-PCTIM
C
       SIF=SIF*PAREA
C
C      SEPARATE CHANNEL COMPONENT OF BASEFLOW
C      FROM THE NON-CHANNEL COMPONENT
C
       TBF=SBF*PAREA
C
C      TBF IS TOTAL BASEFLOW
C
       BFCC=TBF*(1.0/(1.0+SIDE))
C
C      BFCC IS BASEFLOW, CHANNEL COMPONENT
       BFNCC=TBF-BFCC
C
C      BFNCC IS BASEFLOW,NON-CHANNEL COMPONENT
C
C
C..............................................................
C
C      ADD TO MONTHLY SUMS.
C
       SINTFT=SINTFT+SIF
       SGWFT=SGWFT+BFCC
       SRECHT=SRECHT+BFNCC
       SROST=SROST+SSUR
       SRODT=SRODT+SDRO
C
C
C      COMPUTE TOTAL CHANNEL INFLOW FOR THE SIX-HOUR PERIOD.
C
       TCI=ROIMP+SDRO+SSUR+SIF+BFCC
C
C      COMPUTE E4-ET FROM STREAM SURFACES AND RIPARIAN VEGETATION.
C
       E4=EDMND*WATSF+(EDMND-EUSED)*SARRA
C
C      SUBTRACT E4 FROM CHANNEL INFLOW
C
       TCI=TCI-E4
       IF(TCI.GE.0.0) GO TO 250
       E4=E4+TCI
       TCI=0.0
C
C      COMPUTE TOTAL EVAPOTRANSPIRATION-TET
C
  250  EUSED=EUSED*PAREA
       TET=EUSED+E5+E4
       SETT=SETT+TET
C
C
C...............................................................
C
       RO(IRG,IP6,IDA) = TCI
C
C...............................................................
C
       SROT=SROT+TCI
C
C       PRINT SIX-HOUR ACCOUNTING VALUES IF REQUESTED.
C
       IF(IPRINT.EQ.1) PRINT 903,IDA,IP6,UZTWC,UZFWC,LZTWC,LZFSC,LZFPC,AD
      1IMC,SPERC,ROIMP,SDRO,SSUR,SIF,BFCC,TCI,EDMND,TET,PX6
  903  FORMAT(1H ,2I3,6F7.1,7F8.2,3F8.1)
C
       IF((IDA.EQ.ID2).AND.(IP6.EQ.IP2)) GO TO 270
       IP6=IP6+1
C
```

```
      IF(IP6.LE.4) GO TO 205
C
      IP6=1
      IDA=IDA+1
      GO TO 205
C
C
C***********************************************************************
C
C      END OF SIX HOUR AND DAY LOOP
C
C***********************************************************************
C
  270 IF(IRG.NE.NGAGES) GO TO 271
      IF((IPRINT.EQ.1).AND.(ICOUNT.LT.8)) ICOUNT=ICOUNT+1
  271 IPRINT=0
C
C
C     COMPUTE MONTHLY WATER BALANCE FOR AREAL SOIL MOISTURE ACCOUNTING.
C
      BAL(IRG)=(UZTWC+UZFWC+LZTWC+LZFPC+LZFSC-UZTWC1-UZFWC1-LZTWC1-LZFPC
     11-LZFSC1)*PAREA+(ADIMC-ADIMC1)*ADIMP+SROT+SRECHT+SETT-SPRT
C
C
C.......................................................................
C
      SL(IRG,1)=SROT
      SL(IRG,2)=SIMPVT
      SL(IRG,3)=SRODT
      SL(IRG,4)=SROST
      SL(IRG,5)=SINTFT
      SL(IRG,6)=SGWFT
      SL(IRG,7)=SRECHT
      SL(IRG,8)=SPRT
      SL(IRG,9)=SPET
      SL(IRG,10)=SETT
      VL(IRG,1)=UZTWC
      VL(IRG,2)=UZFWC
      VL(IRG,3)=LZTWC
      VL(IRG,5)=LZFPC
      VL(IRG,4)=LZFSC
      VL(IRG,6)=ADIMC
C
C
      RETURN
C
      END
```

```
**************************************************************************
**************************************************************************

          DICTIONARY FOR SUBROUTINE LAND...NWS.HRL. VERSION 9/11/75

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--------------------------------------------------------------------------

SYMBOL ... EXPLAINATION

--------------------------------------------------------------------------

F       ... MEAN SEASONAL POT-EVAP CURVE ARRAY
I       ... INDEX

BF      ... BASE FLOW
EP      ... DAILY EVAPORATION
E1      ... EVAP FROM UPPER ZONE TENSION WATER
E2      ... EVAP FROM UPPER ZONE FREE WATER
E3      ... EVAP FROM LOWER ZONE TENSION WATER
E4      ... EVAP FROM STREAM SURFACES AND RIPARIAN VEGETATION
E5      ... EVAP FROM ADDITIONAL IMPERVIOUS AREA
IC      ... INDEX
PE      ... POTENTIAL EVAPORATION ARRAY
PL      ... INITIAL PARAMETER VALUE ARRAY
PX      ... PRECIPITATION ARRAY
RO      ... RUNOFF ARRAY
SL      ... ARRAY CONTAINING MONTHLY TOTALS OF VARIOUS COMPONENTS
TA      ... VARIABLE IN COMMON
VL      ... ARRAY CONTAINING SOIL MOISTURE STORAGE VOLUMES

AID     ... AREA IDENTIFICATION
BAL     ... WATER BALANCE
DEL     ... INCREMENTAL VOLUME OF WATER
DUZ     ... UPPER ZONE FREE WATER DEPLETION COEFFICIENT
EFC     ... EVAP ADJUSTMENT FACTOR
HPL     ... RATIO      LZFPM/(LZFPM + LZFSM)
IDA     ... DAY INDEX
ID1     ... FIRST DAY
ID2     ... LAST DAY
IPT     ... VARIABLE IN COMMON BLOCK ONLY
IP1     ... FIRST PERIOD OF FIRST DAY
IP2     ... LAST PERIOD OF LAST DAY
IP6     ... SIX HOUR PERIOD INDEX
IRG     ... INDEX
NQ6     ... VARIABLE IN COMMON BLOCK ONLY
PAV     ... MOISTURE IN EXCESS OF UZTW REQUIREMENTS
PEG     ... POTENTIAL EVAPORATION OPTION VARIABLE
PX6     ... SIX-HOUR PRECIPITATION
RED     ... RESIDUAL EVAPORATION DEMAND
SBF     ... SUPPLEMENTAL BASE FLOW
SIF     ... INTERFLOW
SOF     ... VARIABLE IN COMMON ONLY
SSF     ... VARIABLE IN COMMON ONLY
TBF     ... TOTAL BASE FLOW
TCI     ... TOTAL CHANNEL INFLOW
TET     ... TOTAL EVAPOTRANSPIRATION
UZK     ... UPPER ZONE DRAINAGE PARAMETER
YR1     ... FIRST YEAR
YR2     ... LAST YEAR
```

```
AREA    ...  AREA NAME
BFCC    ...  BASE FLOW CHANNEL COMPONENT
DEFR    ...  LOWER ZONE MOISTURE DEFICIENCY RATIO
DINC    ...  LENGTH OF SOIL MOISTURE ACCOUNTING TIME INTERVAL IN DAYS
DLZP    ...  LOWER ZONE PRIMARY STORAGE DEPLETION COEFFICIENT
DLZS    ...  LOWER ZONE SUPPLEMENTAL STORAGE DEPLETION COEFFICIENT
EFCT    ...  EVAPORATION ADJUSTMENT FACTOR
FPID    ...  VARIABLE IN COMMON BLOCK --- FLOW POINT I.D.
IGPE    ...  POTENTIAL EVAP DATA OPTION VARIABLE
LAND    ...  SUBROUTINE NAME
LAST    ...  VARIABLE IN COMMON BLOCK ONLY
LZPK    ...  LOWER ZONE PRIMARY STORAGE DRAINAGE PARAMETER
LZSK    ...  LOWER ZONE SUPPLEMENTAL STORAGE DRAINAGE PARAMETER
MOIN    ...  VARIABLE IN COMMON ONLY
MOSM    ...  MONTHS FOR WHICH A DETAILED SOIL MOISTURE OUTPUT IS REQUESTED
NINC    ...  NUMBER OF INTERVALS IN ONE 6-HR PERIOD USED FOR SOIL MOISTURE
             ACCOUNTING
NPTS    ...  VARIABLE IN COMMON ONLY
NQ24    ...  VARIABLE IN COMMON ONLY --- NUMBER OF DAILY FLOW TIME SERIES
NTAG    ...  VARIABLE IN COMMON ONLY-NUMBER OF AIR TEMPERATURE TIME SERIES
NWEG    ...  VARIABLE IN COMMON ONLY --NUMBER OF WATER EQUIV. TIME SERIES
OFW6    ...  VARIABLE IN COMMON ONLY
PEID    ...  VARIABLE IN COMMON ONLY
PERC    ...  PERCOLATION RATE
PINC    ...  AMOUNT OF AVAILABLE MOISTURE FOR EACH INCREMENT
PLOT    ...  VARIABLE IN COMMON ONLY
PXID    ...  VARIABLE IN COMMON ONLY
Q6ID    ...  VARIABLE IN COMMON ONLY
REXP    ...  EXPONENT IN PERCOLATION EQUATION
SDRO    ...  6-HR SUMMATION OF DIRECT RUNOFF
SETT    ...  MONTHLY SUMMATION OF EVAPOTRANSPIRATION
SFW6    ...  VARIABLE IN COMMON ONLY
SIDE    ...  PARAMETER SEPARATING CHANNEL AND NON-CHANNEL INFLOW
SNOW    ...  SNOW OPTION VARIABLE
SPET    ...  MONTHLY SUM OF POTENTIAL EVAPORATION
SPRT    ...  MONTHLY SUM OF PRECIPITATION
SROT    ...  MONTHLY SUM OF RUNOFF OR TOTAL CHANNEL INFLOW
SSUR    ...  MONTHLY SUM OF SURFACE RUNOFF
STAT    ...  VARIABLE IN COMMON ONLY
STDA    ...  VARIABLE IN COMMON ONLY
STP6    ...  VARIABLE IN COMMON ONLY
UFW6    ...  VARIABLE IN COMMON ONLY
YEAR    ...  CURRENT YEAR
YRIN    ...  VARIABLE IN COMMON ONLY
```

ADDRO ... DIRECT RUNOFF FROM AREA ADIMP
ADMIC ... ADDITIONAL IMPERVIOUS AREA STORAGE
ADIMP ... ADDITIONAL IMPERVIOUS AREA
ADSUR ... SURFACE RUNOFF FROM PORTION OF ADIMP NOT PRODUCING ADDRO
ANAME ... AREA NAME
BASIN ... VARIABLE IN COMMON ONLY
BFNCC ... BASE FLOW-NONCHANNEL COMPONENT
CHECK ... A PERCOLATION RATE CHECK
COVER ... SNOW COVER
CTEST ... VARIABLE IN COMMON ONLY
EDMND ... EVAPORATION DEMAND FOR SIX HOURS
EUSED ... EVAPOTRANSPIRATION FROM PAREA=1.0-ADIMP-PCTIM
INFRO ... VARIABLE IN COMMON ONLY
I06IN ... VARIABLE IN COMMON ONLY
LINEP ... VARIABLE IN COMMON ONLY
LZFPC ... LOWER ZONE PRIMARY FREE WATER STORAGE CONTENTS
LZFPM ... LOWER ZONE PRIMARY FREE WATER STORAGE MAXIMUM
LZFSC ... LOWER ZONE SUPPLEMENTAL FREE WATER STORAGE CONTENTS
LZFSM ... LOWER ZONE SUPPLEMENTAL FREE WATER STORAGE MAXIMUM
LZTWC ... LOWER ZONE TENSION WATER STORAGE CONTENTS
LZTWM ... LOWER ZONE TENSION WATER STORAGE MAXIMUM
MONTH ... CURRENT MONTH
NPEGS ... VARIABLE IN COMMON ONLY
OBSER ... VARIABLE IN COMMON ONLY
OFW24 ... VARIABLE IN COMMON ONLY
PAREA ... PAREA=1.0-ADIMP-PCTIMP
PCTIM ... PERCENT OF AREA THAT IS IMPERVIOUS
PEADJ ... POTENTIAL EVAPORATION ADJUSTMENT FACTOR
PERCM ... DISCHARGE FROM LOWER ZONE
PERCP ... AMOUNT OF PERCOLATED WATER TO LOWER ZONE PRIMARY STORAGE
PERCS ... AMOUNT OF PERCOLATED WATER TO LOWER ZONE SUPPLEMENTAL STORAGE
PFREE ... PERCENTAGE OF PERCOLATED WATER TO LOWER ZONE FREE WATER STORAGE
PPADJ ... PRECIPITATION ADJUSTMENT FACTOR
PTEST ... VARIABLE IN COMMON ONLY
PXADJ ... VARIABLE IN COMMON ONLY
Q24ID ... VARIABLE IN COMMON ONLY
RATIO ... RATIO (ADIMC-UZTWC)/LZTWM
RATLP ... LOWER ZONE PRIMARY CONTENTS TO CAPACITY RATIO
RATLS ... LOWER ZONE SUPPLEMENTAL CONTENTS TO CAPACITY RATIO
RATLZ ... TOTAL LOWER ZONE STORAGE CONTENTS TO CAPACITY RATIO
ROIMP ... RUNOFF FROM IMPERVIOUS AREA
ROUTE ... VARIABLE IN COMMON ONLY
RSERV ... LOWER ZONE FREE WATER THAT IN UNAVAIL TO MEET LZTW REQUIREMENTS
SARRA ... SARRA=SARVA-PCTIM
SARVA ... PERCENT OF AREA IN STREAM AND RIPARION VEGETATION
SAVED ... VOLUME OF LOWER ZONE FREE WATER NOT AVAILABLE FOR LZTW
SGWFT ... MONTHLY SUM OF BASE FLOW REACHING THE CHANNEL
SIXIN ... VARIABLE IN COMMON ONLY
SNOWA ... ARRAY CONTAINING INDICATORS FOR VALID AIR-TEMP DATA FOR EACH MONTH
SPERC ... 6-HR SUMMATION OF PERC
SRODT ... SUMMATION OF DIRECT RUNOFF
SROST ... SUMMATION OF SURFACE RUNOFF
STORE ... VARIABLE IN COMMON ONLY
UZFWC ... UPPER ZONE FREE WATER CONTENTS
UZFWM ... UPPER ZONE FREE WATER MAXIMUM
UZRAT ... UPPER ZONE CONTENTS TO CAPACITY RATIO
UZTWC ... UPPER ZONE TENSION WATER CONTENTS
UZTWM ... UPPER ZONE TENSION WATER MAXIMUM
VPERC ... TEMPORARY STORAGE VARIABLE FOR PERC
WATSF ... WATER SURFACE AREA
ZPERC ... PERCOLATION PARAMETER

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ADIMC1 ... INITIAL CONTENTS OF ADIMC
COMPAR ... VARIABLE IN COMMON ONLY
EPDIST ... DISTRIBUTION OF DAILY POTENTIAL EVAP
FPNAME ... VARIABLE IN COMMON ONLY
FSFLOW ... VARIABLE IN COMMON ONLY
ICOUNT ... INDEX
IPRINT ... PRINT OPTION VARIABLE
IQ24IN ... VARIABLE IN COMMON ONLY
IYEAR1 ... VARIABLE IN COMMON ONLY
LZFPC1 ... INITIAL VALUE OF LZFPC
LZFSC1 ... INITIAL VALUE OF LZFSC
LZTWC1 ... INITIAL VALUE OF LZTWC
METRIC ... VARIABLE IN COMMON ONLY
NGAGES ... NUMBER OF RAIN GAGES
NPTSUP ... VARIABLE IN COMMON ONLY
PLOTMX ... VARIABLE IN COMMON ONLY
PLT6HR ... VARIABLE IN COMMON ONLY
RATLZT ... LOWER ZONE TENSION WATER STORAGE CONTENTS TO CAPACITY RATIO
SAVEFW ... VARIABLE IN COMMON ONLY
SIMPVT ... SUMMATION OF IMPERVIOUS AREA RUNOFF
SINTFT ... MONTHLY SUMMATION OF INTERFLOW
SRECHT ... MONTHLY SUMMATION OF CHANNEL COMPONENT OF BASE FLOW
UPFWID ... VARIABLE IN COMMON ONLY
UZFWC1 ... INITIAL VALUE OF UZFWC
UZTWC1 ... INITIAL VALUE OF UZTWC
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