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LAKE SUPERIOR BASIN RUNOFF MODELING

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LAKE SUPERIOR BASIN RUNOFF MODELING*

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The GLERL Large Basin Runoff Model is applied to the Lake Superior Basin; it is an interdependent tank-cascade model, which employs analytical solutions of climatological considerations relevant for large watersheds. The mass balance is coupled with physically-based concepts of linear reservoir storages, partial-area infiltration, complementary evapotranspiration and evapotranspiration opportunity based on available supply, and degree-day determinations of snowmelt and net supply. Daily or monthly air temperature, precipitation, and runoff data are required for calibration of the nine parameters; data are grouped for 22 watersheds about Lake Superior, as well as for the entire basin above Sault Ste. Marie, Mich. The model is applied to the Lake Superior Basin in both lumped- and distributed-parameter approaches. Twenty subbasins and the entire basin are modeled for l-d, 7-d, and monthly mass-balance computation intervals. The l-d and 7-d models "se daily data and compute net supply and evapotranspirstion opportunity on a daily basis. The monthly model uses monthly data and computes net supply and evapotranspiration opportunity on a monthly basis. Parameter and soil moisture values are interpreted for physical meaning; soil moisture is also related to basin characteristics. Result summaries depicting model applications and validity are given. The model is extended to forecast net basin supplies to Lake Superior. There are examinations of sensitivity of the forecasts to initial conditions and discussions of improvements in forecasting. The model is an accurate, fast representation of weekly or monthly runoff volumes from large watersheds, and it has simple calibration and data requirements. Parameter values have physical relevance and appear reasonable. The model has good potential, when using near real-time data, for semiautomatic generation of practical probabilistic outlooks of runoff and net basin supply.

1. INTRODUCTION

It is necessary to have physically-based rainfall-runoff watershed models in order to simulate basin outflows to the Great Lakes for use in routing models for lake levels simulation and forecasts. The models must be specific for weekly or monthly outflow volumes from large areas with severely limited data availability. Only daily precipitation and air temperatures are available over the Great Lakes Basin in an often sparse meteorological network. The Great Lakes Environmental Research Laboratory recently completed development and testing of its Large Basin Runoff Model; the model and its operation

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are described in detail by Croley (1982a,b, 1983b,c) and Croley and Hartmann (1983). These reports compared the model with others and described its application to the Lake Ontario subbasins for both 7-d and 30-d flow volumes. It is an accurate, fast model with relatively simple calibration and data requirements for large watersheds. Subsequent to the comparisons described in the preceding papers, the model is being used to simulate basin runoff contributions to each of the other Great Lakes for use in routing models.

This report describes the model changes made for, and the application results from. the subbasins of Lake Superior and the entire Lake Superior Basin for l-d, 7-d, and monthly flow volumes. The meteorological record is assessed for its information content, and the calibration procedure is tested against an idealized data set. Calibrated parameter values for each of the subbasin applications are interpreted with regard to their physical meaning; the model behavior is illustrated for the lumped-parameter application to the entire Lake Superior Basin and calculated soil moisture values are examined and related to basin characteristics.

Other applications of the runoff model that are described are for use in probabilistic outlooks of net basin supply to Lake Superior. The model is used in a procedure similar to the Extended Streamflow Prediction (ESP) procedure used by the National Weather Service and other agencies for forecasting flooding probabilities. The procedure, as applied for net basin supply volumes for Lake Superior, is described here. Several studies were required to assess the runoff model's sensitivity to parameters and initial or boundary conditions, and to assess the applicability of a limited near real-time meteorological network. Results from all of these studies and example probabilistic outlooks are presented here. Recommendations for future uses are made and subsequent applications are outlined.

The Large Basin Runoff Model is presented in a user's guide format in the appendices for applications using daily or monthly hydrometeorological data. Appendices C and F-H document the semiautomatic parameter calibration procedure for the model. Appendices B-E document the use of the calibrated model in simulations and statistical summaries. Appendices C and K-N document use of the model for estimation of probabilistic outlooks of net basin supply to Lake Superior. These appendices form a self-contained user's guide to the model and provide full instructions, source code listings, and examples for use of the Large Basin Runoff Model.

2. RUNOFF MODEL

This section briefly describes the Large Basin Runoff Model, as previously applied to the Lake Ontario Basin. In later sections the model is applied to the Lake Superior Basin. Minor changes are necessary in the computation of potential snowmelt and the heat available for evapotranspiration; these are described. Distinctions are made for model use with daily and monthly hydrometeorological data and fixed and variable mass-balance computation intervals. A user's guide for the use of the model in simulations is presented with source code and examples.

2.1 Description of Lake Ontario Basin Model

The general model structure is summarized elsewhere (Croley, 1982a,b, 1983b.c; Croley and Hartmann. 1983) and is only briefly reviewed here. The model uses the tank-cascade concept pictured schematically in figure 1; model parameters are also identified there. Inputs of daily precipitation, daily minimum and maximum air temperatures, and seasonal insolation determine the snowpack accumulation and the resulting net supply rate to the watershed (not to be confused with net supply to the lake, which is basin runoff plus lake precipitation minus lake evaporation). Precipitation accumulates in the snow-pack when air temperatures are below freezing. Snowmelt values are based on the limiting of snowpack volume or potential melt determined from the absorbed insolation (estimated from minimum and maximum air temperatures and seasonal insolation) and from the heat of precipitation. Net supply to the watershed is equal to precipitation plus snowmelt when sir temperatures are above freezing and zero otherwise. Net supply is divided into surface runoff and infiltration into the upper soil zone, based upon a partial-ares concept. Surface runoff occurs over that portion of the watershed surface that is saturated; thus, surface runoff is proportional to the upper soil zone moisture and to the net supply rate.

The proportionality constant is defined as the inverse of the capacity of the upper soil zone (USZC) (not represented in fig. 1). The upper soil zone capacity is typically set to correspond to 2 cm of water over the basin area. Past sensitivity studies have indicated that changes in USZC can be compensated for by changes in other model parameters and so it is set arbitrarily. Percolation from the upper soil zone recharges the lower soil zone and the rate is proportional to the moisture in storage in the upper soil zone (linear reservoir concept). Deep percolation from the lower soil zone recharges the groundwater sons and is proportional to the moisture in storage in the lower soil zone. Flows from these three zones (of surface runoff, interflow, and groundwater) recharge the surface storage; each rate is proportional to the moisture content in the respective zones (see fig. 1). Basin outflow (also referred to herein as basin runoff) flows from the surface storage, which acts as a linear reservoir. There may he evapotranspiration losses from any of these storages although, at present, losses from the surface and groundwater storages are recognized as negligible relative to losses from the upper and lower soil zones; thus, they are set to zero in the model. The combined evapotranspiration rate (e) from the upper and lower soil zones is taken as both proportional to the sensible heat rate of the atmosphere (e_p) and complementary to the heat already used. The sum of evapotranspiration and potential evapotranspiration is estimated as a linear (broken-line) function of air temperature.

The mass-balance equations for all four tanks in the cascade of figure 1 form a set of simultaneous ordinary linear differential equations whose joint solution depends upon the relative magnitudes of all parameters, inputs, and system states (storages) pictured in figure 1. Complete analytical solutions for all possible ranges of values are available (Croley, 1982a). Since analytical solutions exist, the approximation errors and convergence problems associated with numerical solutions are bypassed in the use of the model. Please note that small linear reservoir coefficients imply small releases and,

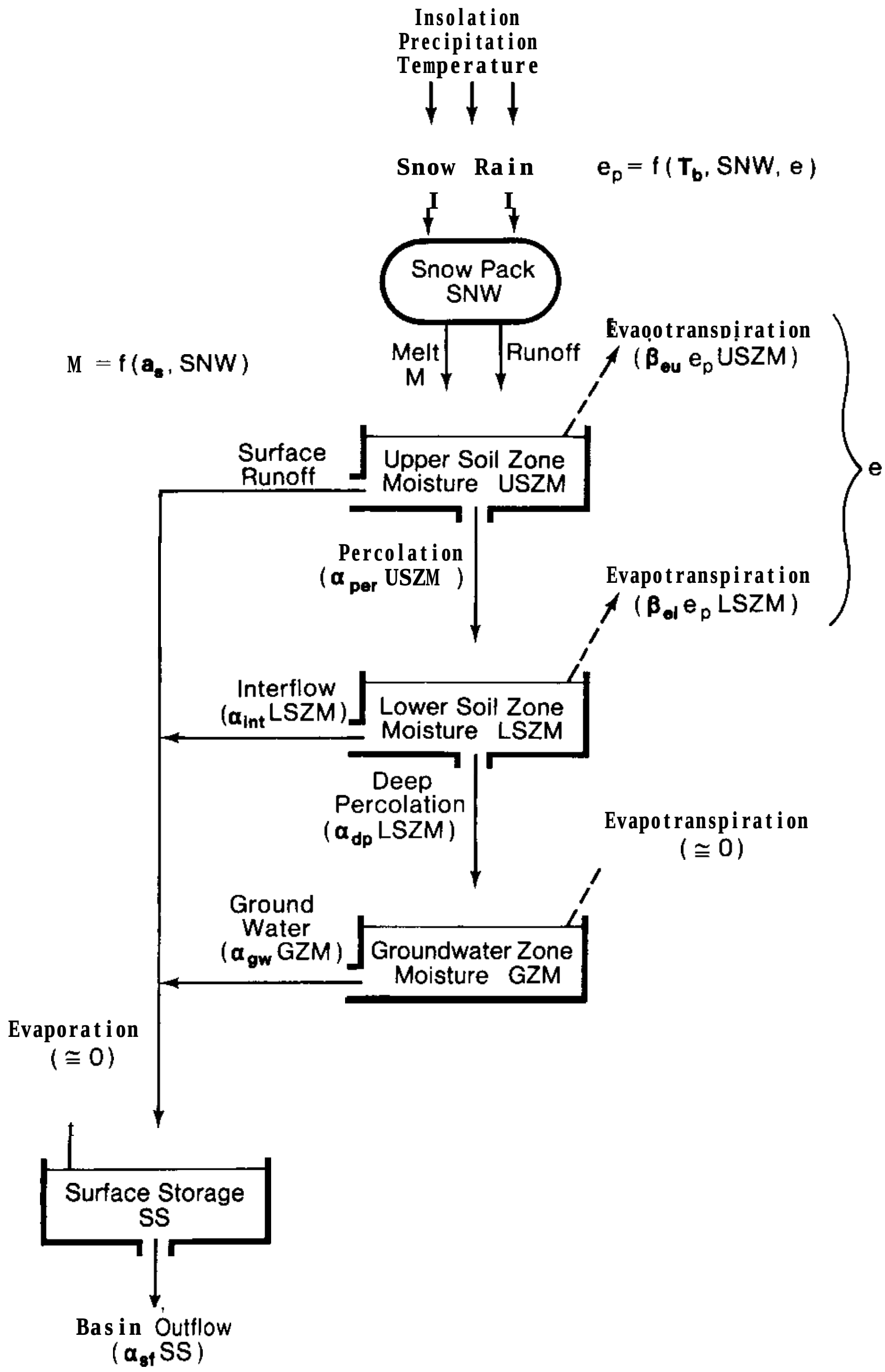

FIGURE 1.--*GLERL Large Basin Runoff Model schematic.*

hence, large storage volumes; large values imply small storages and, therefore, outflows nearly equal to inflows.

Values must then be determined for nine parameters: T_b, a, α_{per}, β_{eu}, α_{int}, α_{dp}, β_{el}, α_{gw}, and asf, where α_{per}, α_{int}, α_{dp}, α_{gw}, and α_{sf} are linear reservoir coefficients on the upper soil zone, lower soil zone, lower soil zone, groundwater zone, and surface storages, respectively, for percolation, interflow, deep percolation, groundwater, and basin outflow. 8," and β_{el} are partial linear reservoir coefficients on the upper and lower soil zone moisture storages for evapotranspiration; they are used with storage and the rate of evapotranspiration still possible.

2.2 Model Adaptations for Lake Superior

2.2.1 Potential Snowmelt

For the application to Lake Superior, two minor changes were made to the model. The first change is in the computation of potential snowmelt. A simple degree-day approach was found to be marginally superior to the "se of absorbed insolation and the heat of rainfall (as used in the previous applications) for the subbasins of Lake Superior. Potential snowmelt is what occurs if the snowpack is not limiting

$$m_p = 0, \qquad T < 0$$
$$= aDD, \qquad T > 0, \qquad (1)$$

where m_p = daily potential snowmelt rate (m^3/d); a = proportionality constant for snowmelt per degree-day ($m^3/°C\text{-}d$); T = air temperature, estimated as the average of the daily maximum and minimum temperatures (°C); and DD = degree-days per day (°C-d/d), computed as the integral of air temperature with time over those portions of the day when it is positive. Since the fluctuation of air temperature during the diurnal cycle is unknown, a triangular distribution is assumed (to approximate en expected sinusoidal variation) for ease of computation. The resulting expression for degree-days is:

$$DD = 0, \qquad T_{max} < 0$$
$$= \frac{1}{2}\frac{T_{max}^2}{(T_{max} - T_{min})}, \qquad T_{min} < 0 < T_{max}$$
$$= T, \qquad 0 < T_{min}, \qquad (2)$$

where T_{max} = maximum daily air temperature (°C) and T_{min} = minimum daily air temperature (°C). The proportionality constant, a, is a model parameter to be determined in calibration of the model to a data set and it replaces the albedo of the snow surface, a_s, used previously (Croley and Hartmann, 1983).

A more complex degree-day approach that also included refreezing and snow quality was tried, but did not improve model performance. (See sppendix A.)

2.2.2 Heat Available for Evapotranspiration

The second model change is in the heat available for evapotranspiration. To allow evapotranspiration throughout the year, with or without snow cover, the broken line relationship was replaced by an exponential with the same parameters

$$W = Ke^{T/T_b}, \qquad (3)$$

where W = total energy available for evapotranspiration during the day (cal), K = units and proportionality constant (cal), and Tb = a base scaling temperature. The constant, K, is determinable from the boundary condition on the long-term heat balance (Croley and Hartmann, 1983) and the base temperature is determined as before from model calibration.

2.3 Computation Intervals

The differential equations for the mass balance can be applied over any time increment by assuming that the net supply and sensible heat available for evapotranspiration are uniform over the time increment. Thus, the resolution of the equations is limited only by the interval for which precipitation and temperature data are available. The mass-balance computation interval may be any length greater than or equal to the interval length for which meteorological data are available.

2.3.1 Daily Data

Use of daily meteorological data allows mass-balance computation intervals of 1 d or longer (e.g., 7 d, 30 d, etc.). Net supply and sensible heat available for evapotranspiration are first computed on a daily basis regardless of the mass-balance interval, but are then summed over the interval to represent the n-d averages, where n is the number of days in the mass-balance computation interval. Values of n are 1 and 7 for daily and weekly model applications, respectively, however, both models use daily data.

2.3.2 Monthly Data

Use of monthly meteorological data permits mass-balance computation intervals of 1 month or more, but the monthly interval may represent 28-31 days, depending on the month and year. A variable computation interval is therefore used for the monthly model to accomodate the variable length of the month. Net supply and heat available for evapotranspiration are computed on a monthly basis from the monthly data and are therefore not summed over the computation interval.

2.4 User's Guide

Appendix B contains source code listings for the Large Basin Runoff Model for use in simulation settings with daily or monthly hydrometeorological data (the files called WATERS and MMWAT, respectively). A short user's guide is also given there. Appendix C contains a partial listing of an example input daily hydrometeorological data set (the file called DATA) and a complete listing of an example input monthly hydrometeorological data set (the file called MDATA). Appendix D contains two example input parameter sets (the files called PARM and MPARM) for daily and monthly simulations, respectively. Appendix E contains partial listings of example output (the files called SUMARY and MSUM) from the simulation packages of appendix B (WATERS and MMWAT, respectively) when used with the data files of appendix C (DATA and MDATA, respectively) and the calibrated parameter sets of appendix D (PARM and MPARM, respectively).

3. DATA PREPARATION

This section describes how the Lake Superior Basin is divided into subbasins and how meteorological and hydrological stations are used with the Large Basin Runoff Model. It also includes an analysis of the meteorological record for data availability and information content and a summary of subbasin information.

3.1 Study Area and Subbasin Delineation

The Lake Superior Basin, above the locks at Sault Ste. Marie, drains about 130,000 km2 of Ontario, Minnesota, Wisconsin, and Michigan. It is divided into 22 subbasins for use with the model (fig. 2). Subbasin boundaries are based on State Hydrologic Unit maps from the U.S. Geological Survey (USGS) for Michigan, Wisconsin, and Minnesota, and on drainage basin map overlays from the Water Resources Branch of the Inland Waters Directorate of Environment Canada for Ontario. Subbasins not draining directly into Lake Superior were combined with those into which they drained so that all resulting subbasins have a direct outlet to the lake.

3.2 Daily Meteorological Data

3.2.1 Areal Averaging

There are 54 meteorological stations used here for the Lake Superior Basin (fig. 2). Thiessen weights for all meteorological stations over all subbasins used in this study are based on planimetered measurements of polygonal areas from 1:500,000 maps and are identified in tahle 1. Meteorological data for stations in the United States are from the National Climatic Data Center; National Environmental Satellite, Data, and Information Service; NOAA. Meteorological data for stations in Canada are from the Canadian Climate Centre, Atmospheric Environment Service, Environment Canada.

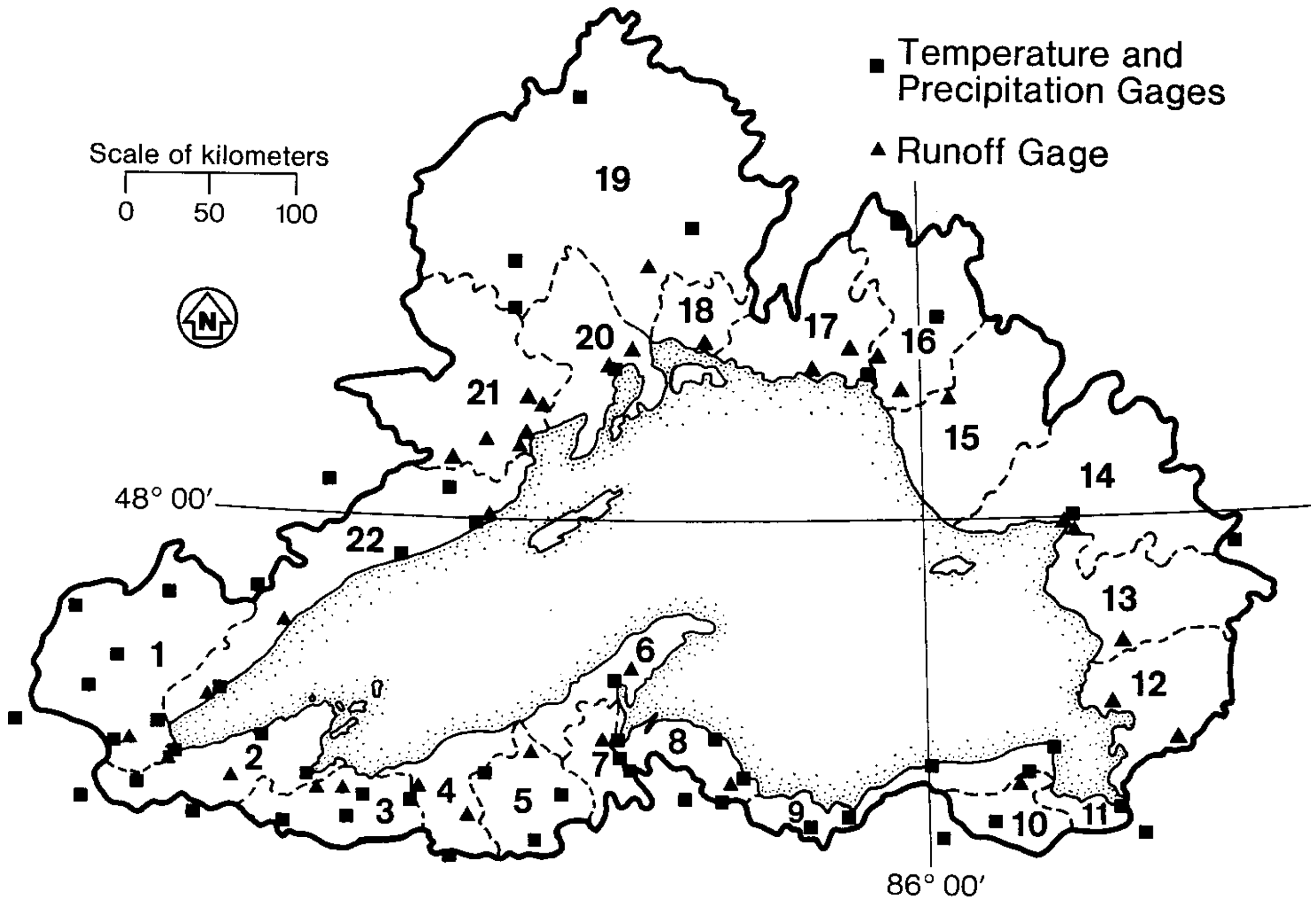

FIGURE   *and runoff gages in the Lake Superior Basin.*

TABLE 1.--*Selected meteorological station Thiessen weights a Lake Superior subbasins*

Met. station number*	1	2	3	4	5	6	7	a	9	10	11	12	13	14	15	16	17	18	19	20	21	22	L†
211840	.18																						.014
213730	.14																						.011
213921	.21																						.015
215298	.16																						.012
217460	.02																						.002
212248	.09																					.03	.009
214068	.03																					.18	.014
218419	.07																					.12	.013
211630	.08	.02																					.007
472889	.01	.17																					.007
47.5349	.01	.14																					.006
215598		.03																					.001
477892		.12																					.005
470349		.25	.09																				.012
472240		.02	.19																				.006
476772		.24	.00																				.009
473332		.01	.20	.01																			.006
475286			.30																				.008
204104			.21	.27																			.011
477092			.01	.22	.01																		.005
208680				.00	.33																		.009
200718				.50	.32	.07																	.021
204328					.34	.06	.19																.013
200485						.06	.35	.16															.009
203908						.81	.08	.01															.019
200089							.29	.03															.005
201439							.00	.05															.001
203744							.09	.15															.004
200770								.35															.007
204127								.16															.003
205178								.09	.10														.004
201484									.23														.006
205690									.13														.003
208920									.05		.00	.23	.07										.013
203319									.25														.006
205816									.05														.011
208043									.19		.29												.012
207515																							.001
202298											.09												.001
207366											.62	.60											.028
6061358												.17	.48	.21									.044
6059409													.45	.79	.31								.100
6044903															.36	.45							.047
6044959															.33	.22	.69						.060
6041193																.33	.18						.025
6040572																	.09	.59					.087
6042067																	.04	.41		.68	.06	.01	.049
6040325																							.064
6040020																				.08	.03		.059
6041109																				.24	.42		.042
213417																					.06	.06	.007
6045675																					.43	.20	.042
213282																						.22	.014
213296																						.18	.011

*Canadian stations (seven-digit numbers) available from Canadian Climate Centre, Environment Canada. United States stations (six-digit numbers) available from National Environmental Satellite, Data, and Information Service, NOAA, U.S. Department of Commerce.

†Entire Lake Superior Basin.

The meteorological stations whose Thiessen polygons intersect a given subbasin and whose records contain no missing data for the day in question are used to determine the Thiessen-weighted subbasin areal averages for minimum air temperature, maximum air temperature, and precipitation for each day. The averaging for each day is accomplished by multiplying data values from each station by the corresponding Thiessen weight, summing all weighted values for the subbasin (from all stations being used), and dividing the sum by the sum of the Thiessen weights for the stations actually used. Thus, missing data at a given meteorological station is effectively "filled-in" by using data at the surrounding stations within the same subbasin. If no stations in a subbasin have data for a given day, then the areal average is set equal to -9999. to denote missing data for subsequent uses of the data set.

A daily meteorological data set for the entire Lake Superior Basin is constructed by multiplying the areal-average daily data values from each subbasin with no missing data for the day in question by the corresponding subbasin area, summing all weighted values for the entire basin (from all subbasins being used), and dividing the sum by the sum of the subbasin areas actually used. Finally, all precipitation values (average daily depths) are converted to daily volumes by multiplying them by the area of the subbasin (for each of the 22 subbasins) or the area of the entire basin (for the entire Lake Superior Basin). The daily meteorological data sets are judged to be very complete; areal-averaged daily air temperatures and precipitation for each subbasin are about 99-percent complete.

3.2.2 Data Availability/Information Content

Figure 3 illustrates the amount of information available from the 54 meteorological stations for daily precipitation since 1900. Daily minimum and maximum air temperature plots are found to be similar. The actual record size plot in figure 3 is computed, for each year of record, by dividing the number

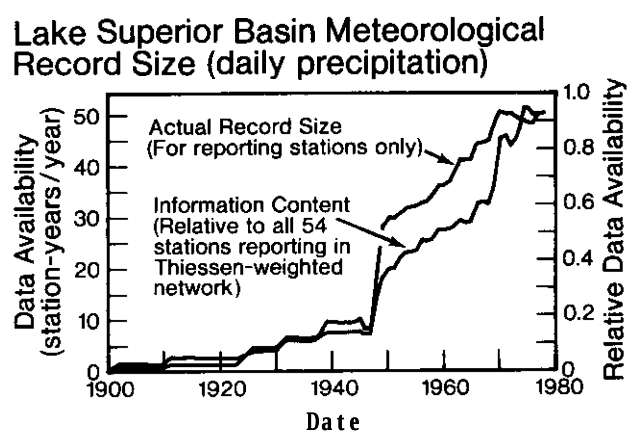

FIGURE 3.--*Daily precipitation data* network *history for the Lake Superior Basin.*

of days of actually available data at each station by the number of days in a year (to get station-years/year for each station) and summing over all 54 stations. It can be interpreted also as relative data availability on a scale of 0 to 1 (the right-hand scale), where unity represents all 54 stations reporting 100 percent of the time. (Each station has 1 station-year/year of available data.) The "information content" plot in figure 3 is computed, relative to the 54-station network with all stations reporting 100 percent of the time (54 station-years/year), by considering each station's contribution to the final 54-station network. Each station's actual record size for each year is weighted by its 54-station Thiessen weight and they are summed over all stations. It can be seen that, from 1947 to 1969, the information available in the Thiessen-weighted network was less than that apparent from the actual record size in terms of the final 54-station network. The stations added in about 1969-70 contributed relatively more to the final network and the information content rose relatively faster than in the previous 20 years or than the record size rise. Figure 3 shows that the last 8 or 9 years prior to 1978 had greater than 65-percent coverage relative to a fully reporting 54-station network. Prior to 1968, this coverage was less than about 60 percent; 1969-78 is used for model applications henceforth.

It is important to note that figure 3 does not give the information content of the data on actual daily precipitation. Since actual values are unknown, the information content of the data cannot be exactly determined. Hence, the low network coverage of the pre-1950's does not necessarily imply that daily basin averages computed from the early data are widely in error, only that our confidence in them is lower than for the later data.

3.3 Daily Hydrological Data

There are 35 streamflow gages used here for the Lake Superior Basin (fig. 2). The drainage area of each gage is given by the USGS (1980a,b,c) or Inland Waters Directorate (1979), while the total area in each subbasin is based on planimetered measurements from 1:500,000 maps. Relative areal drainage coverage for all flow gages used herein are identified in table 2. Flow data are from the Water Resources Division of the USGS and the Water Resources Branch of the Inland Waters Directorate of Environment Canada.

All hydrological stations within a given subbasin whose records contain no missing data for the day in question are used to determine the subbasin outflows into Lake Superior for each day. This aggregation for each day is accomplished by adding data values from each gage within the subbasin and dividing by the sum of the relative area drainage coverages for the gages actually used, to extrapolate for the entire subbasin area. Thus, missing data at a given gage are effectively "filled-in" by using data at nearby gages within the same subbasin. If no gages in a subbasin have data for a given day, then the flow total is set equal to -9999. to denote missing data.

A daily hydrologic data set for the entire Lake Superior Basin is constructed by adding extrapolated subbasin outflows from each subbasin with no missing data for the day in question and dividing by the ratio of the sum of drainage areas of each subbasin actually used with respect to the entire

TABLE 2.--*Selected discharge station areal drainage extents on Lake Superior subbasins.*

Flow station number*	Basin number																						
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	L†
4024000	.91																						.069
4024430		.22																					.008
4025500		.07																					.003
4027000			.47																				.012
4027500			.21																				.006
4031000				.20																			.004
4031500				.16																			.003
4040000					.96																		.027
4043050						.03																	.001
4041500							.50																.007
4044400								.05															.001
4045500										.96													.016
Q02BF001												.23											.009
Q02BF002												.23											.009
Q02BE002													.49										,022
Q02BD002														.54									.041
Q02BD003														.20									.015
Q02BC004															.52								.032
Q02BB002																.29							.015
Q02BB003																.62							.033
Q02BA002																	.22						.009
Q02BA003																	.25						.010
Q02AE001																		.33					.005
Q02AD008																			.96				.191
Q02AC001																				.12			.005
Q02AC002																				.51			.023
Q02AB008																					.02		.001
Q02AB006																					.73		.050
Q02AB014																					.01		.001
Q02AB015																					.06		.004
Q02AB016																					.02		.001
Q02AB017																					.02		.002
4010500																						.19	.012
4014500																						.04	.003
4015330																						.03	.002
All stations																							.652

"Canadian stations (eight-digit numbers) available from Inland Waters Directorate, Environment Canada. United States stations (seven-digit numbers) available from USGS, U.S. Department of Interior.

†Entire Lake Superior Basin.

basin. Finally, all outflows (daily average flow rates) are converted to daily volumes by multiplying them by the daily time period. The daily hydrological data sets are judged to be very nearly complete; except for subbasins 9 and 11, for which there were no flow data, and subbasin 15, for which 6 months were missing, all subbasins are complete.

The hydrological data sets for each subbasin and for the entire Lake Superior Basin are combined with their respective meteorological data sets to provide a complete daily data set containing minimum air temperature, maximum air temperature, precipitation volume, and outflow volume for each day of record for each subbasin and the entire basin. Section 1 in appendix C contains a partial listing of such a data set.

3.4 Monthly Data

The daily data sets for each subbasin were used to determine subbasin monthly data sets. For a given subbasin, the daily minimum and maximum air temperatures were arithmetically averaged for each day to give average air temperature for the day. These were then averaged over the days in each month to determine the monthly air temperature. Likewise, precipitation and outflow volumes were each accumulated over the days in each month to determine the monthly values. If there were missing data for air temperatures or precipitation in the daily data, then the previous day's value was used to fill in the missing data. If there were missing daily outflow data for any days in a month, then the entire month's value was set to -9999. to denote no flow volume for that month in the monthly data set. Monthly data sets for each subbasin are considered very nearly complete. Section 2 in appendix C contains an example such a data set.

The monthly data sets were then combined for groups of subbasins to create monthly data sets for all of the Lake Superior Basin, all of the basin except subbasin 19 (which contains Lake Nipigon, through which diversions from outside the basin are regulated), all of the United States portion of the basin (subbasins 1 through 11 and 22), all of the Canadian portion of the basin (subbasins 12 through 21), and all of the Canadian portion of the basin except subbasin 19. The combination for each large area is similar to the construction of the daily meteorological and hydrological data sets for the entire Lake Superior Basin from the daily data sets for the component subbasins.

3.5 Subbasin Information Summary

The subbasin information is summarized in table 3. Of the 23 data sets identified in table 3 (one for each subbasin and one for the entire basin, L), 2 have incomplete or missing outflow data. Midmonthly cloudless day insolation at Sault Ste. Marie was used for all subbasins (Gray, 1973). Appendix C contains a partial listing of the daily data set (the file named DATA) and a complete listing of the monthly data set (the file named MDATA) for the entire Lake Superior Basin. They are typical in format of the data sets for all basins.

TABLE 3.--*Lake* Superior *subbasin* ***information***

Sub-basin "CD.	Basin area (km^2)	Last date (d-m-y)	Data set length (yrs)	No. of meteorol. stations	Areal extent	Normal annual precip. (cm)*	Normal annual flow (cm)*
1	9,715	31/12/78	30.7	11	0.91	72	27
2	4,909	31/12/78	30.7	9	0.29	77	40
3	3,403	31/12/78	30.7	7	0.68	86	35
4	2,675	31/12/78	30.7	5	0.36	91	38
5	3,628	31/12/78	30.7	4	0.96	82	35
6	2,835	31/12/78	30.7	4	0.03	91	50
7	1,790	31/12/78	21.3	6	0.50	88	40
8	2,439	31/12/78	30.7	8	0.05	86	44
9	3,135	31/12/78	30.7	7	t	89	
10	2,127	31/12/78	30.7	4	0.96	90	43
11	851	31/12/78	48.0	4	t	91	
12	5,075	31/12/78	48.0	3	0.46	90	54
13	5,771	31/12/80	28.3	3	0.49	95	45
14	9,876	31/12/80	15.0	2	0.74	100	42
15	7,951	31/12/80	30.9	3	0.52	92	36
16	6,905	31/12/80	31.2	3	0.91	83	38
17	5,288	31/12/80	31.7	4	0.47	86	38
18	1,875	31/12/80	6.2	2	0.33	70	30
19	25,699	31/12/80	33.0	5	0.96	76	44
20	5,905	31/12/80	33.0	3	0.63	72	29
21	8,837	31/12/80	33.0	5	0.86	82	29
22	8,236	31/12/80	30.7	8	0.26	76	35
L**	128,925	31/12/78	9.1	54	0.65	83	39

*Equivalent depth over basin.

†Unused poor-quality flow data.

**Entire Lake Superior Basin.

4. CALIBRATION

The Large Basin Runoff Model was applied to the 21 complete daily data sets previously identified for the Lake Superior Basin for the l-d and 7-d mass-balance computation intervals. It was applied to the 25 complete monthly data sets previously identified for the Lake Superior Basin for the monthly mass-balance computation interval. Each of these 67 applications required determination of the values of the nine parameters used in the model.

This section describes the calibration procedure used (including a description of a user's guide found in the appendices) and presents the calibrated parameter values for all 67 applications. The parameter values are then interpreted with regard to model sensitivity, simpler model structures they suggest, physical meaning, and basin characteristics. Next, model behavior is interpreted in detail for the entire Lake Superior Basin; each segment of the model structure is considered individually. Finally, problems inherent in the calibration procedure are discussed and improvements are suggested.

4.1 Calibration Procedures

4.1.1 Parameter Determination

Parameters are determined by a systematic search of the parameter space to minimize the sum-of-squared errors between actual outflow volumes and model outflow volumes. The search consists of minimizing this error for each parameter, selected in rotation, until convergence to two significant figures is achieved. This procedure has been implemented in FORTRAN IV on the CDC Cyber 1701750 computer.

4.1.2 User's Guide to Model Calibration

Appendices C and F-H document, and show an example of, Large Basin Runoff Model calibration using daily hydrometeorological data. Appendix F contains the source code listing for the semiautomatic calibration procedure (the file named CALIB) and a short explanation of its use for determining parameter values. Appendix C contains a partial listing of an example daily hydrometeorological data set (the file called DATA) for use in calibrating the model, and appendix G contains a short file (called PARAM) of initial parameter values that can be used to start calibrations. Appendix H contains an entire example calibration session that uses the calibration program of appendix F (CALIB), the data file of appendix c (DATA), and the parameter file of appendix G (PARAM). The session consists of the parameter values searched to find the optimum set. Appendix G also contains the optimum parameter set, printed as output separately at the end of the calibration session.

Appendix F also contains a version of the model using monthly hydrometeorological data for calibration (the file called MMCAL). Appendix C contains an example monthly hydrometeorological data set (the file called MDATA) for use with this model version. However, an initial parameter set and example calibration session for the monthly model calibrations are not provided because use of the monthly calibration procedure is similar to the daily examples.

4.1.3 Initialization and Data Set Period

There are five variables in the model: SNW, USZM, LSZM, GZM, and SS, they are initialized prior to modeling as SNW_0, $USZM_0$, $LSZM_0$, GZM_0, and SS_0, respectively. While it is easy to determine that SNW_0 is zero during portions of the year, the other variables are generally difficult to estimate. The effect of the initial values diminishes with the length of the simulation, and after about 1 year of simulation, the effects are nil from a practical point of view. Therefore, with about a l-year initialization period, the initial values may be set arbitrarily. In all the calibrations described here, the first 630 days of data are used for initializing the model; the remainder of the data is used for measuring goodness-of-fit of the model outflow to the actual outflow.

4.1.4 Calibrated Parameter Sets

There are 21 calibrations each for both the l-d and 7-d runoff models and 25 calibrations for the monthly model. Twenty correspond to the 20 subbasins for which flow data were available and one (L) corresponds to the entire Lake Superior Basin. For the monthly model, four additional calibrations (LEN, LC, LCEN, LU) correspond, respectively, to the entire Lake Superior Basin excluding the Lake Nipigon subbasin, the entire Canadian portion for the Lake Superior Basin, the entire Canadian portion of the Lake Superior Basin excluding the Lake Nipigon subbasin, and the entire United States portion of the Lake Superior Basin. All calibrations use data sets for the common period of 9.1 years beginning December 1, 1969, and ending December 31, 1978, except for subbasin 18, which uses a data set with only 4.2 years of flow data ending December 31, 1978. Optimum parameter values for the l-d, 7-d, and monthly models are presented in tables 4, 5, and 6, respectively.

4.2 Parameter Interpretations

Inspection of tables 4, 5, and 6 suggests some interesting parameter interpretations.

4.2.1 Sensitivity to Air Temperatures

The value of Tb (the scaling parameter for air temperature used in the computation of heat available for evapotranspiration) is relatively large for subbasins 2, 3, 4, 6, 8, 14, and 16 for the l-d model, for subbasins 3, 4, 6, 8, and 14 for the 7-d model, and for subbasins 4 and 18 for the monthly model, indicating that for these subbasins evapotranspiration is relatively insensitive to air temperature. These subbasins are generally located in the southwestern and south-central sections of the Lake Superior drainage basin, and the insensitivity may be a result of their exposure to northwestern air movements, which are dry relative to air currents in other parts of the

TABLE 4.--Lake Superior subbasin l-d model parameters*

Sub-basin no.	T_b (°C)	Melt factor (m^3/°C-d)	Linear reservoir and evapotranspiration coefficients: Percolation (d^{-1})	Upper zone evap. (m^{-3})	Interflow (d^{-1})	Deep percolation (d^{-1})	Lower zone evap. (m^{-3})	Groundwater (d^{-1})	Surface storage outflow (d^{-1})
1	3.0	24e+06	23e-02	99e+00	17e-04	17e-03	64e-07	62e-04	71e-03
2	5.4	76e+05	13e+01	12e-07	71e-03	59e-03	36e-10	50e-04	34e+00
3	4.4	10e+06	34e-01	29e-11	39e-03	23e-03	10e+02	17e-03	24e-02
4	9.5	68e+05	17e+00	15e-07	84e-03	39e-03	57e-10	32e-03	23e-01
5	3.2	10e+06	76e-02	25e+00	66e-04	10e-03	12e-09	75e-04	12e-02
6	5.1	12e+06	89e-02	20e-08	35e-03	24e-03	10e-09	25e-03	27e-02
7	3.9	38e+05	12e-01	16e-08	99e-04	89e-04	19e-09	84e-04	18e-02
8†	99e+07	85e+07	29e+00	60e-09	0	13e-03	85e-11	89e-04	16e-03
10	2.0	49e+05	66e-02	14e+02	26e-04	45e-04	35e-09	24e-04	78e-03
12	2.1	12e+06	18e-02	32e-02	72e-04	0	27e-11		13e-02
13	1.4	91e+05	71e-01	45e+01	90e-05	97e-04	10e-09	36e-04	56e-03
14	4.2	34e+06	83e-01	45e-09	32e-04	11e-03	79e-11	27e-04	85e-03
15	1.2	24e+06	10e+00	0	24e-03	27e-03	28e-04	0	51e-03
16	6.0	16e+06	65e-02	76e-10	0	24e-03	28e-10	58e-03	10e-02
17	2.1	12e+06	57e-02	14e-08	35e-04	29e-04	21e-04	45e-04	53e-03
18**	1.6	30e+05	40e-02	31e-07	0	46e-04	32e-01	27e-05	74e-03
19	2.2	16e+06	∞		0	30e-02	30e-08	60e-04	60e-04
20	2.2	13e+06	49e-02	61e-09	27e-04	50e-06	99e-05	50e+05	31e-03
21	1.7	27e+06	87e-01	81e-04	23e-04	35e-04	44e+00	21e-04	14e-02
22	2.4	11e+06	24e-01	73e-02	39e-03	41e-03	25e-06	22e-03	51e-02
L††	1.7	39e+07	28e-01	14e-11	41e-04	78e-04	25e-05	42e-04	99e-03

*Applications with data sets of 3,318 d, beginning December 1, 1969, and ending December 31, 1978.

†Frequent changes in outflow over two orders of magnitude in a single day; this results from flow regulation in basin 8 that was much more significant than natural variations. Calibration is ineffective.

**Flow data available only for 4.2 yrs (2.5 yrs used for calibration, 1.7 yrs used for initialization).

††Entire Lake Superior Basin.

TABLE *5.--Lake Superior subbasin 7-d model parameters**

Sub-basin no.	Tb (°C)	Melt factor (m^3/°C-d)	Linear reservoir and evapotranspiration coefficients: Percolation (d^{-1})	Upper zone evap. (m^{-3})	Interflow (d^{-1})	Deep percolation (d^{-1})	Lower zone evap. (m^{-3})	Groundwater (d^{-1})	Surface storage outflow (d^{-1})
1	2.5	23e+06	27e-02	78e+00	0	25e-03	68e-07	55e-04	86e-03
2	2.4	66e+05	26e-01	0	1 le-02	20e-02	29e-04	67e-04	45e-02
3	3.0	99e+05	29e-02	82e-01	0	66e-03	81e-05	53e-04	10e-02
5	3.3	67e+05	lle-01	0	31e-03	14e-03	13e-04	18e-05	37e-02
5	1.3	84e+05	62e-02	51e+00	30e-04	59e-05	18e-10	45e-04	19e-02
6	4.6	98e+05	39e-02	13e-08	19e-03	1 le-03	50e-11	74e-04	33e-02
7	1.2	36e+05	69e-02	29e+01	20e-04	17e-04	72e-05	23e-04	18e-02
8†	300000	55e+07	14e-01	0	12e-03	0	12e-10		38e-04
10	1.2	47e+05	50e-02	13e+02	70e-05	21e-04	33e-10	15e-04	88e-03
12	1.3	12e+06	19e-02	31e-02	50e-04	0	15e-10		14e-02
13	1.4	84e+05	32e-01	24e+01	0	13e-03	28e-09	38e-04	46e-03
14	3.6	30e+06	54e-01	0	54e-04	42e-03	12e-04	23e-04	1 le-02
15	1.3	20e+06	19e-01	0	26e-03	27e-03	95e-05	35e-11	40e-03
16	1.5	15e+06	50e-02	0	44e-04	0	68e-05		90e-03
17	1.5	1 le+06	69e-02	0	53e-04	0	76e-05		72e-03
18**	1.0	33e+05	28e-02	50e-04	0	33e-04	44e+00	25e-05	64e-03
19	1.8	16e+06	∞		80e-04	21e-02	10e-04	60e-04	60e-04
20	1.5	1 le+06	60e-02	0	32e-04	0	58e-05		42e-03
21	1.8	24e+06	64e-01	54e-02	25e-04	52e-04	22e-04	27e-04	22e-02
22	2.0	10e+06	15e-02	82e-02	0	1 le-03	90e-06	15e-03	97e-03
L††	1.9	30e+07	27e-01	0	60e-04	17e-03	93e-05	35e-04	17e-02

*Applications with data sets of 3,318 d beginning December 1, 1969, and ending December 31, 1978.

†Frequent changes in outflow over two orders of magnitude in a single day; this results from flow regulation in basin 8 that was much more significant than natural variations. Calibration is ineffective.

**Flow data available only for 4.2 yrs (2.5 yrs used for calibration, 1.7 yrs used for initialization) ending December 31, 1978.

††L = Entire Lake Superior Basin.

TABLE *6.--Lake Superior subbasin monthly model parameter (monthly data)**

Sub-basin no.	T_b (°C)	Melt factor (m^3/°C-d)	Linear reservoir and evapotranspiration coefficients: Percolation (d^{-1})	Upper zone evap. (m^{-3})	Interflow (d^{-1})	Deep percolation (d^{-1})	Lower zone evap. (m^{-3})	Groundwater (d^{-1})	Surface storage outflow (d^{-1})
1	0.99	20e+07	70e-02	12e+01	32e-05	52e-04	83e-07	72e-04	87e-03
2	2.0	18e+06	20e-01	29e-10	10e-02	38e-02	57e-04	44e-04	∞
3	2.0	41e+06	91e-02	36e-05	20e-04	22e-03	92e-05	49e-04	66e-02
4	4.3	43e+06	∞		71e-03	98e-03	42e-09	26e-04	49e-02
5	0.89	30e+06	22e-01	93e+00	20e-04	29e-04	57e-11	27e-04	∞
6	2.3	92e+06	11e-01	95e-10	12e-03	10e-03	13e-09	36e-04	∞
7	0.88	12e+06	17e-01	70e+02	17e-04	45e-04	45e-05	24e-04	57e-02
8	1.0	35e+03	∞		92e-04	17e-04	37e-11	71e-05	48e-04
10	1.0	48e+05	93e-02	11e+02	10e-04	66e-04	40e-10	22e-04	80e-02
12	1.7	15e+06	98e-02	31e-02	37e+07	83e+07	21e-10	33e-04	30e-02
13	0.88	21e+06	46e-01	11e+02	21e-05	75e-04	23e-10	27e-04	48e-03
14	2.1	41e+06	73e+00	0	85e-04	49e-03	85e-04	20e-04	∞
15†	2.0	19e+06	13e+00	66e-08	23e-03	37e-03	70e-04	35e-04	27e-02
16	1.9	32e+06	13e-01	0	13e-03	20e-03	87e-05	31e-04	15e-02
17	1.7	22e+06	26e-01	21e-11	16e-03	31e-03	45e-05	35e-04	15e-02
18**	3.1	78e+05	98e-02	0	68e-11	73e+01	64e+00	26e-04	75e-03
19	1.6	54e+06	29e-01	12e+00	0	33e-01	68e-06	56e-04	59e-04
20	0.88	18e+06	12e-01	0	49e-04	91e-04	98e-05	25e-05	76e-03
21	1.0	99e+06	12e+00	99e-07	19e-04	48e-04	90e-04	19e-04	∞
22	1.3	16e+06	94e-02	95e+00	95e-04	12e-03	58e-06	13e-03	∞
L††	0.82	71e+07	36e-01	59e-10	20e-04	80e-04	48e-05	21e-04	31e-02
LEN	0.81	35e+07	28e-01	0	25e-04	49e-04	31e-05	16e-04	28e-02
LC	0.88	72e+08	32e-01	85e+00	11e-04	11e-03	90e-09	25e-04	11e-02
LCEN	1.0	28e+07	37e-01	0	32e-04	74e-04	42e-04	29e-04	31e-02
LU	1.6	32e+09	25e-01	0	83e-04	11e-03	73e-03	45e-04	∞

*Applications with data sets of 3,318 d beginning December 1, 1969. and ending December 31, 1978.

†Flow data available only for 8.3 yrs (6.6 yrs used for calibration, 1.7 yrs used for initialization) beginning December 1, 1969.

**Flow data available only for 4.2 yrs (2.5 yrs used for calibration, 1.7 yrs used for initialization) ending December 31, 1978.

††L = Entire Lake Superior Basin.
LEN = Entire Lake Superior Basin excluding the Lake Nipigon subbasin.
LC = Entire Canadian portion of the Lake Superior Basin.
LCEN = Entire Canadian portion of the Lake Superior Basin excluding the Lake Nipigon subbasin.
LU = Entire United States portion of the Lake Superior Basin.

Superior drainage basin. However, clear evidence is not available since there are regulated flows in these basins that may give evaporation timing differences not accountable for in the model. The value of Tb for subbasin 8 is extraordinarily high; the data set for that subbasin reveals frequent changes in outflow over two orders of magnitude in a single day due to regulation of flows that are much more significant than natural variations. hence, calibration is probably ineffective for subbasin 8 and the subbasin is not included in the remaining parameter interpretations. However, on a monthly basis, the dominance of regulatory flow variations over natural flow variations becomes less pronounced; it may be more effective to use the monthly model to calibrate for subbasin 8.

4.2.2 Melt Factors

Generally, the larger subbasins have relatively larger melt factors, while the smaller subbasina have relatively small melt factors. This is understandable since higher snowmelt runoff volumes per degree-day are expected from larger areas. However, the melt factor, a, does not increase linearly with subbasin area. For the l-d and 7-d models, subbasin 2 has a melt factor relatively small for its area. For the l-d model, subbasins 3, 5, and 6 have melt factors relatively large for their areas; for the 7-d model, subbasins 3 and 6 have melt factors relatively large for their areas.

This may reflect the influence of the locations of these subbasins. Subbasin 2 is located in the southwestern corner of the Lake Superior Basin and may not be subject to the stabilizing lake effect on air temperatures. Subbasins 3, 5, and 6 are more centrally located to the south of Lake Superior and thus subject to warmer air temperatures and more humid air than subbasin 2. When humidity is high the air can carry more heat at the same air temperature than when it is low, and hence, more snowmelt per degree-day can be expected for subbasins 3, 5, and 6. The relationship between subbasin area and the melt factor is less consistent for the monthly model, probably because the monthly air temperatures represent a loss of information in the averaging of daily values (they are much less variable during the winter) as compared to daily air temperatures.

4.2.3 Simpler Model Possibilities

Inspection of the linear reservoir and evapotranspiration coefficients suggests that some Lake Superior subbasins could be modeled more simply, i.e., with fewer storage tanks.

4.2.3.1 Elimination of Upper Soil Zone. Subbasin 19 for the l-d and 7-d models, and subbasin 4 for the monthly model show an infinite percolation coefficient, indicating zero upper soil zone storage (no upper soil zone is modeled) for these subbasins. For all three models, the remaining subbasins generally have very high percolation values (with half-lives ranging from about 8 min to about 5 days; half-life is the inverse of the coefficient times the logarithm of 2). With a high value for percolation (small half-life), there is not enough water stored in the upper soil zone for even high values of the upper soil zone evapotranspiration coefficient to have substantial effects on runoff volumes. Thus, the values of the upper soil zone evapotranspiration coefficient in tables 4, 5, and 6 have little meaning and may all be considered to be zeros since negligible evapotranspiration occurs from the upper soil zone in any of the applications. The parameters suggest then that evapotranspiration is almost totally controlled by the lower soil zone for the Lake Superior subbasins.

4.2.3.2 Elimination of Interflow. Simulations for subbasins 16, 18, and 19 for the l-d model, subbasins 1, 3, 13, 18. and 22 for the 7-d model: and subbasins 18 and 19 for the monthly model show the interflow coefficient to be very small or zero, indicating that effectively no interflow is modeled for these subbasins.

4.2.3.3 Elimination of Lower Soil Zone. For the monthly model, subbasin 12 shows very large interflow and deep percolation coefficients with an equivalent combined half-life (ignoring evapotranspiration) less than 1 second. Subbasin 18 for the monthly model also shows a large deep percolation coefficient with a half-life of about 1 minute. Thus, zero lower soil zone storage is indicated (no lower soil zone is modeled) for these subbasins, and their lower soil zone evapotranspiration coefficients may be considered to be zero since negligable evapotranspiration is possible from the lower soil zone.

4.2.3.4 Elimination of Groundwater Zone. The deep percolation coefficient is very small or zero for subbasins 12 and 20 for the l-d model; subbasins 12, 16, 17, and 20 for the 7-d model; and subbasin 18 for the monthly model, indicating that effectively no flow to the groundwater zone is modeled for these subbasins. Where the deep percolation coefficient is small, there is not enough water stored in the groundwater zone for even high values of the groundwater flow coefficient to have substantial effects on runoff volumes. Thus, the values of the groundwater flow coefficient for subbasins 12 and 20 in table 4 and for subbasin 18 in table 6 have little meaning and may all be considered to be zeros since negligible groundwater flow occurs from the groundwater zone in these applications.

4.2.3.5 Elimination of Surface Storage. The surface storage outflow coefficient is relatively large for subbasin 2 for the l-d model. The monthly model yielded infinite surface storage outflow coefficients for subbasins 2, 5, 6, 14, 21, and 22. This is equivalent to no surface storage "tank" in figure 1. Generally, these subbasins are relatively narrow strips or rocky areas along the lake with short times of concentration; surface response is faster than a monthly interval and is not detectable at this time scale.

4.2.4 Other Interesting Parameter Value Interpretations

Other parameter values obtained during model calibrations allow interesting interpretation.

4.2.4.1 Entire Basin Parameters and Half-Lives. Table 7 contains storage half-lives for the 7-d lumped-parameter application to the entire Lake Superior Basin. Half-lives are computed as the inverse of the sum of the linear reservoir coefficients for a storage zone times the natural logarithm

TABLE 7.--*Lake Superior Basin lumped-parameter 7-d model half-lives*

Upper soil zone storage half-life*	Lower soil zone storage half-life*	Groundwater zone storage half-life	Surface zone storage half-life
6.2 h	4.3 w	28 w	4.1 d

*Uncorrected for evapotranspiration.

of 2 (for half empty) and are uncorrected for evapotranspiration; see Croley and Hartmann (1983). The surface zone storage half-life is larger than those obtained for the 7-d lumped-parameter application to the entire Lake Ontario Basin (Croley and Hartmann, 1983) and may reflect the boggy, swampy nature of much of the Lake Superior Basin. The groundwater zone storage half-life for Lake Superior is almost an order of magnitude less than the groundwater zone storage half-life for Lake Ontario, and may reflect the presence of the Precambrian shield under much of the Lake Superior Basin. The upper soil zone storage half-life is smaller than that for the Lake Ontario Basin, while the lower soil zone half-life is about the same. This again implies that, for the Lake Superior Basin, a single soil zone may be adequate to model the basin response. This is also consistent with the general structure of the Lake Superior Basin--a thin layer of soil over bedrock.

4.2.4.2 Subbasin Parameters. The value of the groundwater flow coefficient is very small for subbasin 15 for the l-d and 7-d models; the groundwater zone serves as a 'sink' to reduce modeled runoff volumes for this subbasin in response to known unnatural flow regulation in 1977, which retained significant flow volumes in surface storage. Along these same lines for the 7-d and monthly models, subbasins 4 and 19 have large values for the percolation coefficient, indicating large flows to the groundwater zone, while they also have relatively small values for the groundwater coefficient, indicating that the groundwater storage is large. For subbasin 19, which is a large basin, a relatively large groundwater or lower soil zone makes sense. (Model storage volumes for subbasin 19 suggest little lower soil zone moisture, and in fact the large groundwater zone moisture value may be the model representation of the subbasin's soil cover, which is known to exist.) However, the area of subbasin 4 is an order of magnitude smaller than that of subbasin 19 and a relatively large groundwater zone is not reasonable; this suggests that there is groundwater leakage from the subbasin that is reflected in the model as some water entering the groundwater zone and never leaving. Provision of a groundwater flow out of the subbasin, in the model, would undoubtedly improve the model goodness-of-fit for subbasin 4 at the added expense of another parameter in the calibration.

Subbasin 19, the largest subbasin, has the smallest value of the surface storage outflow coefficient for all three models, indicating that surface storage is significant in the models for this subbasin. It is interesting to note that the presence of Lake Nipigon, a large lake, in subbasin 19 corresponds to the largest surface storage (smallest surface storage outflow coefficient) of all of the subbasin model applications.

4.3 Model Interpretations

Figure 4 graphically represents the storage states within the model, applied to the entire Lake Superior Basin for a 7-d computation interval, and reflects the calibrated parameter values for that application. Similar plots illustrating typical behavior of the model for selected Lake Superior subbasins (4, 6, 10, 12, 16, and 20) are given in appendix I; the model performed well for these subbasins and there is a relatively greater degree of confidence in their calibrated parameter values. Large parameter values result in large flows from the storage 'tanks' and small storage volumes; small parameter values result in smell flows from the storage 'tanks' and large storage volumes. The figure shows the modeled 7-d net supply rate to the upper soil zone (precipitation plus snowmelt), in a fashion similar to a rainfall hyetograph, and the modeled water volumes stored in the snowpack or storages at the end of each 7-d computation period. The scales for all single subbasin applications are identical so that relative storage magnitudes are highlighted.

4.3.1 Snowpack and Net Supply

As figure 4 illustrates, during winter all precipitation accumulates in the snowpack and there is no net supply to the upper soil zone. Peak snow pack accumulations generally occur in March and agree with snowpack characteristics observed by Phillips and McCulloch (1972). As melt occurs in early spring, the snowpack drops quickly. The rate of disappearance of the snowpack given by the model is supported by observations by Price *et at.* (1976). The authors measured loss of water from subarctic snowpacks up to 5.9 cm/day from densely wooded north-facing slopes. They also observed that the melt season typically lasts from 7 to 27 days, depending on site characteristics and snowpack depth. The model is judged to have good snowmelt timing; however, comparison with remotely-sensed snow water equivalents (discussed subsequently) suggests model deficiencies regarding snowmelt volumes.

4.3.2 Upper Soil Zone

As the snowpack melts quickly, the upper soil zone experiences large peaks in the net supply rate. Throughout the summer the net supply rate to the upper soil zone is strictly precipitation. Figure 4 also shows the modeled upper soil zone storage for the Lake Superior Basin; it is typically very small since the upper soil zone is modeled to be very 'flashy.' Variations in the upper soil zone storage correspond directly to the net supply rate.

4.3.3 Lower Soil Zone

Peaks in the lower soil zone storage also correspond directly to the net supply rate peaks since almost all the water percolates immediately through

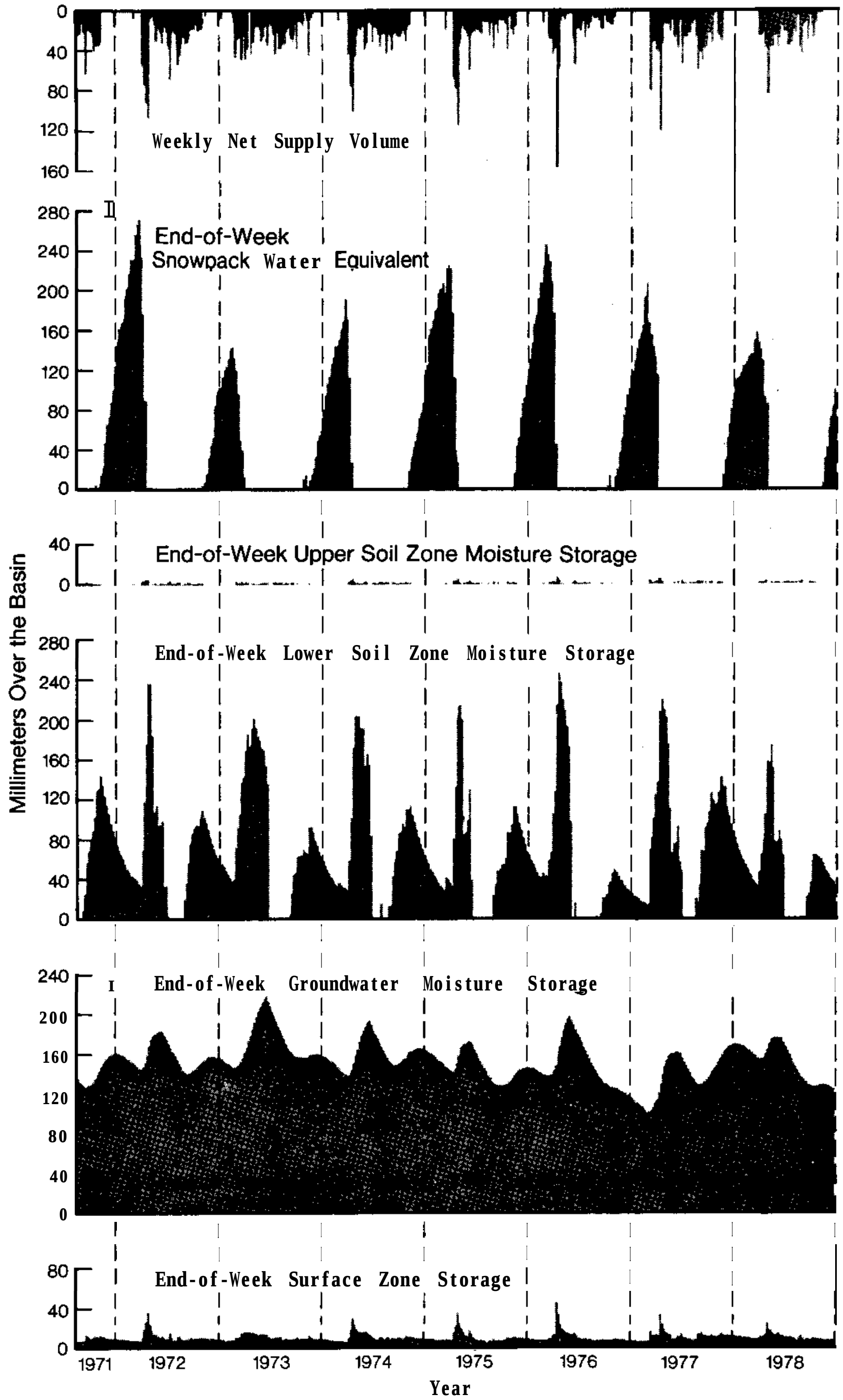

FIGURE 4.—*Seven-day* ***net supply*** *rate* ***to the watershed and 7th day snowpack,*** *soil zones, and* ***surface*** *storages* ***for the entire Lake Superior*** *Basin.*

the upper soil zone; see figure 4. Clear recessions in the lower soil zone moisture are evident in winter when there is no net supply. The peak lower soil zone moisture results from the large spring snowmelt influx. During summer, when evapotranspiration losses are highest, the lower soil zone moisture is quickly depleted. Evapotranspiration demands become significant in May when trees and other vegetation begin to leaf out; with subsequent higher temperatures in June or July, all moisture in the lower soil zone can be removed by evapotranspiration. The continued high temperatures during the remainder of the summer prohibit any recovery of soil moisture levels in the lower zone. Instances where the lower soil zone moisture remains relatively high throughout June are cool springs or late summers. In autumn, as average daily air temperatures decrease and plants cease production, the demands on the lower soil zone from evapotranspiration also fall and the water volume begins to rebuild.

4.3.4 Groundwater Zone

Figure 4 also depicts the modeled groundwater storage. Groundwater zone moisture is seen to be less variable and slower in response to net supply rate than the overlying storages. The groundwater zone peaks and recessions lag the influx variations; this is typical of groundwater. Evapotranspiration from the overlying lower soil zone precludes deep percolation, so the groundwater storage shows a clear recession in summer. Likewise, as evapotranspiration losses from the lower soil zone decline in autumn, the groundwater storage shows a slight recovery before winter.

4.3.5 Surface Storage

Finally, figure 4 shows the modeled surface zone storage. Flows to the surface zone are composed of surface runoff, interflow, and groundwater flow from the upper soil zone, lower soil zone, and groundwater zone, respectively. Because the surface storage contains flows from all the other storages, lags in peak volumes are seen to be intermediate between the near-instantaneous upper and lower soil zones and the slower groundwater zone.

4.3.6 Other Interesting Model Interpretations

Some subbasins are exceptions to the above remarks. Inspection of the model storage plots for subbasin 4 in appendix I reveals that the groundwater storage is apparently growing without limit as was suggested earlier in section 4.2.4.2. The groundwater zone is modeled as a 'sink' for this subbasin and indicates that there is probably groundwater flow out of the subbasin. Subbasins 12, 16, and 20 show no modeled groundwater storage; optimum parameter sets for these subbasins show a deep percolation coefficient of zero, indicating no flow to the groundwater zone is modeled for these subbasins. Of all the subbasins presented in appendix I, and probably of all the subbasins modeled for the Lake Superior Basin, subbasin 10 has the largest lower soil zone moisture values; this is understandable since this subbasin lies in the North American Central Lowlands and probably has the thickest soil cover (B.

Holbrook, personal communication, 1983; Phillips and McCulloch, 1972). Hence, this subbasin should have a comparatively large soil water storage capacity.

4.4 Calibration Problems

The agreement between all parameter values for each subbasin for l-d, 7-d, and monthly model applications is very good. With the exception of 34 out of 180 possible matches, all parameters are within about a" order of magnitude of each other when tables 4 and 5 are compared; when tables 5 and 6 are compared, all but 29 out of 180 possible matches are within about an order of magnitude of each other. Since parameter error compensation is probably present in the calibrations, an order-of-magnitude agreement between the models is considered very good. Agreement would probably be better if more than two-digit convergence were used in the parameter optimizations. With only two digits, the optimum is approached crudely, yielding multiple "ear-optimums dependent on the starting parameter set.

Individual parameter values may reflect only local optimums in the calibration objective function (minimization of root-mean-square error of model outflows). The physical relevance of the linear reservoir and evapotranspiration parameters permits verification as empirical techniques are developed. Admittedly, errors in individual parameters may compensate for one another in the calibration because of the synergistic relationship among all parameters.

4.4.1 Nonuniqueness

Studies on the Lake Ontario Basin (Croley, 1982a) show that the simple search algorithm described herein does not give unique optimums for calibrated parameter sets because of synergistic relationships between parameters. However, the calibration procedure does show a high degree of repeatability for recalibrations with different starting values, and consistent parameter values are obtained for subbasins with similar hydrologic characteristics. The nonuniqueness of the calibrated parameter sets obtained for Lake Superior applications was determined following Sooroshian and Gupta (1983). The hypothesis was that, if parameter sets are unique, then parameter values produced from calibration of a synthetic data set should be identical to the parameter set used to create that synthetic data set. The model was first calibrated to the lumped data set (identified as L in table 3) using a l-d mass-balance computation interval. The model was then used with the calibrated parameters to generate outflows for a meteorological data set and combined with that meteorological data to create a new data set for calibration. Subsequent calibration started with a very different initial parameter set and yielded a different optimum parameter set with a relatively poor goodness-of-fit, illustrating the nonuniqueness of the parameters, the importance of the starting values used in the search, and the problems inherent in searching the parameter space.

4.4.2 Realism

Sooroshian and Gupta (1983) have identified three causes of problems in determining unique and realistic parameter values through calibration: 1) model structure representation, 2) data and their associated measurement errors, and 3) imperfect representation of the real world physical processes by the model.

4.4.2.1 Model Structure Representation. Model structures that include threshold parameters may require search algorithms unable to find the 'true' optimum; hence, the calibration may fail to find the 'true' optimum for other parameters. The runoff model described herein contains no threshold parameters; however, the Ontario versions of the model used a broken-line relationship for the determination of heat available for evapotranspiration (Croley and Hartmann, 1983) and contain a threshold parameter, Tb, that determines the 'base' temperature at which heat becomes available for evapotranspiratfon.

4.4.2.2 Data/Measurement Errors. Errors associated with the measurement of input data (e.g., precipitation, air temperature, insolation, streamflow) will reduce the quality of parameter estimation unless those errors can be filtered out. Also, if the data set used to calibrate the parameters does not adequately represent the entire range of possible events, some model storages or processes may be activated too infrequently for a meaningful parameter determination. However. use of more data may not be the best solution; Sooroshian et *al.* (1983) show that use of long calibration data sets is not as important as the use of data sets with adequate hydrologic variability. The authors suggest that the use of 'wet years' is more likely to sufficiently activate all parameters so that realistic parameter values are obtained. Sooroshian (1983) also cautions that, when excessively long data sets are used for calibration, data 'noise' interpreted as valid information may result in 'over-fitting' of the model.

4.4.2.3 Conceptual Errors. Rainfall-runoff models certainly are simplifications of actual hydrologic processes. Time-invariant parameters, such as snow albedo (used in application of the model to the Lake Ontario basin), are unlikely to represent reality. The parameters most likely to portray watershed response could actually vary seasonally or trend with time because of physical changes in the watershed, such as deforestation or urbanization. Also, lumping of spatially distributed data to represent the entire watershed can adversely affect parameter optimization. On the other hand, spatial filtering can imply that data or model errors for small areas cancel each other out as the areas are added together; this was apparent in the application of the model to both the Lake Ontario Basin (Croley and Hartmann, 1983) and the Lake Superior Basin here. Additionally, some components in a conceptual model are more likely to adequately represent their processes in the real world than others. Sooroshian and Gupta (1983) suggest that parameter estimation techniques that properly weight the more accurate parts of the model could improve parameter estimates.

4.4.3 Objective Function/Convergence Criteria

Sooroshian (1983) reviews additional questions concerning calibration of rainfall-runoff models, including choice of an appropriate objective function and convergence criteria. Sooroshian et at. (1983) asserts that statistical measures other than root-mean-square error can result in more realistic parameter values and improved forecast performance even though the root-mean-square error criteria may provide a better fit to the calibration data. Also, parameters should be allowed to stabilize rather than depending solely on the convergence of the objective function value (e.g.. root-mean-square error) because parameter values may still change considerably. Parameter stabilization to two significant digits was used in all Large Basin Runoff Model calibrations in lieu of convergence criteria on the objective function.

5. APPLICATION

This chapter presents application results of the Large Basin Runoff Model for the 21 daily data sets with outflow data for the l-day and 7-d mass-balance computation intervals and for the 25 monthly data sets for the monthly mass-balance computation interval. Statistical summaries of the goodness-of-fit for these 67 applications are first made with observations on natural flow applications and spatial integration effects. Hydrographs of actual and simulated weekly flow volumes are given next and problems in matching winter flow recessions are addressed. Seasonal statistics are used to assess model deficiencies and to compare with an existing climatic water balance model performance.

5.1 Statistical Summary of Model Fits

5.1.1 Statistics

Statistical summaries for the l-d, 7-d, and monthly model applications to Lake Superior and its subbasins are presented in tables 8, 9, and 10, respectively. These summaries include mean precipitation, mean actual outflow, mean model outflow, relative difference between outflows, standard deviation of the actual outflows, root-mean-square error between outflows, and the correlation coefficient (root explained variance) between outflows. The 7-d and 30-d correlations between the l-d model and actual flows approximate weekly and monthly correlations, respectively; these are also presented in table 8. The 28-d correlations between the 7-d model and actual flows approximate monthly correlations and are presented in table 9. For convenience, all dimensional units are expressed as depths over the basin. The 20 subbasins for which flow data are available are presented by subbasin number; see figure 2. L again represents a lumped-parameter application of the model to the entire Lake Superior drainage basin. The results from the 20 subbasin applications are combined and represented by S. These combined results represent a distributed-parameter application to the entire Lake Superior drainage basin. The statistics for S were computed by summing the actual flow from the individual data sets of subbasins l-8, 10, and 12-22 and the model flow from the model applications for these data sets. The summed results were extrapolated to account for ungaged subbasins. Data sets for subbasins 9 and 11 were not used since they contain no flow data and the model was were applied to them.

TABLE 8.--*Lake Superior subbasin l-d model results*

Sub-basin no.	Mean l-d precip. (mm)*	Mean l-d flow (mm)*	Mean l-d model flow (mm)*	Rel. diff. in mean	Stand. dev. of flows (mm)*	Root-mean-square error (mm)*	Correlation coefficient l-d	Correlation coefficient 7-d	Correlation coefficient 30-d
1	1.98	0.74	0.73	-0.006	0.85	0.46	0.84	0.85	0.88
2	2.11	1.10	1.10	0.002	1.15	0.77	0.74	0.76	0.78
3	2.35	0.95	0.94	-0.013	1.23	0.65	0.85	0.88	0.89
4	2.48	1.05	1.04	-0.012	1.49	0.69	0.89	0.90	0.93
5	2.24	0.97	0.95	-0.018	1.12	0.67	0.80	0.86	0.91
6	2.49	1.39	1.35	-0.028	2.58	1.18	0.89	0.93	0.96
7	2.42	1.10	1.09	-0.009	1.22	0.57	0.88	0.92	0.95
8	2.37	1.22	1.24	0.012	0.56	0.51	0.44	0.50	0.59
10	2.48	1.17	1.16	-0.004	1.17	0.47	0.92	0.93	0.95
12	2.47	1.48	1.52	0.027	2.17	0.96	0.90	0.91	0.94
13	2.59	1.24	1.23	-0.010	0.54	0.48	0.48	0.57	0.62
14	2.73	1.14	1.15	0.006	0.61	0.40	0.75	0.77	0.79
15	2.51	0.99	0.95	-0.040	0.97	0.47	0.88	0.86	0.88
16	2.26	1.05	1.09	0.036	1.39	0.55	0.92	0.94	0.96
17	2.36	1.04	1.06	0.018	1.15	0.54	0.88	0.89	0.91
18†	2.00	0.82	0.82	-0.004	1.19	0.66	0.83	0.89	0.89
19	2.07	1.20	1.18	-0.015	0.36	0.31	0.53	0.57	0.61
20	1.96	0.78	0.81	0.034	0.76	0.37	0.88	0.89	0.90
21	2.24	0.79	0.80	0.004	0.55	0.40	0.68	0.69	0.70
22	2.09	0.95	1.00	0.053	1.41	0.79	0.83	0.84	0.89
L**	2.27	1.06	1.06	0.001	0.63	0.27	0.90	0.91	0.93
S††	2.27	1.06	1.06	0.002	0.62	0.25	0.92	0.93	0.93

*Equivalent depth over basin.

†Flow data available for 4.2 yrs (2.5 yrs used for calibration, 1.7 yrs used for initialization) ending December 31, 1978.

**Entire Lake Superior Basin.

††Combined results from the 20 subbasin applications (l-8, 20, 12-22).

TABLE *9.--Lake Superior subbasin 7-d model results*

Sub-basin no.	Mean 7-d precip. (cm)*	Mean 7-d flow* (cm)	Mean 7-d model flow* (cm)	Rel. diff. in mean	Stand. dev. of flows* (cm)	Root-mean-square error (cm)*	Correlation coefficient 7-d	Correlation coefficient 28-d
1	1.39	0.52	0.51	-0.016	0.56	0.31	0.83	0.84
2	1.48	0.77	0.75	-0.031	0.74	0.48	0.76	0.77
3	1.65	0.67	0.68	0.012	0.77	0.46	0.80	0.86
4	1.73	0.74	0.72	-0.026	0.97	0.45	0.89	0.93
5	1.57	0.68	0.67	-0.006	0.72	0.40	0.83	0.89
6	1.74	0.97	0.95	-0.021	1.63	0.66	0.92	0.96
7	1.70	0.77	0.76	-0.008	0.80	0.36	0.89	0.93
8	1.66	0.85	0.84	-0.016	0.35	0.33	0.32	0.37
10	1.73	0.82	0.80	-0.020	0.81	0.30	0.93	0.95
12	1.73	1.04	1.06	0.023	1.44	0.62	0.90	0.93
13	1.81	0.87	0.86	-0.010	0.32	0.26	0.59	0.64
14	1.91	0.80	0.79	-0.015	0.41	0.28	0.74	0.74
15	1.76	0.70	0.67	-0.035	0.67	0.32	0.88	0.88
16	1.58	0.74	0.78	0.063	0.93	0.37	0.92	0.95
17	1.65	0.73	0.75	0.035	0.78	0.37	0.88	0.90
18†	1.40	0.58	0.58	0.003	0.74	0.35	0.88	0.90
19	1.45	0.84	0.84	-0.005	0.24	0.19	0.62	0.64
20	1.37	0.55	0.58	0.051	0.52	0.24	0.89	0.90
21	1.57	0.55	0.56	0.009	0.36	0.26	0.68	0.67
22	1.46	0.67	0.66	-0.014	0.91	0.50	0.84	0.88
L**	1.59	0.74	0.75	0.016	0.43	0.19	0.89	0.91
S††	1.59	0.74	0.74	0.000	0.42	0.16	0.93	0.94

*Equivalent depth over basin.

†Flow data available for 4.2 yrs (2.5 yrs used for calibration, 1.7 yrs used for initialization) ending December 31, 1978.

**Entire Lake Superior Basin.

††Combined results from the 20 subbasin applications (l-8, 10, 12-22).

TABLE 10.--*Lake* **Superior** *subbasin* **monthly model** *results (monthly data)*

Sub-basin no.	Mean monthly precip. (cm)*	Mean monthly flow (cm)*	Mean monthly model flow (cm)*	Rel. diff. in mean	Stand. dev. of flows (cm)*	Root-mean-square error (cm)*	Correlation coefficient
1	6.03	2.25	2.28	0.012	1.85	1.13	0.80
2	6.43	3.35	3.21	-0.041	2.39	1.63	0.74
3	7.16	2.91	2.91	-0.001	2.52	1.45	0.82
4	7.56	3.20	3.16	-0.014	3.24	2.15	0.75
5	6.83	2.96	2.88	-0.027	2.34	1.69	0.69
6	7.60	4.23	3.97	-0.062	5.14	2.19	0.91
7	7.38	3.36	3.34	-0.007	2.72	1.44	0.85
8	7.22	3.72	3.72	0.002	1.30	1.08	0.56
10	7.54	3.56	3.56	-0.002	2.98	1.14	0.92
12	7.53	4.53	4.52	-0.002	4.93	2.12	0.90
13	7.89	3.78	3.76	-0.005	1.25	0.91	0.71
14	8.33	3.49	3.43	-0.018	1.52	1.12	0.69
15†	7.64	3.13	3.11	-0.007	2.72	1.20	0.90
16	6.91	3.21	3.18	-0.008	3.30	1.09	0.94
17	7.21	3.17	3.23	0.019	2.88	1.20	0.91
18**	6.08	2.51	2.47	-0.018	2.65	1.72	0.76
19	6.30	3.65	3.68	0.008	0.98	0.77	0.63
20	5.98	2.39	2.38	-0.005	2.04	0.92	0.89
21	6.81	2.42	2.44	0.008	1.32	1.04	0.62
22	6.37	2.90	3.04	0.047	3.30	1.86	0.83
L††	6.91	3.23	3.23	-0.003	1.60	0.88	0.84
LEN	7.07	3.13	3.14	0.004	2.00	1.07	0.85
LC	6.84	3.27	3.26	-0.002	1.40	0.67	0.88
LCEN	7.07	3.10	3.14	0.013	1.98	0.89	0.89
LU	7.07	3.15	3.14	-0.004	2.35	1.26	0.84
S*†	6.91	3.24	3.23	-0.001	1.59	0.70	0.90

*Equivalent depth over basin.

†Flow data available for 8.3 yrs (6.6 yrs used for calibration. 1.7 yrs used for initialization) beginning December 1, 1969.

**Flow data available for 4.2 yrs (2.5 yrs used for calibration, 1.7 yrs used forinitialization) ending December 31, 1978.

††L = Entire Lake Superior Basin.
LEN = Entire Lake Superior Basin excluding the Lake Nipigon subbasin.
LC = Entire Canadian portion of the Lake Superior Basin.
LCEN = Entire Canadian portion of the Lake Superior Basin excluding the Lake Nipigon subbasin.
LU = Entire United States portion of the Lake Superior Basin.

*†Combined results from the 20 subbasin applications (l-8, 10, 12-22).

5.1.2 Natural Basins

The root-mean-square error and correlation for these model applications allow several comparisons to be made. The model performs noticeably better for subbasins with natural flow only since diversions and regulations of flows are not represented in the model. Flows from subbasins 10 and 16 are both unaffected by man and yield the best model fits among all subbasins for all three models (l-d, 7-d, and monthly). In contrast, goodness-of-fit values are not as good for subbasins 1, 8, and 19. Flow from subbasin 1 is somewhat affected by extensive iron mining activities in the basin. Flow regulations in subbasin 8 result in frequent changes of outflow amounting to over two orders of magnitude in a single day; this prohibits effective calibration. The Ogoki diversion and regulation of outflow from Lake Nipigon for hydropower purposes both affect subbasin 19.

5.1.3 Spatial Integration Effects

Spatial integration effects tend to cancel model errors for small areas when the areas are added together; the entire-basin models perform as well or better than the subbasin models.

The distributed-parameter model shows better correlation and root-mean-square error than the lumped-parameter model, undoubtedly because of the use of more information for the distributed-parameter applications, which is then lost in the spatial integration of data by the lumped-parameter model. Even so, the improvement in model performance is not striking and the distributed-parameter model costs about 20 times as much to use as the lumped-parameter model.

5.1.4 Monthly Lumped Models

The monthly model was applied to five lumped data sets to correspond, respectively, to the entire Lake Superior Basin (L), the entire Lake Superior Basin excluding the Lake Nipigon subbasin (LEN), the entire Canadian portion of the Lake Superior Basin (LC), the entire Canadian portion of the Lake Superior Basin excluding the Lake Nipigon subbasin (LCEN), and the entire United States portion of the Lake Superior Basin (LU). Entire basin applications include sizeable 'unnatural' flows reflecting diversions and regulations throughout the basin. The largest single cause of this 'unnaturalness' is the diversion and regulation of flows through Lake Nipigon, which drain8 almost 20 percent of the entire Lake Superior Basin. Model performance does not significantly improve, however, when the Lake Nipigon subbasin (subbasin 19) is excluded from the lumped applications in table 10. This suggests that Lake Nipigon diversions and regulation8 do not significantly alter the character of entire-basin flows over an extended time period. However, for short periods (e.g., 1 month) control of Lake Nipigon flows may substantially affect entire-basin flows. Also, model performance improved significantly when only the Canadian portion of the entire Lake Superior Basin was modeled. Flows in the United States portion of the basin are generally subject to more human influence, which is not represented in the model, than are those in the Canadian portion of the basin.

5.2 Hydrograph Comparisons

Figure 5 shows the actual and modeled hydrographs (weekly flow volumes) of the entire Lake Superior Basin for 1971-78; it represents the distributed-parameter (S) application. Plots similar to figure 5 for the 7-d model application to each of the subbasins are included in appendix J. The model produces an obvious recession of winter flows, although actual flows are more constant during winter for the entire Lake Superior Basin. This discrepancy probably results from the regulation of winter flows that the model cannot represent. For most subbasins in which flow is natural (unregulated), actual flows also recede in winter; see, for example, the hydrographs for subbasins 10, 12, 16, and 20. Subbasins in which flow is somewhat regulated may show actual winter recessions. The model generally performs well for these subbasins and it is presumed that the flow regulations do not significantly interfere with parameter calibration for these subbasins; see, for example, the hydrographs for subbasins 15, 17, and 22. In other subbasins, that experience highly variable flows because of regulation, actual flows do not recede in winter. The model does not perform well for these subbasins, and it is presumed that regulations of their flows prevent accurate parameter calibration for them; see, for example, the hydrographs for subbasins 8 and 19.

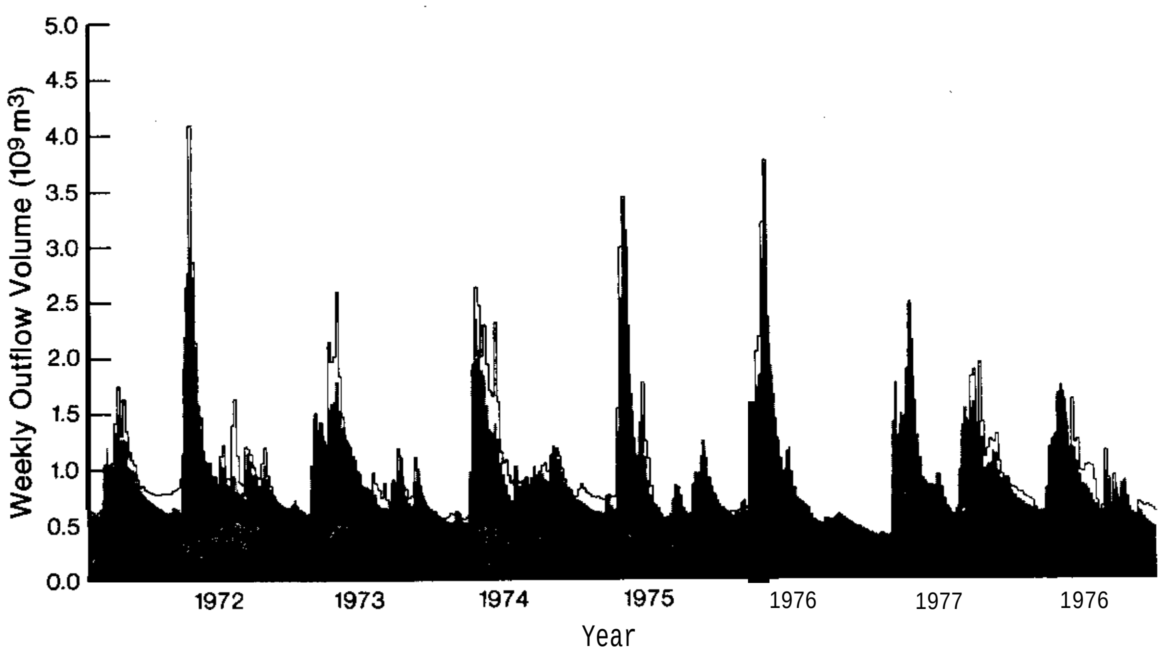

FIGURE 5.--*Seven-day* ***distributed-parameter*** model ***fit to Lake Superior*** *Basin.*

Additionally, this discrepancy in winter recessions may result from freezing of bogs and swamps, which inhibits the surface and interflow supply of water, but is not reflected in the model. Flow may drop to a level sustainable by groundwater flow and snowmelt owing to ground heat conduction. In comparison to summer, little water is being used in evapotranspiration. In addition, swampy areas tend to supply groundwater for evapotranspiration. As a result, groundwater is able to sustain a level of flow without showing clear recessions.

5.3 Seasonal Statistics

Model strengths and weaknesses are highlighted by monthly statistics for the l-d model applied to the entire Lake Superior Basin on a distributed-parameter basis; see tables 11 and 12. The daily flow volumes (both actual and model) are summed for each month in the data period. The monthly deviations are presented in table 11 as model flow minus actual flow, expressed in centimeters over the basin. Large deviations result from the inclusion of Ogoki diversions in the flow from Lake Nipigon into Lake Superior. Statistics computed for each month of the year are summarized in table 12 and enable comparisons with other basin-wide runoff models. Model fits are good for all months except March.

The poor model fit for March is probably due, at least in part, to large deviations between actual and model flows for that month in 1977 when flow regulation from Lake Nipigon (in subbasin 19) was significant. Also, the lower correlation in March reflect8 recognized model deficiencies regarding snowmelt. Inspection of figure 5 and its companion plots in appendix J suggests that the model handles the timing of snowmelt runoff adequately. Major snowmelt generally begins sometime between the second week of March and the second week of April for southern Lake Superior subbasins and between the end of April and the beginning of June for northern Lake Superior subbasins. However, the hydrograph plots and remotely-sensed snow-water equivalents (discussed subsequently) suggest that the model overestimates snowmelt volumes. Improvement of March flow modeling depends upon improved conceptual accounting of snowpack conditions; this appears unlikely without the use of more data than is presently available (daily air temperatures and precipitation and midmonthly insolation).

Attempt8 to describe snow accumulation and ablation in more detail within the Large Basin Runoff Model did not improve its performance. Incorporation of sublimation into the model removes water from the snowpack, so less water is available to produce outflow. When this approach was tested, the model showed that almost no water was stored in the snowpack all winter, which is unlikely for any subbasins about Lake Superior; the root-mean-square error and correlation coefficient between actual and model outflow volumes did not improve. A more sophisticated degree-day approach using melting degree-day8 and freezing degree-days, along with considerations of a snow quality threshold for runoff, was tested, but did not improve the root-mean-square error or the correlation coefficient between actual and model outflows. (See appendix A.)

TABLE 11.--Lake Superior monthly deviations for 1-d model*

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aue.	Sent.	Oct.	Nov.	Dec.
1971									-0.03	0.08	-0.52	-0.23
1972	-0.45	-0.66	-0.78	-0.31	-1.16	0.24	-0.20	-0.95	-0.42	-0.40	-0.29	-0.05
1973	-0.12	-0.16	0.30	-0.48	-1.33	-0.02	-0.17	-0.47	-0.44	-0.28	-0.13	0.09
1974	-0.10	-0.33	-0.07	-0.55	-1.14	-1.42	-0.66	-0.05	0.00	-0.34	0.01	-0.14
1975	-0.62	-0.61	-0.39	-1.12	0.15	-0.22	-0.21	0.08	0.66	0.53	1.00	0.29
1976	-0.12	-0.14	-0.02	-1.74	0.44	0.82	0.44	0.31	0.29	0.41	0.25	0.20
1977	0.27	0.20	2.22	1.13	0.97	0.62	0.52	0.79	-0.23	-0.63	-0.59	-0.07
1978	-0.20	-0.31	-0.16	-0.15	-0.14	-0.80	-0.50	0.09	0.14	0.37	-0.07	-0.52

*Model flow volume minus actual flow volume, expressed as equivalent depth over the basin area in centimeters.

TABLE 12.--Lake *Superior monthly statistics for l-d model*

Month	Mean (cm)* (actual)	Mean (cm)* (model)	STDV (cm)† (actual)	STDV (cm)† (model)	RMSE (cm)**	Corr.
Jan.	2.20	2.00	0.54	0.31	0.32	0.95
Feb.	1.92	1.63	0.44	0.22	0.40	0.88
Mar.	2.64	2.80	0.58	1.05	0.91	0.52
Apr.	5.77	5.31	1.50	1.18	0.94	0.84
May	6.07	5.76	1.72	1.19	0.89	0.90
June	3.70	3.59	1.01	0.44	0.74	0.77
July	2.76	2.64	0.54	0.22	0.42	0.72
Aug.	2.56	2.53	0.87	0.49	0.52	0.86
Sept.	2.72	2.72	1.05	0.89	0.35	0.95
Oct.	3.05	3.01	1.02	0.69	0.41	0.96
Nov.	3.14	3.09	1.03	0.84	0.47	0.89
Dec.	2.49	2.44	0.59	0.57	0.25	0.91

*Equivalent depth over basin.

†Standard deviation (equivalent depth over basin).

**Root-mean-square error (equivalent depth over basin).

5.4 Comparison with Other Modeling Approaches

5.4.1 Climatic Water Balance Model

Monthly statistics for the monthly model applied to the entire Lake Superior Basin on a distributed-parameter basis allow fair comparison with other basin-wide runoff models that use monthly meteorological data. One such model currently in use (to provide runoff and soil moisture outlooks) is the climatic water balance model described by Quinn and Croley (1983); it uses the Thornwaite procedure to estimate evapotranspiration and a tank-cascade concept for runoff and soil moisture accounting. Table 13 shows monthly statistics for both the Large Basin Runoff Model and the climatic water balance model. The Large Basin Runoff Model produce8 substantially better model fits for most months. Some differences between model statistics are due to the different periods used for the model applications. However, both applications encompass the known significant Lake Nipigon flow manipulations.

5.4.2 Climatology

Climatological analysis represents a "minimum model" or "no model" approach to characterizing basin runoff and thus suggests a minimum acceptable predictive capability for any model applied to the Lake Superior Basin. The

TABLE 13.--*Lake Superior monthly statistics for monthly models*[*]

Month	Mean (cm)[†] (actual)	Mean (cm)[†] (model)	STDV (cm)** (actual)	STDV (cm)** (model)	RMSE (cm)[††]	Corr.
Jan.	2.20 (2.31)	2.27 (2.25)	0.54 (0.51)	0.22 (0.45)	0.34 (0.32)	0.97 (0.78)
Feb.	1.92 (2.06)	1.91 (1.93)	0.44 (0.45)	0.19 (0.26)	0.26 (0.32)	0.96 (0.70)
Mar.	2.64 (2.64)	2.21 (2.57)	0.58 (0.58)	0.60 (0.77)	0.56 (0.64)	0.82 (0.00)
Apr.	5.77 (6.30)	4.90 (6.49)	1.50 (1.61)	1.49 (1.16)	1.45 (1.03)	0.70 (0.77)
May	6.07 (6.36)	5.97 (6.30)	1.72 (1.99)	1.08 (1.41)	0.87 (1.16)	0.91 (0.81)
June	3.70 (4.05)	3.83 (4.11)	1.02 (1.22)	0.57 (0.96)	0.64 (0.64)	0.84 (0.85)
July	2.76 (2.89)	2.79 (2.96)	0.54 (0.90)	0.25 (0.77)	0.33 (0.51)	0.90 (0.82)
Aug.	2.57 (2.51)	2.59 (2.57)	0.88 (0.77)	0.24 (0.51)	0.76 (0.58)	0.60 (0.66)
Sept.	2.73 (2.70)	2.80 (2.64)	1.05 (0.90)	0.43 (1.16)	0.66 (0.45)	0.95 (0.87)
Oct.	3.05 (3.21)	3.14 (3.15)	1.02 (0.96)	0.46 (1.54)	0.71 (0.90)	0.80 (0.36)
Nov.	3.14 (3.21)	2.87 (3.47)	1.02 (0.96)	0.38 (1.03)	0.82 (0.58)	0.76 (0.80)
Dec.	2.50 (2.57)	2.48 (2.57)	0.59 (0.64)	0.26 (0.58)	0.39 (0.32)	0.86 (0.87)

[*]Values in parentheses adapted from climatic water balance model of Quinn and Croley (1983) applied over the period 1968-80.

[†]Equivalent depth over basin.

**Standard deviation (equivalent depth over basin).

[††]Root-mean-square error (equivalent depth over basin).

time series of flow for the basin is used to compute the mean flow for each interval in the year. Each mean is then considered as a predictor (estimator) of flow for the appropriate intervals in the same time series. Table 14 presents an analysis of the Lake Superior Basin climatology for daily, weekly, and monthly time periods and can be compared to the l-d, 7-d, and monthly model results, respectively, for the entire Lake Superior Basin applications (L and S in tables 8, 9, and 10, respectively). The Large Basin Runoff Model is substantially better than the simple climatological approach (as measured by root-mean-square error and correlation) on a daily and weekly basis; it is also better on a monthly basis, but by a smaller margin.

6. NET BASIN SUPPLY FORECASTS

Probabilistic outlooks of accumulated net basin supply to Lake Superior (basin runoff plus lake precipitation minus lake evaporation) for several forecast lengths are required for use in the Lake Superior regulation plan. To assess the capability and use of the Large Basin Runoff Model in making such forecasts, a probabilistic outlook was generated for the period March 15-September 30, 1983. This period is of critical interest since large, variable snowpack accumulations usually precede it, and can greatly affect runoff timing and volume. First, a procedure for generating a probabilistic outlook is described in detail. The use of available mean real-time data to extend the data set to the beginning of the forecast period is then explained and the representation of basin meteorology with few stations is addressed. Initialization of model storages on the beginning of the forecast period is described and the sensitivity of the model to initial storages is analyzed. A 6-month probabilistic outlook of net basin supply to Lake Superior is

TABLE 14.--*Lake Superior Basin climatological analysis**

Interval	Mean Predictor† (cm)**	Std. Dev. Predictor (cm)**	Mean Flow† (cm)**	Std. Dev. Flow (cm)**	RMSE††(cm)	Corr.
Daily	0.11	0.05	0.11	0.07	0.04	0.77
Weekly	0.77	0.35	0.77	0.44	0.27	0.79
Monthly	3.35	1.35	3.35	1.66	0.97	0.81

*Used data set beginning December 1, 1969, and ending December 31, 1978.

†Mean predictor and mean flow computed from the same time series and consequently identical.

**Equivalent depth over basin.

††Root-mean-square error (equivalent depth over basin).

presented, and improvements in the forecasting procedure to compensate for interbasin diversions are suggested.

6.1 Probabilistic Extensions

6.1.1 Procedure

The 5-percent, 50-percent, and 95-percent exceedance quantiles of accumulated net basin supply to Lake Superior (basin runoff plus lake precipitation minus lake evaporation) for several forecast length8 are required for use in the Lake Superior regulation plan. A probabilistic extension estimation procedure is used; termed Extended Streamflow Prediction (ESP), it is similar to the procedure use by the National Weather Service and other agencies. The runoff model is first initialized to correspond to the present state in the field by setting soil moisture, base storage, and snowpack to correspond to the present conditions within the basin. The historical meteorological data then are used to compute runoff with the model for the portion of each year of record that matches the forecast period. Model runoff, lake precipitation, and lake evaporation for the same periods are combined to compute net basin supply time series for the period of interest. Each net basin supply time series is accumulated over n months (for ultimately determining the lake level n month8 into the future) and the years of record are sorted from smallest to largest based on the n-month accumulated net basin supply. This is then repeated for successively larger n-month periods; n = 1, ... 6 is used here. The n-month order statistic8 are thus obtained based upon the n-month accumulated net basin supply for the first n months. This produces a narrower, more realistic bracketing of extremes than approaches that use nth month (i.e., nonaccumulated) net basin supplies. Quantile probabilities are given by the order number and a suitable plotting position formula, in this case the California Method, which is characterized as being unbiased with no special considerations for extreme events (Adamowski, 1981). These probabilities represent the nonexceedance probabilities, and their complements represent the exceedance probabilities. The quantiles of interest can then be identified for each n-month period and used in lake-level calculations.

6.1.2 User's Guide to Model in ESP Setting

The lumped-parameter application of the GLERL Large Basin Runoff Model to the Lake Superior Basin for purposes of generating probabilistic extensions of net basin supply for forecast purposes is documented in appendices C and K-N. Appendix K contains a source code listing of the Large Basin Runoff Model adapted for use in an ESP setting, with daily meteorological data (the file called WATESP) and a short explanation of its use. Appendix C contain8 a partial listing of an example daily hydrometeorological data set (the file called DATA). Appendix L contains a complete listing of monthly lake evaporation/condensation for Lake Superior (the file called ZSEVAP). Appendix M contains an example calibrated parameter set (the file called PARME); the files DATA, ZSEVAP, and PARME are for input to the ESP package. Appendix N contain8 example model output (the file called STAT) and consists of tables of net basin supply ordered from smallest to largest; one table is included for each forecast length from April 1983: 1, 2, 3, . . ., 6 month forecasts. The tables list the basin runoff, lake precipitation, and lake evaporation/ condensation for each year of record. The information in appendix N can be used to estimate lake levels under different management strategies as an aid in determining the most effective regulations of Lake Superior lake levels.

Appendix K also contains a version of the model that uses monthly meteorological data to generate net basin supply forecasts (the file called MLESP). Appendix C contains an example monthly hydrometeorological data set (the file called MDATA) for use with this model version. No example use of the monthly ESP procedure is provided in the appendices since its use is similar to the use of WATESP in appendix K.

6.2 Data Set Extension

6.2.1 Extension Procedure

To use the Large Basin Runoff Model for forecasting, it is necessary to acquire meteorological data on a near real-time basis. To illustrate the use of the model in near real time, we used existing data linkages to prepare the March 15-September 30 outlook in the latter part of March 1983. The Lake Superior data set, described in the preceding sections, extends through December 1978. We incorporated meteorological data through July 1982 (Canadian stations) and December 1982 (United States stations) from the published records for selected stations for which unpublished provisional data through March 15, 1983 was also available. The U.S. Army Corps of Engineers, Detroit District, and the National Weather Service indicated that, presently, only seven meteorological stations offered practical near real-time data collection (1- or 2-week delay); four were United States and three were Canadian stations. These stations are listed in table 15. The three Canadian stations are not part of the original 54-station network. The data set for the period January 1, 1979, through March 15, 1983, is based on the stations in table 15; the data from January 1, 1983, through March 15, 1983, is provisional and not yet published by the collecting agencies. For this portion of the data set, the Thiessen weights are determined based only on these seven stations. However, there are questions about the adequacy of using so few stations to represent meteorological conditions for the entire Lake Superior Basin.

6.2.2 Meteorological Network Assessment

In regard to the question of adequate coverage, the existing meteorological station network was evaluated with a simple assessment of the number of gages and the useful information gained from them. Questions of data transmittal, timeliness, and gage location are not addressed. The evaluation consisted of examining the existing climatological data base on the Lake Superior Basin and applying the Large Basin Runoff Model to subsets of this

TABLE 15.--*Near real-time meteorological stations a Lake Superior Basin*

Station	Station number*
Duluth	212248
Houghton	203908
Marquette	205184
Sault Ste. Marie	207366
Geraldton	6042715
Thunder Bay A	6048261
Wawa A	6059D09

*United States stations (six-digit stations) and Canadian stations (seven-digit numbers).

data base. Since the model uses only daily precipitation and air temperatures, assessment of the usefulness of wind and humidity data is not made.

The general approach is as follows. All 54 stations were first considered to determine Thiessen weight8 by using a grid-square (1 km^2 resolution) weighting program. One station was eliminated since it represented less than 0.1 percent of the area. The remaining 53 station records were combined by weighting them accordingly to build a whole-basin data set consisting of daily precipitation and daily minimum and maximum air temperatures. The Large Basin Runoff Model was then calibrated with this data set. Then, the 10 stations with the smallest areas of representation (smallest Thiessen weights) were eliminated to identify 43 stations. The Thiessen weights were recomputed from this subset, and the model application was repeated. This process of elimination, computation of Thiessen weights, and model application was repeated to look at successively smaller subsets of available stations. Data sets containing 53, 43, 33, 23, 13, 10, 9, 8. 7, and 6 meteorological stations were analyzed. In addition, two stations were added to the 10-station data set (Sault Ste. Marie Weather Service Office and Meadowlands 9 S, both in the United States) to give subjectively assessed uniform coverage. This data set was also analyzed. Basin maps showing the locations of stations for each of the successively smaller subsets are presented elsewhere (Croley, 1983a). Thiessen weights for all data sets are summarized in table 16.

TABLE 16.—*Data network assessment Thiessen weights on Luke Superior Basin*

Number'	Name	Networks and associated station weights 54	43	33	23	13	12	10	9	8	7	6
6059409	Wawa	9.8	9.8	9.8	9.8	14.4	10.0	14.4	15.1	15.1	21.9	21.9
6040020	Abitibi Camp 230	8.7	8.7	8.7	8.7	8.7	11.7	11.7	11.7	14.1	14.1	20.2
6040572	Beardmore	7.1	7.1	7.1	7.1	7.1	10.4	10.4	11.3	15.6	15.6	15.6
6040325	Armstrong Airport	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7			
6044959	Marathon	5.5	5.5	5.5	5.5	5.6	5.7	5.7				
6061358	Chapleau	4.5	4.5	4.5	4.5	6.6	4.6	6.8	6.8	6.8		
6045675	Nolalu	4.3	4.3	4.3	7.1	a.5	9.3	9.3	9.3	9.3	9.3	
6044903	Manitouwadge	3.7	3.7	3.7	3.7	7.1	7.1	7.1	11.4	11.4	11.4	11.4
6041109	Cameron Falls	3.6	3.6	3.6	3.6	3.6						
6041193	Caramat	3.5	3.5	3.5	3.5							
6042067	Dorion TCPL 70	3.5	3.5	3.5	3.6	3.6						
207366	Sault Ste. Marie WSO†	2.4	2.4	2.4	2.4		6.6					
200718	Bergland Dam	2.0	2.2	2.8	3.9	5.0						
214068	Isabella 1 W	1.7	1.7	1.7	2.4							
213921	Hoyt Lakes 5 N	1.6	1.6	1.6	1.7							
208920	Whitefish Point	1.6	1.6	1.6	2.1							
203908	Houghton FAA** Airport	1.4	1.4	1.4								
211840	Cotton 3 E	1.4	1.4	1.7	2.4							
200485	Baraga 5 WNW	1.3	1.3	2.0	5.1	7.1	10.2	10.4	10.4	10.4	10.4	11.2
470349	Ashland Experiment Farm	1.3		3.0	4.5	15.6	8.0	17.3	17.3	17.3	17.3	19.6
213282	Grand Marais	1.3	1::	1.3								
2 15298	Meadowlands 9 S	1.2	1.4	2.9	3.3		9.3					
216419	Two Harbors	1.2	1.2	2.6	2.8							
204328	Kenton	1.2	1.2	2.1	2.1							
213296	Grand Portage R S	1.2	1.2	1.2								
206043	Tahquamenon Falls State Park	1.2	1.2	1.2								
213730	Hibbing FM** Airport	1.2	1.2	1.2								
213417	Gunflint Lake 10 NW	1.2	1.2	1.2								
205816	Newberry State Hospital	1.1	1.2	1.7	3.3							
204104	Ironwood	1.1	1.5	1.5								
476772	Port Wing 2 E	1.0	1.0									
208680	Watersmeet	1.0	1.1									
212248	Duluth WSO† Airport	0.8	0:s									
475266	Mellen 4 NE	0.8	1.2	1.2								
472889	Foxboro	0.7	0.9									
472240	Drummond	0.7	0.9									
200770	Big Bay 1 S	0.7	1.2	1.3								
203319	Grand Marais 1 SE	0.6	0.7									
201464	Chathsm Exp. Farm	0.6	1.2	1.3								
200089	Alberta Ford For Center	0.6	0.6									
203744	Herman	0.6	0.6									
211630	Cloquet	0.6	0.6									
478349	Superior	0.6	0:s									
477092	Rat Lake	0.5										
473332	Gurney	0.5										
477892	Solon Springs	0.5										
205178	Marquette	0.4										
205690	Munising	0.4										
204127	Ishpeming	0.3										
217460	Sandy Lake Dam Libby	0.2										
201439	Champion Van Riper Park	0.1										
215598	Moose Lake 1 SSE	0.1										
207515	Seney Natl. Wildlife Refuge	0.1										
202298	Dunbar Forest Exp. Sta.	0.0										

*United States stations(six-digit numbers) and Canadian stations (seven-digit numbers).

†Weather Service Office.

**Federal Aeronautics Administration.

The length of record considered in the data set was 3,318 days from December 1, 1969, through December 31, 1978, and the first 630 days were used for initialization. The model parameters are summarized in table 17. The goodness-of-fit summary is presented in table 18 and plotted in figure 6. Inspection of figure 6 reveals that there is little information lost between the 53- and the 23-station data sets when using the model to estimate weekly runoff volumes. The explained variance of basin runoff is about 82 percent (correlation = 0.91) for the 53, 43, 33, and 23 station data sets. As the number of stations drops to 6, the explained variance drops to about 78 percent (correlation = 0.88). It appears that between 20 and 30 stations are adequate for "se with this model; they should be selected in accordance with the above procedures as used In this simple study. Even the use of as few as 6 to 10 index stations results in useful modeling with between 78 percent and 80 percent explained variance. Inspection of table 17 reveals that the calibrated values of the model parameters are largely unaffected as long as about the 20 to 30 largest-area stations are used. Thus, ancillary model calculations of moisture storage in each of the soil and surface zones should be approximately the same.

It is important to note that most of the meteorological stations that were eliminated in the successively smaller subsets of this study were based in the United States. Thus, It is difficult to assess how much more information would be useful if stations were added In the Canadian portion of the basin. Since the coverage is sparse there, it seems likely that the addition of a few stations in Canada would result in modeling improvements.

TABLE 17.--*Data network* **assessment** *7-d model* **parameters for Lake Superior** *Basin**

No. of met. sta.	T_b (°C)	Melt constant (m^3/°C-d)	Percolation (d^{-1})	Upper zone evap. (m^{-3})	Interflow (d^{-1})	Deep percolation (d^{-1})	Lower zone evap. (m^{-3})	Groundwater (d^{-1})	Surface storage outflow (d^{-1})
53	1.7	30e+7	27e-1	0	45e-4	9e-3	10e-5	38e-4	15e-2
43	1.7	31e+7	26e-1	0	44e-4	9e-3	11e-5	37e-4	13e-2
33	1.7	30e+7	25e-1	0	44e-4	9e-3	15e-5	38e-4	14e-2
23	1.7	31e+7	27e-1	0	42e-4	9e-3	22e-5	37e-4	14e-2
13	1.7	34e+7	30e-1	0	39e-4	8e-3	30e-5	33e-4	14e-2
12	1.6	31e+7	30e-1	0	38e-4	8e-3	33e-5	34e-4	16e-2
10	1.7	34e+7	32e-1	0	41e-4	8e-3	29e-5	30e-4	15e-2
9	1.7	35e+7	32e-1	0	39e-4	8e-3	38e-5	32e-4	14e-2
8	1.7	34e+7	32e-1	0	37e-4	8e-3	38e-5	30e-4	14e-2
7	1.7	37e+7	34e-1	0	35e-4	8e-3	33e-5	26e-4	13e-2
6	1.7	35e+7	34e-1	0	37e-4	8e-3	35e-5	25e-4	14e-2

*Applications made to each data set with 3,318 days beginning December 1, 1969, ending December 31, 1978; with the first 630 days used for initialization.

TABLE 18.--*Data network assessment* goodness-of-fit *summary* for Lake Superior Basin

No of meterol. stations	Root-mean-square error (cm)*	Explained variance
53	0.168	0.822
43	0.169	0.820
33	0.168	0.822
23	0.171	0.815
13	0.178	0.802
12	0.180	0.798
10	0.180	0.797
9	0.179	0.798
8	0.184	0.787
7	0.187	0.780
6	0.189	0.776

*Equivalent depth over basin.

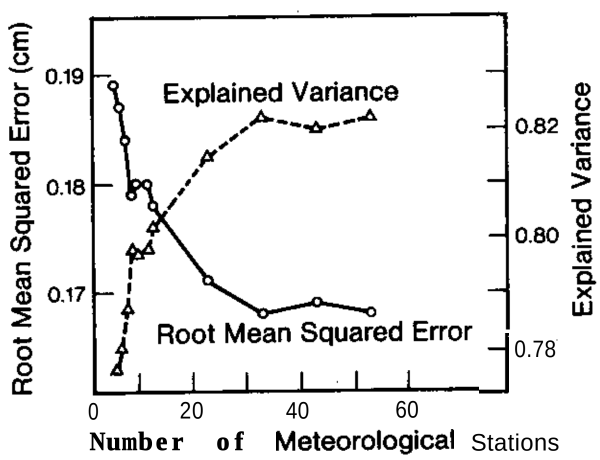

FIGURE 6.--*Data network assessment goodness-of-fit* for Lake *Superior* ***Basin.***

It appears that the use of data from the seven stations listed in table 15 to extend the data set through March 15 is reasonable. Parameter determination, however, remains based on the 54-station record.

6.3 Initialization of Tank Storages

6.3.1 Estimation of Initial Values

Initial values of the storages in each of the tanks (see fig. 1) are required for use of the runoff model in an ESP setting. If there are sufficient field data available describing soil and groundwater moisture contents on the beginning day of the outlook simulations, then it is possible to determine initial values from this data. Since sufficient data on soil moisture are not presently available in near real-time for the Lake Superior Basin, the initial tank storages must be estimated in another fashion. By using the model with an input data set for a sufficiently long period, up to the beginning day for the outlook simulations, the tank storages on the last day of the data set (first day for the outlook simulations) may be computed. These values are then used as the initial values for the ESP procedure. The model was run with a 14-year record up to March 15, 1983, to establish initial tank storages for use in the ESP procedure; the initial tank storages were determined as follows: 0.00 cm (upper soil zone), 6.43 cm (lower soil zone) 13.10 cm (groundwater zone), and 1.02 cm (surface storage).

6.3.2 Sensitivity to Initial Soil Moisture

Before these initial tank storages can be used, however, some idea of model sensitivity to the initial conditions is required. Errors in the estimation of initial conditions can then be assessed for their impact on calculated values of basin runoff. This sensitivity was looked at by using the runoff model with three different sets of initial tank storages and with 30 years of meteorological data broken into thirty 6.5-month time periods, each beginning March 15 (chosen to coincide with the desired forecast period to be used subsequently). The initial tank storages were taken from prior model runs to correspond with March 15 conditions for the minimum, maximum, and average total soil moisture. Total soil moisture is defined as the sum of the four tanks: upper soil zone, lower soil zone, groundwater zone, and surface storage zone. The minimum total soil moisture was 16.00 cm, the average was 18.14 cm, and the maximum was 22.00 cm. The distribution of the total between tanks was assumed to be identical to that observed in the model for the year during which both the minimum and maximum occurred. For the average, the average values of each tank storage on March 15 were used. Initial snow-water equivalent was set at 10.33 cm, consistent with the aerial gamma survey for March 15, 1983, discussed subsequently. The runoff totals for the first month, first 2 months, ... first 6 months were ordered from smallest to largest and the number 1 ranked (smallest), 15th ranked (median), and 30th ranked (largest) basin runoff volumes are presented in table 19 for each period for each set of initial conditions for the entire Lake Superior Basin. Runoff is expressed as equivalent depth over the basin.

TABLE 19.--*Lake* Superior **Basin** runoff as a function of ***initial soil moisture****

Rank (1 to 30)	Minimum record soil moisture (16 cm)	Average record soil moisture (18.14 cm)	Maximum record soil moisture (22 cm)
		April totals (cm)	
1	2.64	2.89	3.30
15	4.26	4.53	4.92
30	5.39	5.64	6.04
		April-May totals (cm)	
1	7.14	7.60	8.30
15	8.72	9.20	9.89
30	11.00	11.49	12.16
		April-June totals (cm)	
1	10.37	10.99	11.96
15	12.54	13.21	14.13
30	15.50	16.18	17.10
		April-July totals (cm)	
1	12.72	13.46	14.58
15	15.37	16.12	17.17
30	19.06	19.89	21.00
		April-August totals (cm)	
1	14.71	15.55	16.75
15	17.60	18.44	19.65
30	21.82	22.75	23.99
		April-September totals (cm)	
1	16.71	17.64	18.94
15	19.92	20.84	22.10
30	24.62	25.63	27.00

*Equivalent depths over basin.

It is instructive to look at the Increases in basin runoff that result from increases in initial total soil moisture. Table 20 presents the results of table 19 in this format. An increase in the Initial total soil moisture produces an increase in runoff (for each time period in table 20) that is nearly constant, being almost independent of the precipitation and temperature (rank) after the initial conditions. However, the rank assigned to any year's data is seen to depend upon the initial conditions somewhat. Hence, the initial condition affects the distribution of runoff over the succeeding months and, for example, the 30th ranked 2-month total may not come from the same year of record as the 30th ranked 6-month total. Although the rank may represent different model runs (different years of record selected in the ESP procedure) down the table (in table 19). the same year of record was seen to apply across the tables, almost without exception; e.g., the 30th ranked 2-month total for an initial total soil moisture of 16 cm came from the same year of record (same model run) as the 30th ranked 2-month total for an initial total soil moisture of 18.14 cm or 22 cm. The largest increase occurs earliest, but the increase is still ongoing 6 months later. Tables 19 and 20 present results for the model applied to the entire Lake Superior Basin; results were also generated for selected subbasins (1, 10, 12, 19). The Importance of the initial conditions in comparison to subsequent precipitation and air temperatures varies from subbasin to subbasin. For subbasins with large variations in total soil moisture from year to year, it is very significant. On the Tahquamenon River (subbasin 10), for example, the initial total soil moisture was more important than precipitation in determining the 6-month basin runoff volume. The importance of the initial conditions with respect to subsequent precipitation and air temperatures in determining basin runoff is less for the entire Lake Superior Basin. Table 20 illustrates that about one-third of the difference between the minimum and maximum initial total soil moistures (6.00 cm) runs off in about 5 months, not counting the initial 2 weeks (March 15-31). Relatively more of this difference runs off for an initially small storage (look at the 2.14-cm increase above minimum) and relatively less of this difference runs off for an initially large storage (look at the 3.86-cm increase above average). It appears then that the entire Lake Superior Basin model (lumped model) is more sensitive to variations of record in initial soil moisture than to variations of record in precipitation and temperature. This sensitivity exists to a greater degree on some of the subbasin applications. It is thus important to have accurate estimates of initial soil moistures for the probabilistic outlooks to be generated with the ESP procedure. While the initial values determined from use of the model for the preceding time period are used herein, improvements in probabilistic outlooks may be possible if adequate field measurements are available in the future. Soil moisture measurements taken in the joint United States-Canadian gamma radiation aerial survey experiment will henceforth be taken in a form suitable for incorporation into the model. The use of field measurements of soil moisture may also be important in calibration of the models. If soil moisture measurements are available, they can be used as boundary conditions in the parameter calibrations.

6.4 Initialization of Snowpack

Just as initial tank storages are required in order to use the runoff model in an ESP setting, so is the initial value of the snowpack (see fig. 1).

TABLE 20.--Lake Superior Basin runoff increase with initial soil moisture increase*

Rank (1 to 30)	Increase above minimum record soil moisture (16.00 cm) (2.14 cm)	Increase above minimum record soil moisture (16.00 cm) (6.00 cm)	Increase above average record soil moisture (18.14 cm) (3.86 cm)
	April runoff increases (cm)		
1	0.25 (12%)	0.66 (11%)	0.41 (11%)
15	0.27 (13%)	0.66 (11%)	0.39 (10%)
30	0.25 (12%)	0.65 (11%)	0.40 (10%)
	April-May runoff increases (cm)		
1	0.46 (21%)	1.16 (19%)	0.70 (18%)
15	0.48 (22%)	1.17 (20%)	0.69 (18%)
30	0.49 (23%)	1.16 (19%)	0.67 (17%)
	April-June runoff increases (cm)		
1	0.62 (29%)	1.59 (27%)	0.97 (25%)
15	0.67 (31%)	1.59 (27%)	0.92 (24%)
30	0.68 (32%)	1.60 (27%)	0.92 (24%)
	April-July runoff increases (cm)		
1	0.74 (35%)	1.86 (31%)	1.12 (29%)
15	0.75 (35%)	1.80 (30%)	1.05 (27%)
30	0.83 (39%)	1.94 (32%)	1.11 (29%)
	April-August runoff increases (cm)		
1	0.84 (39%)	2.04 (34%)	1.20 (31%)
15	0.84 (39%)	2.05 (34%)	1.21 (31%)
30	0.93 (43%)	2.17 (36%)	1.24 (32%)
	April-September runoff increases (cm)		
1	0.93 (43%)	2.23 (37%)	1.30 (34%)
15	0.92 (43%)	2.18 (36%)	1.26 (33%)
30	1.01 (47%)	2.38 (40%)	1.37 (35%)

*Differences between runoff volumes (equivalent depths over basin) that occur between the base initial soil moisture (either 16.00 cm or 18.14 cm) and the increased initial soil moisture. Parenthetical table entries express this difference as a percentage of the increase in the initial soil moisture.

It is possible to determine an initial value of snow-water equivalent for the first day of the outlook simulations in the same manner as used for initial tank storages; i.e., the runoff model can be run for the period preceding this first day. However, there are field data available from the joint United States-Canada experimental aerial gamma radiation surveys that can be used directly as an initial condition in the model simulations.

6.4.1 Airborne Snow Survey

The airborne snow survey is a cooperative study conducted jointly by the U.S. Army Corps of Engineers, Environment Canada, the Geological Survey of Canada, and the National Weather Service (Gauthier *et* at., 1983). One of its purposes is to collect information on the snowpack water equivalent on the Lake Superior Basin. Prior to the study, only limited field measurements were being taken. It is hoped that these additional data will ultimately enable more accurate regulation of the Great Lakes and particularly Lake Superior.

The measurement system used to infer the snow-water equivalent is based on the attenuation of natural terrestrial gamma radiation. Since water absorbs gamma radiation, measurements of the radiation emitted from the soil vary inversely with snow-water content. By prior measurement of background levels of radiation, it is possible to infer the amount of change in water present. In this study, gamma radiation spectrometer systems are operated on airplanes. Fifty-seven flight lines were flown, including at least one for each of the 22 subbasins used in this study; see figure 7. A total of 1,500 flight-line kilometers are included in the network, with lines ranging in length from 20 to 30 km. By applying the measurement for an individual flight line at its midpoint, it was determined that the Thiessen-weighted average for the Lake Superior Basin was 10.33 cm of snow-water equivalent on March 15, 1983. Thiessen-weighted averages of snowpack water equivalent for each Lake Superior subbasin are presented in table 21.

It is the present intent of the study participants to continue the survey for another 4 years. The use of the model with the snow survey data is also of interest to the cooperating agencies, in their assessment of the usefulness of the data acquired from the aerial surveys. They desire that the results be applied to a number of operational systems for forecasting net basin supply and/or levels on Lake Superior.

6.4.2 Sensitivity to Initial Snowpack Water Equivalent

Before this initial snow-water equivalent can be used in the ESP application for Lake Superior, some idea of model sensitivity to the initial conditions is required. This sensitivity was investigated by using the runoff model with three different initial snow-water equivalents and with 30 years of meteorological data broken into thirty 6.5-month time periods, each beginning March 15 (similar to the preceding sensitivity calculations for initial total soil moisture). The initial snow-water equivalent values for this sensitivity study were set at 8.00 cm, 10.33 cm, and 12.00 cm, representing the observed value for March 15, 1983, and a small range about this value. Initial tank

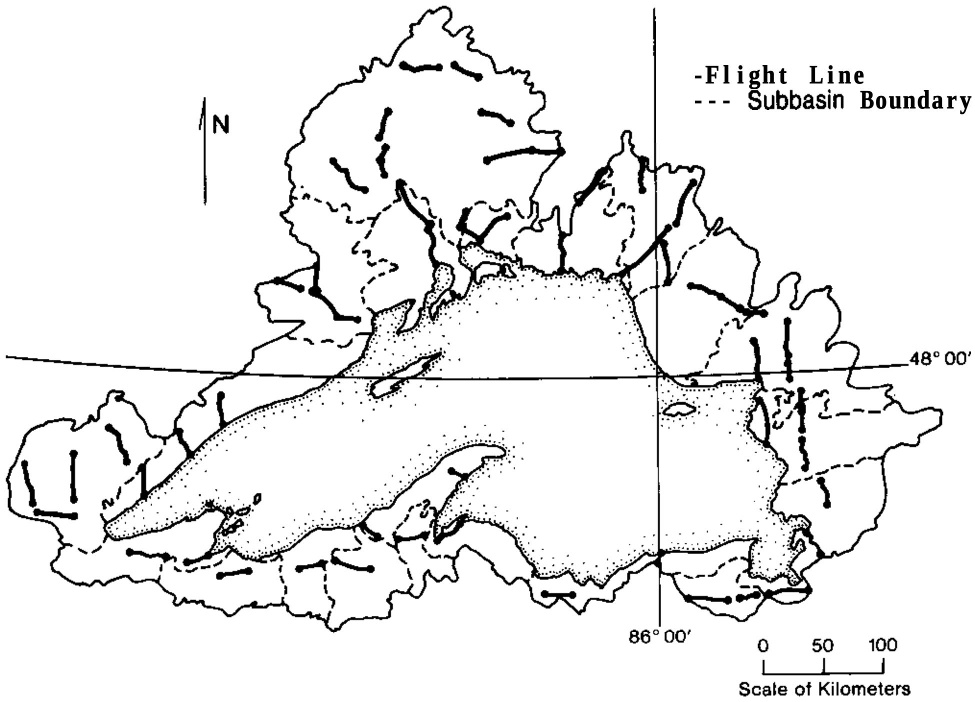

FIGURE *7.--Location map for Lake Superior Baein aerial gamma radiation survey flight tines.*

storages were taken as the average values for March 15 from simulations with data from the period 1949-78. The runoff totals for the first month, first 2 months,..., first 6 months were ordered from smallest to largest and the rank 1 (smallest), 15 (median), and 30 (largest) basin runoff volumes are presented in table 22 for each period for each set of initial conditions for the entire Lake Superior Basin. Runoff is expressed as equivalent depth over the basin.

It is again instructive to look at the increases in basin runoff that result from increases in initial snow water equivalent. Table 23 presents the results of table 22 in this format. An increase in the initial snow-water equivalent produces an increase in runoff (for each time period in table 23) that is not nearly as constant with rank as initial total soil moisture increase effects were (see table 20). The increase in runoff for a given n-month period, attendant to an increase in initial snow-water equivalent, appears to be dependent on the precipitation and air temperatures (rank) subsequent to the initial conditions. This dependence, particularly on air temperature, is expected since air temperature governs how much of the snowpack melts.

It was again observed that the rank assigned to any year's data depends upon the initial conditions. The dependence is greater than that observed with initial total soil moisture values. The distribution of runoff over the succeeding months is affected more by the initial snow-water equivalent than

Table 21.--*Lake Superior subbasin remotely-sensed snots-water equivalents* for *March 15, 1983.*

Subbasin number	Mean area1 S.W.E. (cm)*
1	5.4
2	7.8
3	10.1
4	10.9
5	7.4
6	9.7
7	8.8
8	8.5
9	7.1
10	1.4
11	2.5
12	8.2
13	13.5
14	14.3
15	12.9
16	15.5
17	15.5
18	14.0
19	11.0
20	9.9
21	9.6
22	9.1
L†	10.3

*Snow-water equivalent depth over basin.

†Entire Lake Superior Basin.

by the initial total soil moisture. Also, it has been observed that the year representing each rank both down and across in tables 22 and 23 varied more than in tables 19 and 20. Table 23 reveals that there was no change in rank 1 (smallest) runoff volume for April as the initial snow-water equivalent was increased. Rank 1 corresponds to 1950 data in which April was very cold with little snowmelt. Outside of these values, it appears that the runoff increases most in the early months, but is still increasing 6 months later. Table 23 illustrates that about one-half of the difference between the minimum and maximum initial snow-water equivalents (4.00 cm) runs off in about 6 months, not counting the initial 2 weeks (March 15-31). This response is a little faster than for changes in initial total soil moisture, but it is to be expected since part of the snowmelt runs off directly into the surface

TABLE 22.--*Lake Superior Basin* runoff *as* a function of initial *snow water**

Rank (1 to 30)	Initial snow-water equivalent (8.00 cm)	(10.33 cm)	(12.00 cm)
		April totals (cm)	
1	2.87	2.87	2.87
15	4.03	4.53	4.82
30	5.11	5.64	6.02
		April-May totals (cm)	
1	6.94	7.60	8.04
15	8.47	9.20	9.66
30	10.55	11.49	12.10
		April-June totals (cm)	
1	10.20	10.99	11.51
15	12.20	13.21	13.76
30	15.03	16.18	16.88
		April-July totals (cm)	
1	12.45	13.46	14.07
15	15.17	16.12	16.62
30	18.72	19.89	20.51
		April-August totals (cm)	
1	14.62	15.55	16.18
15	17.39	18.44	19.15
30	21.51	22.75	23.43
		April-September totals (cm)	
1	16.65	17.44	18.30
15	19.63	20.84	21.63
30	24.34	25.63	26.37

*Equivalent depths over basin.

TABLE 23.--*Lake Superior Basin runoff increase with initial snow-water increase**

Rank (1 to 30)	Initial snow-water equivalent increase above 8.00 cm		Initial snow-water equivalent increase above 10.33 cm
	(2.33 cm)	(4.00 cm)	(1.67 cm)
	April runoff increases (cm)		
1	0.00 (0%)	0.00 (0%)	0.00 (0%)
15	0.50 (21%)	0.79 (20%)	0.29 (17%)
30	0.53 (23%)	0.91 (23%)	0.38 (23%)
	April-May runoff increases (cm)		
1	0.66 (28%)	1.10 (28%)	0.44 (26%)
15	0.73 (31%)	1.19 (30%)	0.46 (28%)
30	0.94 (40%)	1.55 (39%)	0.61 (37%)
	April-June runoff increases (cm)		
1	0.79 (34%)	1.31 (33%)	0.52 (31%)
15	1.01 (43%)	1.56 (39%)	0.55 (33%)
30	1.15 (49%)	1.85 (46%)	0.70 (42%)
	April-July runoff increases (cm)		
1	1.01 (43%)	1.62 (41%)	0.61 (37%)
15	0.95 (41%)	1.45 (36%)	0.50 (30%)
30	1.17 (50%)	1.79 (45%)	0.62 (37%)
	April-August runoff increases (cm)		
1	0.93 (40%)	1.56 (39%)	0.63 (38%)
15	1.05 (45%)	1.76 (44%)	0.71 (43%)
30	1.24 (53%)	1.92 (48%)	0.68 (41%)
	April-September runoff increases (cm)		
1	0.79 (34%)	1.65 (41%)	0.86 (51%)
15	1.21 (52%)	2.00 (50%)	0.79 (47%)
30	1.29 (55%)	2.03 (51%)	0.74 (44%)

*Differences between runoff volumes (equivalent depths over basin) that occur between the base initial snow-water equivalent (either 8.00 cm or 10.33 cm) and the increased initial snow-water equivalent. Parenthetical table entries express this difference as a percentage of the increase in the initial snow-water equivalent.

storage. Relatively more of this difference runs off for an initially small storage (look at the 2.33-cm increase above 8.00 cm) and relatively less of this difference runs off for an initially large storage (look at the 1.67-cm increase above 10.33). although there are exceptions for rank 1 (smallest) runoff volumes.

It appears then that the entire Lake Superior Basin model (lumped model) is very sensitive to variations in the initial snow-water equivalent, as was expected. Additionally, variations in air temperatures are reflected directly in snowmelt, implying that snow-water sensitivity varies with the year of record. The sensitivity means that it is very important to have accurate estimates of initial snow-water equivalent in order for the probabilistic outlooks to be generated with the ESP procedure.

As previously mentioned, the initial value can be determined in a manner similar to that used to determine the initial total soil moisture. However, by using the model with several years of meteorological data prior to the starting date of the probabilistic outlooks, estimates of the initial snow-water equivalent are available from the aerial gamma radiation surveys; they are used herein.

Eventually, when enough soil moisture and snow-water equivalent measurements have been collected, it may be appropriate to weight objectively the field measurements and model-produced values for updating the model. Both values have worth; yet they are also both subject to error and uncertainty. It should also be noted that, while remotely-sensed estimates of snow-water equivalent may improve modeling of runoff volumes, they should not be expected to improve the timing of runoff due to snowmelt.

6.5 Probabilistic Outlook for March 15-September 30, 1983

Generation of a probabilistic outlook for net basin supply to Lake Superior requires adding lake precipitation to, and subtracting lake evaporation from, basin runoff (as outlined in the beginning of this chapter). Basin runoff is computed on a daily basis for the March 15-September 30 period by using the initial tank storages and snow-water equivalent described previously for each year of historical daily precipitation and air temperatures (1949-78). The daily basin runoff is summed over each month of the outlook period for each year of record to compute monthly runoff volumes. Monthly lake precipitation is estimated similarly by using daily basin precipitation (over land) summed over each month. Lake evaporation is estimated from the application of aerodynamic equations on a monthly basis (Derecki, 1980). The second-, fifteenth-, and twenty-ninth-order statistics derived from "se of the model in an ESP setting "sing daily meteorological data are plotted in figure 8. Net basin supply, computed from these three components (basin runoff, lake precipitation, and lake evaporation) does not include interbasin diversions. In regulation decisions, diversions are considered separately from net basin supply. Unfortunately, the Lake Superior Basin diversions are complicated. The Long Lake diversion is a flow addition to Lake Superior separate from other subbasin outflows and so can easily be considered separately from net basin supply. The only other interbasin diversion is the Ogoki diversion and

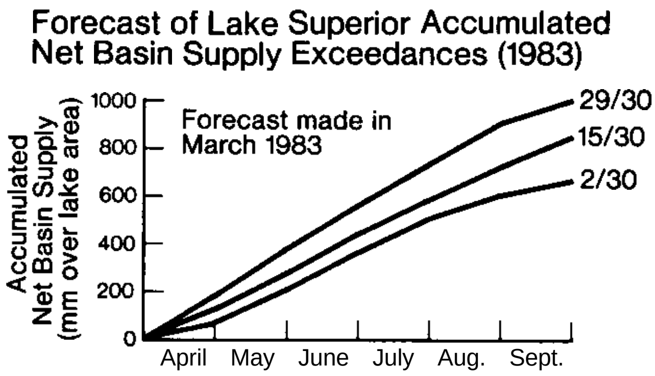

FIGURE 8.--*Lake Superior net basin supply order statistics for April-September 1983 computed in March 1983.*

it is more complicated. The Ogoki diversion is a flow addition from outside the basin to Lake Nipigon in subbasin 19. The flow records for the gage at the outlet of subbasin 19 thus represent the drainage from the subbasin, as well as the diversion. Lake Nipigon is a large regulated lake, and it is not possible to simply subtract the Ogoki diversion from the flow gage records since there may be considerable residence time for the diversion. Thus, the flow record is treated as if it represents runoff only and the diversion is ignored. The model application to the Lake Superior Basin thus treated the Ogoki diversion as part of the basin runoff and Ogoki diversions should not be treated separately in the use of the net basin supply probabilistic outlooks for determining reservoir regulations. Furthermore, if changes in the Ogoki diversions are anticipated, it may be appropriate to consider them separately in model calibrations. While this is not possible for the lumped-parameter application of the model to the entire Lake Superior Basin, it is possible in the distributed-parameter applications of the model in an ESP setting that are currently underway at GLERL.

7. SUMMARY

The Large Basin Runoff Model developed at GLERL is an accurate, fast model of weekly runoff volumes from the Lake Superior watershed; it has relatively simple calibration and data requirements. Parameters have physical significance and calibrated values obtained from parameter optimizations appear reasonable. Seven-day distributed-parameter and lumped-parameter applications to the Lake Superior Basin illustrate spatial integration effects on model resolution and filtering of both information and data errors coosequent with these applications. The distributed-parameter application is marginally better than the lumped-parameter application on a weekly and monthly basis, at about 20 times the cost to use. The 7-d lumped-parameter application to the entire Lake Superior Basin yielded a weekly and monthly correlation of 0.89 and 0.91, respectively. The 7-d distributed-parameter application yielded a weekly and monthly correlation of 0.93 and 0.94, respectively. Applications of the model to subbasins about Lake Superior show good-to-exceptional agreement with available flow data where flows are natural and unregulated; applications to subbasins with regulated flows varied from poor to good.

Continued investigation into parameter calibration appears warranted, especially minimum data set length requirements, the importance of hydrologic variability within the calibration data set, parameter interactions, and use of different calibration objective functions and convergence criteria. The goal should be to obtain unique parameter sets while retaining their realism. Also, continued model improvement is appropriate, especially concerning snowmelt runoff volumes. However, it is unlikely that any model modifications will be able to adequately simulate the extreme variability because of regulation of flows.

The model has potential for use in predictive studies since basin storages are represented directly. Predictions are limited by available meteorological information, but forecasting is practical if near real-time data are available. Since requisite data are limited to precipitation and air temperature, these requirements may soon be met on a continuing basis for many areas of the Great Lakes Basin. Efforts are underway at GLERL to develop communication data links allowing near real-time transmittal of basic meteorological data. Also, the 5-year United States-Canadian Airborne Snow Survey Project will result in the upgrading of 10 existing National Weather Service meteorological stations to provide real-time data to be transmitted through the NOAA Geostationary Operational Environmental Satellite.

The "se of aerial gamma radiation surveys of snowpack water equivalent has been illustrated for the 1982-83 snow season. Changes in the snow survey project during the upcoming years may allow inclusion of soil moisture measurements in the model initialization process. Sensitivity studies on initial snow-water equivalent and initial soil moisture indicate that these quantities are as important as precipitation in determining basin runoff and that accurate estimates of them are requisite to generation of practical probabilistic outlooks. The model enables tracking of these quantities in near real-time to enable their estimation. Because snowmelt is such an important part of the runoff process on the Lake Superior Basin, improvement in the hydrometeorological data network will enable model improvements with regard to snowmelt calculations. Also, satellite evaluation of the area1 extent and surface temperatures of the snowpack will be available on a near real-time basis beginning in winter 1983-84 from the United States-Canadian Airborne Snow Survey Project. Conclusions about the value of the remotely-sensed snow-water equivalents in a simulation or forecast setting cannot yet be made. when actual flow values for the forecast period become available, they can be compared with streamflow predictions made using measured snow-water equivalents and with streamflow predictions made using model-generated snow-water equivalents. However, one comparison will not be enough for any meaningful conclusions; it is just an indication. More measured values for snow-water equivalent and more forecasts are necessary.

Diversions and regulations of flows into the Lake Superior Basin cannot be modeled well; yet, they can significantly affect net supply to Lake Superior. GLERL is currently developing an easily implemented distributed-parameter extended streamflow prediction package for use with the Large Basin Runoff Model that allows exclusion of selected subbasins. Significant improvement in simulation and forecasting results are expected by isolating Lake Nipigon and other 'unnatural' subbasins. Lake level determinations can then consider their flows separately, and the improved forecasts of net basin supplies can then be used to make better estimates of future lake levels.

The model is now to be applied to the large sized basins around the remaining Great Lakes to simulate basin runoff for use in routing models. Data acquisition and reduction is complete for the remaining portions of the Great Lakes Basin. As near real-time reporting of hydrometeorological information progresses, the runoff and net basin supply forecasting will be implemented on a semiautomatic basis.

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Appendix A.--USING MELTING DEGREE-DAYS, FREEZING DEGREE-DAYS, AND SNOW QUALITY TO MODEL SNOWMELT

In the Lake Superior Basin, the air temperatures often fall below freezing for extended periods of time. As a result, a large dry snowpack accumulates. The simple degree-day approach described in the main text ignores the insulation of the ground provided by the snowpack and assumes that ground heat (as well as other heat-balance terms) is reflected in the air temperature. In an attempt to improve snowmelt modeling. an alternate approach was tried; it is described here. It was assumed that either melting or freezing may occur and that both are proportional (with the same proportionality constant, a) to degree-days above freezing (melting degree-days) or degree-days below freezing (freezing degree-days), respectively. Likewise, it was assumed that runoff from the snowpack occurs only when snow quality (fraction of the snowpack that is liquid) exceeds a threshold value, x, even though some ice may be melting.

$$MDD = \int_{\Omega_1} T(t)dt, \qquad \Omega_1 = \{t:T(t)\geq 0\} \tag{4}$$

$$FDD = -\int_{\Omega_2} T(t)dt, \qquad \Omega_2 = \{t:T(t)<0\}, \tag{5}$$

where MDD = melting degree-days in a day (°C-d/d), FDD = freezing degree-days in a day (°C-d/d), T(t) = air temperature at time t (°C), Ω_1 = set of all times during a day when the air temperature is nonnegative, and Ω_2 = set of all times during a day when the air temperature is below freezing. With these concepts, total degree-days (DD) is redefined as

$$DD = MDD - FDD = \int_{\Omega_1+\Omega_2} T(t)dt = \int_0^d T(t)dt \tag{6}$$

and if d = 1 day, DD = $T \cdot d$. Now if T > 0 (DD > 0), net melt occurs

$$m_p = aDD \qquad \text{(potential melt)} \tag{7}$$

$$\begin{aligned} m &= m_p, && m_p d < SNW_0 - SNWL_0 \\ &= (SNW_0 - SNWL_0)/d, && m_p d > SNW_0 - SNWL_0 \end{aligned} \tag{8}$$

Actual melt, m (m^3/d), equals potential melt if enough solid water is available to melt; otherwise it is limited to the solid water that is available, where SNW_0 = snowpack water equivalent at the beginning of the day (m^3) and $SNWL_0$ = snowpack liquid water content at the beginning of the day (m^3). Runoff rate from the snowpack, r (m^3/d), is

$$\begin{aligned} r &= 0, && (SNWL_0 + md + pd)/SNW_0 < x \\ &= \frac{1}{1-x}(SNWL_0 - xSNW_0 + md + pd)/d, && (SNWL_0 + md + pd)/SNW_0 > x \end{aligned} \tag{9}$$

where p = precipitation rate (m^3/d). The runoff from the snowpack is zero if the new snow quality is less than the runoff threshold; otherwise, runoff from the snowpack occurs such 'that the new quality equals the threshold: $(SNWL_0 + md + pd - rd)/(SNW_0 - rd) = x$. Finally, the snowpack at the end of the day is described by

$$SNWL_d = SNWL_0 + md - rd \tag{10}$$

$$SNW_d = SNW_0 - rd \tag{11}$$

NOW if $T < 0$ ($DD < 0$), net freezing occurs

$$f_p = -aDD \quad \text{(potential freeze)} \tag{12}$$

$$f = \begin{cases} f_p, & f_p d < SNWL_0 \\ SNWL_0/d, & f_p d > SNWL_0 \end{cases} \tag{13}$$

Actual freeze, f, equals potential freeze, f_p, if enough liquid water is available; otherwise, it is limited to the liquid water that is available. The snowpack at the end of the day is described by

$$SNWL_d = SNWL_0 - f_d \tag{14}$$

$$SNW_d = SNW_0 + pd \tag{15}$$

Equations (4)-(15) were used as alternates for eqs. (1) and (2), but they did not improve the goodness-of-fit (as measured by the root-mean-square error of model runoff volumes) of the model parameter calibrations on the entire Lake Superior lumped data set. This was true for a range of values of the threshold quality, x. Therefore, eqs. (1) and (2) were used in all subsequent model applications, and refreezing and threshold runoff quality of the snowpack were not considered further.

Appendix B.--MODEL APPLICATION PROGRAMS (WATERS AND MMWAT)

B.l Instructions for Model Application Programs

Appendices B-E illustrate the use of the Large Basin Runoff Model for basin outflow simulation. This appendix contains instructions on program use and requirements; it also contains source code listings (ANSI Ver. X3.9-1966 FORTRAN) for two versions of the model. The first, WATERS, uses daily meteorological data and allows the user to specify the mass-balance computation interval, which is then fixed throughout the application. The second, MMWAT, uses monthly meteorological data; the mass-balance interval automatically varies between 28-31 days, depending on the month and year. Appendix C contains example input files of daily and monthly hydrometeorological data (the files called DATA and MDATA, respectively). Appendix D contains example input parameter files (the files called PARM and MPARM) for use with WATERS and MMWAT, respectively. Appendix E contains example output files (SUMARY AND MSUM) resulting from the application of WATERS and MMWAT, respectively; they contain a statistical summary of the simulation, actual and model flow volumes for each computation interval, and the equivalent depth of water over the basin in each of the model's storages at the end of each computation interval.

B.l.l Comments on Source Code

The following comments apply to both source code listings in this appendix (WATERS and MMWAT). No changes to the source code are required for application to the basins of Lakes Superior. Michigan, or Ontario. Lines 00260-00265 describe dimension requirements for an array defined in line 00190. Line 00175 creates arrays for the January through December average midmonth cloudless day insolation (10 langleys/d), which are specified in lines 00444-00450 for applications to Lake Ontario (by using insolation at Ithaca, N.Y., and Toronto, Ont.), Lake Superior (by using insolation at Sault Ste. Marie, Mich.), and Lake Michigan (by using insolation at Madison, Wis.), respectively. The appropriate insolation array is chosen in lines 00456-00469 based on the parameter input file heading. Use of the model for other areas hence requires modification of these program elements to agree with the intended application. Also, if evapotranspiration from the groundwater zone or evaporation from surface storages is considered to be important. lines 00510 and 00520, respectively, may be changed. Subroutine OUTFLOW is identical to that in the calibration program (the program CALIB in appendix F) and is omitted here for brevity. Subroutine LENGTH in WATERS is identical to that in CALIB (appendix F). Subroutine LENGTH in MMWAT is identical to that in MMCAL (appendix F).

B.1.2 Model using Daily Meteorological Data (WATERS)

The simulation program WATERS requires two input files, one containing calibrated parameter values and other application-specific information (the file called PARM) and one containing daily meteorological data (the file called DATA).

B.1.2.1 Input Parameter File (PARM). The final updated parameter file from the calibration program (in appendix G) could be used without modification as input to the simulation program (WATERS), but it contains unnecessary information. Hence, PARM is given in appendix D to show the essential information required. The first line is a header indicating the specific lake and basin application; the first four characters are used in selecting the proper insolation array within WATERS. The second line is the watershed area in square meters. Line 3 defines the number of days to be used to initialize the model storages prior to actual simulation with respect to the starting date specified on the next line. Lines 4 and 5 indicate the first and last dates (DDMMYYYY), respectively, of that portion of the data set to be used in simulation including the initialization period. The sixth line is the mass-balance computation interval. Lines 7-15 provide parameter values in this order: T_b, a, α_{per}, β_{eu}, α_{int}, α_{dp}, β_{el}, α_{gw}, α_{sf}.

B.1.2.2 Input Data File (DATA). A partial listing of DATA is given in appendix C: it contains the date, minimum daily air temperature, maximum daily air temperature, daily precipitation volume over the watershed, and daily basin outflow volume from the watershed, each in the units indicated in the file. The first four lines are header information skipped over by the program. Missing data are denoted by "-9999." and are subsequently filled in by the model, which uses the value for the previous day. However, temperature and precipitation data must be present (no -9999. values) for the starting simulation date within the data set. Observed flows contained in DATA are not required for simulation of flows, but are required for proper computation of some summary statistics (e.g., mean actual flow, correlation between actual and model flows, root-mean-square error between actual and model flows). Missing outflow data are not filled in by the model, but are simply unused in the computation of these statistics.

B.1.3 Model Using Monthly Meteorological Data (MMWAT)

The simulation program MMWAT requires two input files, one containing calibrated parameters and other application-specific information (the file called MPARM) and one containing monthly meteorological data (MDATA).

B.1.3.1 Input Parameter File (MPARM). MPARM is given in appendix D; it is different from PARM in only three respects. 1) Line 3 defines the number of months to be used to initialize the model storages prior to actual simulation, with respect to the starting date specified on the next line. 2) Lines 4 and 5 still indicate the first and last dates, respectively, of that portion of the data set to be used in simulation, including the initialization period; the format, however, is MMYYYY. 3) The mass-balance computation interval (the 6th line in PARM) is eliminated, since the monthly simulation program automatically varies the mass-balance interval based on the specific month.

B.1.3.2 Input Data File (MDATA). A complete listing of MDATA is given in appendix C; it contains the date (month and year), number of days in the specific month, average monthly sir temperature, monthly precipitation volume over the watershed, and monthly basin outflow volume from the watershed, each in the units indicated in the file. The first four lines are header information skipped over by the program.

There should be no missing temperature or precipitation data. Missing data for flow is denoted by "-9999." Observed flows contained in MDATA are not required for flow simulation, but are required for proper computation of some summary statistics (e.g., mean actual flow, correlation between actual and model flows, root-mean-square error between actual and model flows). Missing outflow data are not filled in by the model, but are simply unused in the computation of these statistics.

B.2 Source Code for Simulation Program Using Daily Data (WATERS)

```
      PROGRAM WATERS(DATA,TAPE5=DATA,OUTPUT,TAPE6=OUTPUT,
     +                PARM,TAPE4=PARM,SUMARY,TAPE7=SUMARY)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
      DIMENSION ONTI(12),ONTT(12),SUP(12),MICH(12)
      DIMENSION R(14),INDPM(13)
      DIMENSION PARM(9),DATA(9,4748),INAME(8)
      DIMENSION IERR(6)
      DATA IERR/6*0/
      DATA INDPM/0,31,59,90,120,151,181,212,243,273,304,334,366/
CC*****
CC***** PROGRAM FOR INTERACTIVE INVESTIGATION OF MODEL
CC*****
CC          NOTE -- THE ARRAY 'DATA' SHOULD BE DIMENSIONED AS:
CC                  DATA(9,NUMBER OF DAYS IN DATA SET)
CC*****
CC AREA    = WATERSHED AREA, SQ. M.
CC FLOW    = ACTUAL BASIN OUTFLOW VOLUME, CDR. M.
CC ID      = CALENDAR DAY OF THE YEAR
CC IFDMR = FIRST DATE FOR MODEL RUN (DDMMYYYY)
CC ILDMR = LAST DATE FOR MODEL RUN (DDMMYYYY)
CC IM      = CALENDAR MONTH OF THE YEAR
CC INDPGOD= NUMBER OF DAYS PER GROUP OF DAYS. DAYS
CC INODAYS= NUMBER OF DAYS TO BE CONSIDERED IN DATA SET, DAYS
CC IY      = CALENDAR YEAR
CC PRECIP = DAILY PRECIPITATION VOLUME (LIQUID EQUIVALENT), CDR. M.
CC R       = AVERAGE MID-MONTH CLOUDLESS-DAY INSOLATION, LANGLEYS/DAY
CC           (INPUT IN "NITS OF 10*LANGLEYS/DAY)
CC RR      = DAILY SURFACE INSOLATION. CAL.
CC SNW     = SNOWPACK VOLUME (LIQUID EQUIVALENT). CUB. M.
CC TA      = AVERAGE DAILY AIR TEMPERATURE, DEG. C.
CC TMAX    = MAXIMUM DAILY AIR TEMPERATURE, DEG. C.
CC TMIN    = MINIMUM DAILY AIR TEMPERATURE, DEG. C.
CC*****
CC*****
CC***** INPUT CONSTANTS
CC*****
      DATA ONTI/20.,33.,46.,59.,69.,74.,70.,62.,51.,38.,24.,18./
      DATA ONTT/20.,31.,46.,60.,70.,74.,71.,61.,48.,34.,22.,18./
      DATA SUP/19.,33.,49.,64.,77.,79.,77.,67.,51.,36.,20.,15./
      DATA MICH/22.,34.,48.,62.,70.,73.,70.,61.,49.,36.,24.,19./
      REWIND 4
      READ (4,2000) ILAKE
 2000 FORMAT(A4)
```

```
      DO 45 I=1,12
      IF(ILAKE.EQ.4HIONT) R(I)=ONTI(I)
      IF(ILAKE.EQ.4HTONT) R(I)=ONTT(I)
      IF(ILAKE.EQ.4HSUPE) R(I)=SUP(I)
      IF(ILAKE.EQ.4HMICH) R(I)=MICH(I)
   45 CONTINUE
CC*****
CC         NOTE -- SYSTEM SPECIFIC PROCEDURE SUPPLIES ZERO
CC                 WHEN EXPONENTIAL UNDERFLOW OCCURS
CC*****
      CALL SYSTEMC(115,IERR)
CC*****
      EPSILON=1.E-7
      DPSILON=1.E-200
      GPSILON=1.E-3
      ALPGEV=0.
      ALPSEV=0.
      R(14)=R(1)*10.
      DO 33 IXY=1, 12
   33 R(14-IXY)=R(13-IXY)*10.
      R(1)=R(13)
      READ (4,559)AREA
      READ(4,560)ISTART
  560 FORMAT(I8)
      READ(4,560)IFDMR
      READ(4,560)ILDMR
      READ(4.560)INDPGOD
      CALL LENGTH(IFDMR,ILDMR,INODAYS)
      DAY=FLOAT(INDPGOD)
      IIST=ISTART/INDPGOD
      USZC    = AREA*0.02
      DO 36 I=1,9
   36 READ(4,557) PARM(I)
  557 FORMAT(E10.3E2)
      REWIND 4
      TBASE  = PARM(1)
      ALBEDS = PARM(2)
      ALPPER = PARM(3)
      ALPUEV = PARM(4)
      ALPINT = PARM(5)
      ALPDPR = PARM(6)
      ALPLEV = PARM(7)
      ALPGW  = PARM(8)
      ALPSF  = PARM(9)
      REWIND 5
      SNW=0.
      IKNTR=0
      IKNTRF=0
      TIME =  0.
      AVGTA =  0.
      AVGPR = 0.
      AVGF =  0.
      AVGHPLE= 0.
      AVGNS = 0.
```

```
      AVGRR = 0.
      READ(5,1000)INAME
      READ(5,1000)
      READ(5,1000)
      READ(5,1000)
 1000 FORMAT(8A10)
CC*****
CC***** FOR PROPER DATA PREPARATION, THE FIRST
CC***** LINE OF DATA MUST NOT CONTAIN -9999.
CC***** FOR ANY VARIABLE
CC*****
   15 READ(5,1010) ID,IM,IY,TMIN,TMAX,PRECIP,FLOW
      IF(ID*1000000+IM*10000+IY.NE.IFDMR)GOTO 15
      IF(TMIN.LT.-900..OR.TMAX.LT.-900..OR.PRECIP
     +   .LT.-900.)GOTO 9999
      BACKSPACE 5
CC*****
CC***** DAILY LOOP -DATA PREPERATION (BEGINNING)
CC*****
      DO 300 I=1,INODAYS
CC*****
CC*****          INPUT AND PILL IN DAILY DATA
CC*****
 1010 READ(5,1010) ID,IM,IY,NTMIN,NTMAX,NPRECIP,FLOW
      FORMAT(1X,I3,I3,I5,5X,2F10.2,2F20.0)
      GOTO TMIN.GT.NTMAX.OR.NTMIN.LT.-900..OR.NTMAX.LT.-900.) GOTO 920
  920 NTMIN=TMIN
      NTMAX=TMAX
  921 TMIN=NTMIN
      TMAX=NTMAX
      IF(NPRECIP.LT.-900.) NPRECIP=PRECIP
      PRECIP=NPRECIP
CC*****
CC*****          COMPUTE DAILY INSOLATION
CC*****
      X=(TMAX-TMIN)/15.
      X=AMIN1(X,1.0)
      IF(ID.GT.15) GOTO 203
      IF(IM.EQ.1) GOTO 200
      II=INDPM(IM)-INDPM(IM-1)
      IF(II.NE.28) GOTO 201
      IF(INT((FLOAT(IY)+.5)/4.)*4.NE.IY) GOTO 201
      II=29
      GOTO 201
  200 II=31
  201 NDYS=FLOAT(II)
      NDY=NDYS-15.+FLOAT(ID)
      RR=(R(IM+1)-R(IM))/NDYS*NDY+R(IM)
      GOTO 204
  203 II=INDPM(IM+1)-INDPM(IM)
      IF(II.NE.28) GOTO 202
      IF(INT((FLOAT(IY)+.5)/4.)*4.NE.IY) GOTO 202
      II=29
```

```
  202 NDYS=FLOAT(II)
      NDY=FLOAT(ID)-15.
      RR=(R(IM+2)-R(IM+1))/NDYS*NDY+R(IM+1)
  204 RR=RR*(0.355+0.68*X)*10000.*AREA
CC*****
CC*****       HEAT BALANCE
CC*****
      TA=(TMIN+TMAX)/2.
      MELT=0.
      IF(TA.LE.0.)GOTO 903
      IF(SNW.LT.1.)GOTO 904
      IF(TMIN.LT.0.)GOTO 950
      DD=TA
      GOTO 951
  950 DD=TMAX**2/(TMAX-TMIN)/2.
  951 MELT=ALBEDS*DD
      IF(MELT.LE.SNW)GOTO 904
      MELT=SNW
  904 SNW=SNW-MELT
      NS=PRECIP+MELT
      GOTO 905
  903 SNW=SNW+PRECIP
      NS=0.
  905 DATA(1,I)=NS
      DATA(2,I)=TA
      DATA(3,I)=FLOW
      DATA(5,I)=SNW
      IF(I.LE.ISTART)GOTO 300
      AVGTA=AVGTA+TA
      AVGPR=AVGPR+PRECIP
      IF(FLOW.LT.-900)GOTO 620
      AVGF=AVGF+FLOW
      IKNTRF=IKNTRF+1
  620 AVGNS=AVGNS+NS
      AVGRR=AVGRR+RR-MELT*1000000.*79.7
      IKNTR=IKNTR+1
  300 CONTINUE
CC*****
CC***** DAILY LOOP -DATA PREPARATION (END)
CC*****
CC*****
CC***** SUMMARY INFORMATION
CC*****
      FI=IKNTR
      AVGTA=AVGTA/FI
      AVGPR=AVGPR/FI
      AVGF=AVGF/FLOAT(IKNTRF)
      AVGNS=AVGNS/FI
      AVGEVP=AVGNS-AVGF
      AVGHPLE=0.
      DO 910 I=1,INODAYS
      HPLSE=EXP(DATA(2,I)/TBASE)
      DATA(4,I)=HPLSE
      IF(I.LE.ISTART)GOTO 910
```

```
      AVGHPLE=AVGHPLE+HPLSE
  910 CONTINUE
      CONS=AVGRR/AVGHPLE
      AVGHPLE=0.
      DO 911 I=1,INODAYS
      HPLSE=DATA(4,I)/(596.-.52*DATA(2,I))/1000000.*CONS
      IF(I.LE.ISTART)GOTO 911
      AVGHPLE=AVGHPLE+HPLSE
  911 DATA(4,I)=HPLSE
      AVGHPLE=AVGHPLE/FI
      AVGEVPP=AVGHPLE-AVGEVP
CC*****
CC***** CONVERT TO GROUPS OF DAYS INPUTS
CC*****
      VAR=0.
      MEAN=0.
      NS=0.
      HPLSE=0.
      FLOW=0.
      II=0
      III=0
      INMP=0
      INVD=0
      DO 400 I=1,INODAYS
      NS=NS+DATA(1,I)
      HPLSE=HPLSE+DATA(4,I)
      IF(DATA(3,I).LT.-900.)GOTO 621
      FLOW=FLOW+DATA(3,I)
      INVD=INVD+1
  621 II=II+1
      IF(II.NE.INDPGOD)GOTO 400
      III=III+1
      DATA(1,III)=NS
      DATA(4,III)=HPLSE
      IF(INVD.LT.INDPGOD)GOTO 622
      FLOW=FLOW*II/INVD
      GOTO 623
  622 FLOW=-9999.
  623 DATA(3,III)=FLOW
      DATA(5,III)=DATA(5,I)/AREA*100.
      IF(III.LE.IIST)GOTO 710
      IF(FLOW.LT.-900.)GOTO 710
      VAR=VAR+FLOW**2
      MEAN=MEAN+FLOW
      INMP=INMP+1
  710 NS=0.
      HPLSE=0.
      FLOW=0.
      11-o.
      INVD=0
  400 CONTINUE
      FI=FLOAT(INMP)
      VAR=VAR/FI
      MEAN=MEAN/FI
```

```
      VAR=VAR-MEAN**2
CC*****
CC***** INPUT INITIAL VARIABLE VALUES
CC*****
      USZM=.00698*AREA/100.
      LSZM=.03335*AREA/100.
      GZM=0.00000*AREA/100.
      SS=.00931*AREA/100.
CC*****
CC***** INITIALIZE
CC*****
      AVGFM = 0.
      "ARM-0.
      PROD-0.
      AVGSSZ = 0.
      AVGUSZ = 0.
      AVGLSZ = 0.
      AVGGZ = 0.
      AVGEVM = 0.
      SSQERR = 0.
CC*****
CC***** DAILY LOOP (BEGINNING)
CC*****
      DO 100 I=1,III
CC*****
CC*****       INPUT PREPARED DATA
CC*****
      NS     = DATA(1,I)
      HPLSE=DATA(4,I)
      FLOW   = DATA(3,I)
CC*****
CC*****       MASS BALANCE
CC*****
      CALL OUTFLOW(NS)
CC*****
      DATA(2,I)=NS
      DATA(6,I)=USZM/AREA*100.
      DATA(7,I)=LSZM/AREA*100.
      DATA(8,I)=GZM/AREA*100.
      DATA(9,I)=SS/AREA*100.
      IF(I.LE.IIST)GOTO 100
      IF(FLOW.LT.-900.)GOTO 625
      AVGFM=AVGFM+NS
      VARM=VARM+NS**2
      PROD=PROD+FLOW*NS
      SSQERR=SSQERR+(FLOW-NS)**2
  625 AVGSSZ=AVGSSZ+SS
      AVGUSZ=AVGUSZ+USZMAVG
      AVGLSZ=AVGLSZ+LSZMAVG
      AVGGZ=AVGGZ+GZM
      AVGEVM=AVGEVM+EVAP
  100 CONTINUE
CC*****
CC***** DAILY LOOP (END)
```

```
CC*****
CC*****
CC*****
CC***** SUMMARY INFORMATION
CC*****
      AVGFM=AVGFM/FI
      VARM=VARM/FI
      VARM=VARM-AVGFM**2
      PROD=PROD/FI
      EXVA=(PROD-MEAN*AVGFM)**2/VAR/VARM
      SSQERR=SSQERR/FI
      FI=FLOAT(III-IIST)
      AVGSSZ=AVGSSZ/FI
      AVGUSZ=AVGUSZ/FI
      AVGLSZ=AVGLSZ/FI
      AVGGZ=AVGGZ/FI
      AVGEVM=AVGEVM/FI
      AVGPR=AVGPR/AREA*100.
      AVGF=AVGF/AREA*100.
      AVGHPLE=AVGHPLE/AREA*100.
      AVGNS=AVGNS/AREA*100.
      AVGEVP=AVGEVP/AREA*100.
      AVGEVPP=AVGEVPP/AREA*100.
  559 FORMAT(6E13.6E2)
      MEAN=MEAN/AREA*100.
      VAR=SQRT(VAR)/AREA*100.
      AVGFM=AVGFM/AREA*100.
      AVGEVM=AVGEVM/AREA*100.
      AVGSSZ=AVGSSZ/AREA*100.
      AVGUSZ=AVGUSZ/AREA*100.
      AVGLSZ=AVGLSZ/AREA*100.
      AVGGZ=AVGGZ/AREA*100.
      SSQERR=SQRT(SSQERR)/AREA*100.
      EXVA=SQRT(EXVA)
      REWIND 7
      WRITE(7,1000) INAME
      WRITE(7,1020) ISTART,INODAYS,INDPGOD
 1020 FORMAT(/,8HFROM DAY,I6,7H TO DAY,I6,3H IN,I3,11H-DAY GROUPS,/)
      WRITE(7,1030)
 1030 FORMAT(52H     CONSTANT        ALBEDS      TBASE(C)      AREA(M2))
      WRITE(7,559) CONS,ALBEDS,TBASE,AREA
      WRITE(7,1040) AVGTA,AVGPR,AVGF,AVGHPLE,AVGNS,AVGEVP,AVGEVPP
 1040 FORMAT(/,14HDAILY AVERAGES,
+          /,37H                  TEMPERATURE (C):,E13.6E2,
+          /,37H              PRECIPITATION (CM.):,E13.6E2,
+          /,37H                       FLOW (CM.):,E13.6E2,
+          /,37H      HEAT LOSS. WATER EQU. (CM.):,E13.6E2,
+          /,37H                 NET SUPPLY (CM.):,E13.6E2,
+          /,37H         EVAPOTRANSPIRATION (CM.):,E13.6E2,
+          /,37H    POT. EVAPOTRANSPIRATION (CM.):,E13.6E2)
      WRITE(7,1050)
 1050 FORMAT(/,39H     USZC(M3)  ALPPER(D-1)  ALPUEV(M-3),
+            26H  ALPDPR(D-1)  ALPINT(D-1))
      WRITE(7,559) USZC,ALPPER,ALPUEV,ALPDPR,ALPINT
```

```
      WRITE(7,1060)
 1060 FORMAT(/,39H ALPLEV(M-3)   ALPGW(D-1)   ALPGEV(M-3),
                26H   ALPSF(D-1)   ALPSEV(M-3))
      WRITE(7,559) ALPLEV,ALPGW,ALPGEV,ALPSF,ALPSEV
      YaITE(7.1070) INDPGOD
 1070 FORMAT(/,I3,15H-DAY STATISTICS)
      WRITE(7,1080) MEAN,VAR,
                          AVGFM.AVGEVM.AVGSSZ,AVGUSZ,AVGLSZ,AVGGZ,SSQERR,EXVA
 1080 FORMAT( 37H                         FLOW MEAN (CM.):,E13.6E2,
              1.37"                     FLOW STD. DEV. (CM.):,E13.6E2,
              //,37H        MODEL 1             MEAN (CM.):.E13.6E2.
              /,37H            EVAPOTRANSPIRATION (CM.):,E13.6E2,
              /,37H                        MEAN SS (CM.):,E13.6E2,
              /,37H                      MEAN USZM (CM.):,E13.6E2,
              /,37H                      MEAN LSZM (CM.):,E13.6E2,
              /,37H                       MEAN GZM (CM.):,E13.6E2,
              1.37"                          RMSE (CM.):,E13.6E2,
              /,37H          COEFFICIENT OF CORRELATION:,E13.6E2,/)
      WRITE(7,1090) INDPGOD,INDPGOD
 1090 FORMAT(45HFLOW RATES AND NET SUPPLY IN CUBIC METERS PER,I3,
                46H DAYS. STORAGES IN CENTMETERS OVER THE BASIN ,
                2HON,I3,6HTH DAY,
                /,51H ACTUAL  FLOW   MODEL FLOW     NET SUPPLY    USZM     ,
                53H     LSZM          GZM           SS            SNOW WATER)
      IIST=IIST+1
      DO 750 I=IIST,III
  750 WRITE(7,1100) DATA(3,I),DATA(2,I),DATA(1,I),DATA(6,I),DATA(7,I),
                          DATA(8,I),DATA(9,I),DATA(5,I)
 1100 FORMAT(8E13.6E2)
      REWIND 7
      REWIND 5
      GOTO 10
 9999 YRITE(7.9000)
 9000 FORMAT(32HWARNING: FIRST LINE OF DATA MUST,
              2% NOT CONTAIN -9999. VALUE)
   10 STOP
      EN"
      SUBROUTINE OUTFLOW (NS)
```

(SEE LISTING FOR CALIB)

```
      SUBROUTINE LENGTH(IFDP,ILDP,INODAYS)
```

(SEE LISTING FOR CALIB)

B.3 Source Code for Simulation Program Using Monthly Data (MMWAT)

```
      PROGRAM MMWAT(MDATA,TAPE5=MDATA,OUTPUT,TAPE6=OUTPUT,
+                   MPARM,TAPE4=MPARM,MSUM,TAPE7=MSUM)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
      DIMENSION ONTI(12),ONTT(12),SUP(12),MICH(12)
      DIMENSION R(14),INDPM(13)
      DIMENSION PARM(9),DATA(10,109),INAME(8)
      DIMENSION IERR(6)
      DATA IERR/6*0/
CC*****
CC***** MONTHLY MODEL FOR MONTHLY DATA
CC***** PROGRAM FOR INTERACTIVE INVESTIGATION OF MODEL
CC*****
CC          NOTE -- MONTHLY DATA SET SHOULD BE COMPLETE
CC                  (NO -9999. VALUES) FOR TEMPERATURE AND
CC                  PRECIPITATION.  FLOW DATA MAY HAVE
CC                  MISSING (-9999.) VALUES.
CC
CC                  THE ARRAY 'DATA' SHOULD SE DIMENSIONED AS:
CC                  DATA(10,NUMBER OF MONTHS IN DATA SET)
CC*****
CC  AREA   = WATERSHED AREA, SQ. M.
CC  FLOW   = ACTUAL BASIN OUTFLOW VOLUME, CUB. M.
CC IFDMR = FIRST MONT" FOR MODEL RUN (MMYYYY)
CC  ILDMR  = LAST MONT" FOR MODEL RUN (MMYYYY)
CC  IM     = CALENDAR MONTH OF THE YEAR
CC INDIM= NUMBER OF DAYS IN THE CURRENT MONTH
CC INODAYS= NUMBER OF MONTHS TO SE CONSIDERED IN DATA SET
CC  IY     = CALENDAR YEAR
CC PRECIP = MONTHLY PRECIPITATION VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  R      = AVERAGE MID-MONTH CLOUDED INSOLATION, LANGLEYS/DAY
CC           (INPUT IN "NITS OF 10*LANGLEYS/DAY)
CC  RR     = MONTHLY SURFACE INSOLATION. CAL.
CC  SW     = SNOWPACK VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  TA     = AVERAGE MONTHLY AIR TEMPERATURE, DEG. C.
CC*****
CC*****
CC***** INPUT CONSTANTS
CC*****
      DATA ONTI/20.,33.,46.,59.,69.,74.,70.,62.,51.,38.,24.,18./
      DATA ONTT/20.,31.,46.,60.,70.,74.,71.,61.,48.,34.,22.,18./
      DATA SUP/19.,33.,49.,64.,77.,79.,77.,67.,51.,36.,20.,15./
      DATA MICH/22.,34.,48.,62.,70.,73.,70.,61.,49.,36.,24.,19./
      REWIND 4
```

```
      READ (4,2000) ILAKE
 2000 FORMAT(A4)
      DO 45 I=1,12
      IF(ILAKE.EQ.4HIONT) R(I)=ONTI(I)
      IF(ILAKE.EQ.4HTONT) R(I)=ONTT(I)
      IF(ILAKE.EQ.4HSUPE) R(I)-SOP(I)
      IF(ILAKE.EQ.4HMICH) R(I)=MICH(I)
   45 CONTINUE
C*****
C          NOTE -- SYSTEM SPECIFIC PROCEDURE SUPPLIES ZERO
C                  WHEN EXPONENTIAL UNDERFLOW OCCURS
C*****
      CALL SYSTEMC(115,IERR)
C*****
      EPSILON=1.e-7
      DPSILON=1.E-200
      GPSILON=1.E-3
      ALPGEV=0.
      ALPSEV=0.
      DO 33 IXY=1,12
   33 R(IXY)=R(IXY)*10.
      REM (4,559)AREA
      READ(4,560)ISTART
  560 FORMAT(I8)
      REM (4,560)IFDMR
      READ(4,560)ILDMR
      CALL LENGTH(IFDMR,ILDMR,INODAYS)
      IIST=ISTART
      III=INODAYS
      USZC   = AREA*0.02
      DO 36 I-1.9
   36 READ(4,557) PARM(I)
  557 FORMAT(E10.3E2)
      REWIND 4
      TBASE  = PARM(1)
      ALBEDS = PARM(2)
      ALPPER = PARM(3)
      ALPUEV = PARM(4)
      ALPINT = PARM(5)
      ALPDPR = PARM(6)
      ALPLEV = PARM(7)
      ALPGW  = PARM(8)
      ALPSF  = PARM(9)
      REWIND 5
      SNW=0.
      IKNTR=0
      IKNTRF=0
      TIME =  0.
      AVGTA =  0.
      AVGPR =  0.
      AVGF  =  0.
      AVGHPLE= 0.
      AVGNS =  0.
      AVGRR =  0.
```

```
      VAR   = 0.
      READ(5,1000)INAME
      READ(5,1000)
      READ (5.1000)
      READ(5,1000)
 1000 FORMAT(8A10)
   15 READ(5,1010)IM,IY,INDIM,TA,PRECIP,FLOW
      IF(IM*10000+IY.NE.IFDMR)GOTO 15
      BACKSPACE 5
C*****
C***** MONTHLY LOOP -DATA PREPERATION (BEGINNING)
C*****
      DO 300 I-1,INODAYS
C*****
C*****       INPUT AND FILL IN MONTHLY DATA
C*****
      READ(5,1010) IM,IY,INDIM,TA,PRECIP,FLOW
 1010 FORMAT(1X,I3,I5,2X,I3,5X,F10.2,2F20.0)
C*****
C*****       COMPUTE MONTHLY INSOLATION
C*****
      RR=R(IM)*FLOAT(INDIM)*10000.*AREA
C*****
C*****       HEAT  BALANCE
C*****
      MELT-O.
      IF(TA.LE.0.)GOTO 903
      IF(SNW.LT.1.)GOTO 904
      DD=TA*FLOAT(INDIM)
  951 MELT=ALBEDS*DD
      IF(MELT.LE.SNW)GOTO 904
      MELT=SNW
  904 SNW=SNW-MELT
      NS=PRECIP+MELT
      GOTO 905
  903 SNW=SNW+PRECIP
      NS=0.
  905 DATA(1,I)=NS
      DATA(10,I)=FLOAT(INDIM)
      DATA(2,I)=TA
      DATA(3,I)=FLOW
      DATA(5,I)=SNW/AREA*100.
      IF(I.LE.ISTART)GOTO 300
      AVGTA=AVGTA+TA
      AVGPR=AVGPR+PRECIP
      IF(FLOW.LT.-900.)GOTO 620
      AVGF=AVGF+FLOW
      VAR=VAR+FLOW**2
      IKNTRF=IKNTRF+1
  620 AVGNS=AVGNS+NS
      AVGRR=AVGRR+RR-MELT*1000000.*79.7
      IKNTR=IKNTR+1
  300 CONTINUE
C*****
```

```
CC***** MONTHLY LOOP -DATA PREPARATION (END)
CC*****
CC*****
CC***** SUMMARY INFORMATION
CC*****
      FI=IKNTR
      AVGTA=AVGTA/FI
      AVGPR=AVGPR/FI
      AVGF=AVGF/FLOAT(IKNTRF)
      VAR=VAR/FLOAT(IKNTRF)-AVGF**2
      MEAN=AVGF
      AVGNS=AVGNS/FI
      AVGEVP=AVGNS-AVGF
      AVGHPLE=0.
      DO 910 I=1,INODAYS
      HPLSE=EXP(DATA(2,I)/TBASE)
      DATA(4,I)=HPLSE
      IF(I.LE.ISTART)GOTO 910
      AVGHPLE=AVGHPLE+HPLSE
  910 CONTINUE
      CONS=AVGRR/AVGHPLE
      AVGHPLE=0.
      DO 911 I=1,INODAYS
      HPLSE=DATA(4,I)/(596.-.52*DATA(2,I))/1000000.*CONS
      IF(I.LE.ISTART)GOTO 911
      AVGHPLE=AVGHPLE+HPLSE
  911 DATA(4,I)=HPLSE
      AVGHPLE=AVGHPLE/FI
      AVGEVPP=AVGHPLE-AVGEVP
CC*****
CC***** INPUT INITIAL VARIABLE VALUES
CC*****
      USZM=.00698*AREA/100.
      LSZM=.03335*AREA/100.
      GZM=0.00000*AREA/100.
      SS=.00931*AREA/100.
CC*****
CC***** INITIALIZE
CC*****
      AVGFM = 0.
      "ARM-0.
      PROD=0.
      AVGSSZ = 0.
      AVGUSZ = 0.
      AVGLSZ = 0.
      AVGGZ  = 0.
      AVGEVM = 0.
      SSQERR = 0.
CC*****
CC***** MONTHLY LOOP (BEGINNING)
CC*****
      DO 100 I=1,III
CC*****
CC*****       INPUT PREPARED DATA
```

```
CC*****
      NS     = DATA(1,I)
      HPLSE=DATA(4,I)
      FLOW  =  DATA(3,I)
      DAY=DATA(10,I)
CC*****
CC*****       MASS BALANCE
CC*****
      CALL OUTFLOW(NS)
CC*****
      DATA(2,I)=NS
      DATA(6,I)=USZM/AREA*100.
      DATA(7,I)=LSZM/AREA*100.
      DATA(8,I)=GZM/AREA*100.
      DATA(9,I)=SS/AREA*100.
      IF(I.LE.IIST)GOTO 100
      IF(FLOW.LT.-900.)GOTO 625
      AVGFM=AVGFM+NS
      VARM=VARM+NS**2
      PROD=PROD+FLOW*NS
      SSQERR=SSQERR+(FLOW-NS)**2
  625 AVGSSZ=AVGSSZ+SS
      AVGUSZ=AVGUSZ+USZMAVG
      AVGLSZ=AVGLSZ+LSZMAVG
      AVGGZ=AVGGZ+GZM
      AVGEVM=AVGEVM+EVAP
  100 CONTINUE
CC*****
CC*****  MONTHLY LOOP (END)
CC*****
CC*****
CC*****
CC*****  SUMMARY INFORMATION
CC*****
      FI=FLOAT(IKNTRF)
      AVGFM=AVGFM/FI
      VARM=VARM/FI
      VARM=VARM-AVGFM**2
      PROD=PROD/FI
      EXVA=(PROD-MEAN*AVGFM)**2/VAR/VARM
      SSQERR=SSQERR/FI
      FI=FLOAT(III-IIST)
      AVGSSZ=AVGSSZ/FI
      AVGUSZ=AVGUSZ/FI
      AVGLSZ=AVGLSZ/FI
      AVGGZ=AVGGZ/FI
      AVGEVM=AVGEVM/FI
      AVGPR=AVGPR/AREA*100.
      AVGF=AVGF/AREA*100.
      AVGHPLE=AVGHPLE/AREA*100.
      AVGNS=AVGNS/AREA*100.
      AVGEVP=AVGEVP/AREA*100.
      AVGEVPP=AVGEVPP/AREA*100.
  559 FORMAT(6E13.6E2)
```

```
      MEAN=MEAN/AREA*100.
      VAR=SQRT(VAR)/AREA*100.
      AVGFM=AVGFM/AREA*100.
      AVGEVM=AVGEVM/AREA*100.
      AVGSSZ=AVGSSZ/AREA*100.
      AVGUSZ=AVGUSZ/AREA*100.
      AVGLSZ=AVGLSZ/AREA*100.
      AVGGZ=AVGGZ/AREA*100.
      SSQERR=SQRT(SSQERR)/AREA*100.
      EXVA=SQRT(EXVA)
      REWIND 7
      WRITE(7,1000) INAME
      WRITE(7,1020) IFDMR,ILDMR
 1020 FORMAT(/,19HFROM MONTH AND YEAR,I8,18H TO MONTH AND YEAR,I8,
          2%IN CALENDAR MONTH GROUPS,/)
      WRITE(7,1030)
 1030 FORMAT(52H     CONSTANT       ALB EDS       TBASE(C)       AREA(M2))
      WRITE(7,559) CONS,ALBEDS,TBASE,AREA
      WRITE(7,1040) AVGTA,AVGPR,AVGF,AVGHPLE,AVGNS,AVGEVP,AVGEVPP
 1040 FORMAT(/,23HCALENDAR MONTH AVERAGES,
               /,37H                        TEMPERATURE (C):,E13.6E2,
               /,37H                   PRECIPITATION (CM.):,E13.6E2,
               /,37H                            FLOW (CM.):,E13.6E2,
               /,37H         "RAT LOSS, WATER EQU. (CM.):,E13.6E2,
               /,37H                      NET SUPPLY (CM.):,E13.6E2,
               /,37H              EVAPOTRANSPIRATION (CM.):,E13.6E2,
               /,37H         POT. EVAPOTRANSPIRATION (CM.):,E13.6E2)
      WRITE(7,1050)
 1050 FORMAT(/,39H     USZC(M3)  ALPPER(D-1)  ALPUEV(M-3),
                26H  ALPDPR(D-1)  ALPINT(D-1))
      WRITE(7,559) USZC,ALPPER,ALPUEV,ALPDPR,ALPINT
      WRITE(7,1060)
 1060 FORMAT(/,39H ALPLEV(M-3)    ALPGW(D-1)  ALPGEV(M-3),
                26H   ALPSF(D-1)  ALPSEV(M-3))
      WRITE(7,559) ALPLEV,ALPGW,ALPGEV,ALPSF,ALPSEV
      WRITE(7,1070)
 1070 FORMAT(/,25HCALENDAR MONTH STATISTICS)
      WRITE(7,1080) MEAN,VAR,
                     AVGFM,AVGEVM,AVGSSZ,AVGUSZ,AVGLSZ,AVGGZ,SSQERR,EXVA
 1080 FORMAT(37"                        FLOW MEAN (CM.):,E13.6E2,
               /,37H                    FLOW STD. DEV. (CM.):,E13.6E2,
              //,37H         MODEL 1              MEAN (CM.):,E13.6E2,
               /,37H              EVAPOTRANSPIRATION (CM.):,E13.6E2,
               /,37H                          MEAN SS (CM.):,E13.6E2,
               /,37H                         MEAN USZM (CM.):,E13.6E2,
               /,37H                         MEAN LSZM (CM.):,E13.6E2,
               /,37H                          MEAN GZM (CM.):,E13.6E2,
               /,37H                              RMSE (CM.):,E13.6E2,
               /,37H          COEFFICIENT OF CORRELATION:,E13.6E2,/)
      WRITE(7,1090)
 1090 FORMAT(45HFLOW RATES AND NET SUPPLY IN CUBIC METERS PER
         15H CALENDAR MONTH,10X,39HSTORAGES IN CENTIMETERS OVER THE BASIN ,
                23HON THE END OF THE MONTH,
                /,51H ACTUAL FLOW   MODEL FLOW   NET SUPPLY   USZM     ,
```

```
              53H     LSZM        GZM          SS             SNOW WATER)
        IIST=IIST+1
        DO 750 I=IIST,III
    750 WRITE(7,1100) DATA(3,I),DATA(2,I),DATA(1,I),DATA(6,I),DATA(7,I),
                      DATA(8,I),DATA(9,I),DATA(5,I)
   1100 FORMAT(8E13.6E2)
        REWIND 7
        REWIND 5
        STOP
        END
        SUBROUTINE OUTFLOW (NS)


        (SEE LISTING FOR CALIB)


        SUBROUTINE LENGTH(IFDP,ILDP,INODAYS)


        (SEE LISTING FOR MMCAL)
```

Appendix C.--EXAMPLE INPUT FILES OF HYDROMETEOROLOGICAL DATA (DATA and MDATA)

C.1 Daily Hydrometeorological Data (DATA, partial listing)

COMBINED SUBBASINS: 1111111111111111111111
3318 DAILY RECORDS STARTING 1 12 1969
(1X,I3,I3,I5,5X,2F10.2,2F20.0)

DAY	MONTH	YEAR	TMIN(C)	TMAX(C)	PRECIP(M3/D)	FLOW(M3/D)
1	12	1969	-14.46	.44	8076520.	108116487.
2	12	1969	-8.17	3.18	111788690.	108561833.
3	12	1969	-11.26	-4.34	172579693.	106388330.
4	12	1969	-15.97	-5.23	30244749.	104232792.
5	12	1969	-15.26	-.65	0.	103014651.
6	12	1969	-7.49	.91	148430030.	102788234.
7	12	1969	-4.47	-.21	923058231.	101809911.
8	12	1969	-5.23	.01	1199378354.	101726518.
9	12	1969	-5.96	-1.73	771683365.	104755007.
10	12	1969	-8.64	-2.28	292391647.	104007556.
11	12	1969	-11.31	-3.85	34669370.	104815042.
12	12	1969	-10.89	-5.48	171080964.	105704279.
13	12	1969	-11.65	-3.47	359620031.	103790161.
14	12	1969	-11.00	-5.71	226498489.	99250936.
15	12	1969	-14.37	-5.78	70565998.	105579107.
16	12	1969	-18.08	-3.45	77005575.	108490664.
17	12	1969	-7.53	-1.11	212989949.	105518246.
18	12	1969	-7.90	-2.47	219585344.	102042547.
19	12	1969	-12.69	-6.62	125212475.	105712963.
20	12	1969	-16.34	-6.36	370082621.	101384836.
21	12	1969	-16.54	-7.95	158044914.	101007934.
22	12	1969	-26.13	-14.10	59220370.	105667365.
23	12	1969	-26.15	-11.87	57357942.	104628278.
24	12	1969	-24.58	-6.25	424892148.	94943385.
25	12	1969	-10.18	-5.03	302235708.	78546245.
26	12	1969	-10.70	-3.56	218479582.	90275678.
27	12	1969	-15.38	-3.66	3775045.	98069180.
28	12	1969	-13.03	-4.66	293822087.	97063930.
29	12	1969	-12.25	-4.76	217587799.	96759840.
30	12	1969	-16.62	-5.61	33165905.	100596282.
31	12	1969	-16.34	-6.56	30339043.	92148727.
1	1	1970	-17.62	-7.61	119942938.	72890601.
2	1	1970	-18.86	-7.86	274472937.	89804590.
3	1	1970	-18.31	-7.21	193964436.	95916193.
4	1	1970	-20.13	-9.31	521543288.	95263317.
5	1	1970	-24.13	-13.39	50393751.	99352180.
6	1	1970	-24.05	-14.66	15266223.	99849855.
7	1	1970	-26.63	-14.72	120112298.	104905632.
8	1	1970	-21.85	-11.69	202045239.	102138397.
9	1	1970	-19.41	-12.65	86316744.	106238464.
10	1	1970	-23.73	-9.93	58263744.	102702188.
11	1	1970	-19.24	-7.77	658749011.	96155270.
12	1	1970	-18.05	-9.66	145510044.	105319287.
13	1	1970	-28.01	-18.61	48365094.	107218303.

14 1 1970	-29.80	-15.12	215449036.	105858150.
15 1 1970	-20.84	-6.45	662128087.	102004273.
16 1 1970	-20.74	-9.33	292106081.	101474341.
17 1 1970	-28.60	-18.42	25176025.	102899553.
18 1 1970	-30.86	-20.61	33004400.	101612394.
19 1 1970	-33.71	-20.07	21953751.	105505053.
20 1 1970	-32.54	-20.28	38369782.	108704160.
21 1 1970	-31.23	-14.69	118731998.	103892080.
22 1 1970	-26.69	-13.19	224882573.	103208375.
23 1 1970	-29.92	-10.25	65611697.	103222972.
24 1 1970	-18.39	-5.41	146898803.	99498212.
25 1 1970	-12.19	-3.83	6269451.	99449949.
26 1 1970	-12.22	-3.83	419361750.	102402958.
27 1 1970	-14.64	-2.25	148412733.	104685406.
28 1 1970	-8.10	-.76	926471074.	99748869.
29 1 1970	-23.59	-9.71	74064841.	97993970.
30 1 1970	-21.65	-3.89	50003272.	98818238.
31 1 1970	-10.91	-.42	237583106.	93806108.
1 2 1970	-11.14	-.56	441770054.	85454739.
2 2 1970	-29.92	-14.33	71699494.	96685153.
3 2 1970	-36.92	-22.50	47252258.	102955938.
4 2 1970	-33.26	-12.71	228485125.	104106677.
5 2 1970	-19.74	-6.88	261424510.	102444000.
6 2 1970	-18.93	-2.35	105687336.	100906625.
7 2 1970	-14.93	-.99	18487849.	98291565.
8 2 1970	-21.07	-3.56	626233.	93862388.
9 2 1970	-21.86	-3.04	135181132.	97406672.
10 2 1970	-13.27	-4.27	136560130.	99707234.
11 2 1970	-21.94	-10.18	9478574.	103404957.
12 2 1970	-27.18	-16.56	39913007.	99302776.
13 2 1970	-31.01	-17.13	17487412.	102214767.
14 2 1970	-32.88	-12.68	16506746.	98017411.
15 2 1970	-24.26	-12.12	11780599.	93770677.
16 2 1970	-29.97	-8.90	955551356.	96197479.
17 2 1970	-17.40	-5.00	787396589.	97099400.
18 2 1970	-16.93	-7.45	38526086.	99178882.
19 2 1970	-26.57	-11.91	6031728.	98539939.
20 2 1970	-23.52	-8.48	13451181.	100914211.
21 2 1970	-16.85	1.28	2167282.	97326309.
22 2 1970	-12.04	.85	9828727.	85189914.
23 2 1970	-20.02	.42	109182735.	98145321.
24 2 1970	-16.57	-6.26	59125958.	102058989.
25 2 1970	-25.71	-10.89	149009508.	101765055.
26 2 1970	-22.23	-7.53	285028092.	102141920.
27 2 1970	-24.90	-5.66	15277426.	98709747.
28 2 1970	-25.61	-3.59	4334783.	94061505.
1 3 1970	-17.76	-3.55	200671527.	84368835.
2 3 1970	-13.89	-2.35	106298004.	97031677.
3 3 1970	-5.39	1.43	1169796727.	100371706.
4 3 1970	-6.02	.99	256336882.	100316365.
5 3 1970	-17.97	-1.92	303101982.	94844644.
6 3 1970	-13.38	-3.68	88823565.	93751640.
7 3 1970	-21.28	-8.69	27047445.	91403870.
8 3 1970	-21.32	-5.79	15044201.	85968985.

9	3	1970	-22.17	-5.80	12644008.	95453413.
10	3	1970	-24.18	-4.74	1027305.	99362028.
11	3	1970	-19.57	-1.49	394071.	99702755.
12	3	1970	-17.78	-2.14	56708898.	92263343.
13	3	1970	-14.99	-3.70	55023445.	90794718.
14	3	1970	-17.11	-7.14	12104882.	87279478.
15	3	1970	-18.19	-2.57	5150256.	76789437.
16	3	1970	-18.63	2.47	2 12355.	88168736.
17	3	1970	-12.55	4.89	0.	91708408.
18	3	1970	-13.72	6.64	0.	95084925.
19	3	1970	-12.35	8.38	0.	88934126.
20	3	1970	-7.87	7.44	125196556.	92188817.
21	3	1970	-7.78	6.77	8786307.	86757663.
22	3	1970	-8.75	6.51	0.	83018443.
23	3	1970	-8.38	5.82	0.	94631146.
24	3	1970	-7.92	4.72	168982.	97362609.
25	3	1970	-8.20	3.76	703904.	96791513.
26	3	1970	-8.49	.36	231420775.	101918160.
27	3	1970	-15.78	-3.73	308606516.	93525544.
28	3	1970	-22.14	-7.95	19514221.	93451432.
29	3	1970	-24.51	-4.14	201231116.	79135001.
30	3	1970	-12.09	-.15	424283194.	89342592.
31	3	1970	-14.53	.03	16089000.	101801603.
1	4	1970	-16.23	.26	51273726.	98440794.
2	4	1970	-16.84	2.36	396413.	96020032.
3	4	1970	-11.83	2.97	23977426.	97344438.
4	4	1970	-11.34	1.08	141837296.	96828805.
5	4	1970	-10.49	2.09	546158367.	90761285.
6	4	1970	-3.96	4.03	100347573.	95560143.
7	4	1970	-7.61	8.97	318533.	109667946.
8	4	1970	.50	12.44	26266568.	139491337.
9	4	1970	-6.28	1.83	56369534.	178088236.
10	4	1970	-10.85	.62	3413770.	167530675.
11	4	1970	-10.30	2.28	0.	150075044.
12	4	1970	-8.88	4.78	0.	140455845.
13	4	1970	-5.21	6.93	0.	149746179.
14	4	1970	-3.90	7.97	0.	162579761.
15	4	1970	-2.65	9.40	121804427.	172240649.
16	4	1970	-.02	6.27	719857506.	200087451.
17	4	1970	-1.36	4.65	48959065.	222080562.
18	4	1970	-4.30	7.06	626233.	202262127.
19	4	1970	-3.62	6.41	478278196.	174479649.
20	4	1970	-.68	3.47	1525120699.	175402790.
21	4	1970	-.20	4.78	181258718.	181932749.
22	4	1970	-1.32	7.69	905571609.	186986102.
23	4	1970	.17	6.27	794118374.	245644663.
24	4	1970	-.95	9.21	48355356.	250294406.
25	4	1970	-2.02	15.44	0.	263204357.
26	4	1970	.94	17.17	55480781.	296503979.
27	4	1970	2.27	16.37	962250467.	341659692.
28	4	1970	4.73	12.94	479581742.	383654981.
29	4	1970	3.73	19.43	717925366.	381674165.
30	4	1970	5.62	17.28	210230162.	425792664.
1	5	1970	1.29	9.22	985258142.	436889960.

2 5 1970	-1.52	7.03	252247660.	434622416.
3 5 1970	.15	13.20	162784248.	382262964.
4 5 1970	.63	10.66	47381201.	347730920.
5 5 1970	-1.67	7.04	155379638.	330450160.
6 5 1970	-5.88	8.62	29355015.	307358303.
7 5 1970	.87	15.04	191051961.	284689552.
8 5 1970	2.77	13.51	157252875.	274083147.
9 5 1970	2.12	7.56	1357632329.	285462321.
10 5 1970	-.71	4.42	1274333845.	362091041.
11 5 1970	-1.96	6.40	133256699.	351339978.
12 5 1970	-.38	5.55	77963074.	323157405.
13 5 1970	-1.21	11.16	1203041.	299113087.
14 5 1970	-.63	11.42	33140193.	273247388.
15 5 1970	3.38	8.40	1373876743.	272574500.
16 5 1970	1.83	8.63	356640040.	273504572.
17 5 1970	-.21	16.92	5754377.	251637137.
18 5 1970	6.45	23.74	41977810.	241522885.
19 5 1970	4.65	17.70	11913499.	241343495.
20 5 1970	.97	12.79	2909717775.	245281531.
21 5 1970	5.50	14.82	834040130.	337377931.
22 5 1970	3.63	18.00	85386711.	333359065.
23 5 1970	2.47	18.64	8350954.	305885152.
24 5 1970	5.57	14.93	577721318.	284436440.
25 5 1970	4.86	12.96	1555685506.	292928009.
26 5 1970	1.33	7.28	122499765.	306668669.
27 5 1970	-.45	11.17	2 189350.	294272180.
28 5 1970	-.60	14.77	14939945.	275834435.
29 5 1970	5.59	18.07	1538626447.	260470335.
30 5 1970	8.38	20.61	661629087.	269187322.
31 5 1970	8.51	19.62	1738079906.	316795125.
1 6 1970	8.96	14.90	329932442.	356775812.
2 6 1970	4.09	17.53	35414612.	346237689.
3 6 1970	2.24	20.35	0.	314867305.
4 6 1970	7.27	25.15	0.	282164179.
5 6 1970	5.23	24.31	0.	259030951.
6 6 1970	6.77	28.71	403786518.	225837722.
7 6 1970	9.62	24.08	5064809.	206849392.
8 6 1970	6.96	25.95	7969937.	207852299.
9 6 1970	12.84	27.18	774972771.	197430400.
10 6 1970	13.13	22.46	1761752546,	189318551.
11 6 1970	9.03	21.75	402864860.	194059068.
12 6 1970	8.23	20.77	162950138.	195447010.
13 6 1970	5.67	21.43	86974525.	187034456.
14 6 1970	5.54	21.91	66787216.	181298751.
15 6 1970	7.05	22.93	5494743.	170580134.
16 6 1970	10.21	22.47	712451811.	164113576.
17 6 1970	12.16	26.34	790181798.	166602428.
18 6 1970	7.38	17.01	1169587918.	175670663.
19 6 1970	2.19	15.88	25718547.	178670106.
20 6 1970	1.97	18.97	0.	168073589.
21 6 1970	4.15	21.51	16827059.	158283499.
22 6 1970	6.28	23.43	81738618.	153052726.
23 6 1970	8.31	25.30	318051175.	149575355.
24 6 1970	8.44	18.83	95886851.	148893984.

25 6 1970	3.84	16.27	61209029.	145317170.
26 6 1970	6.02	19.39	102934671.	136723900.
27 6 1970	5.12	21.68	16999969.	130921687.
28 6 1970	6.86	22.15	264317945.	118863954.
29 6 1970	12.18	28.48	25807754.	120164492.
30 6 1970	12.44	27.35	1374942434.	122423247.
1 7 1970	13.69	27.42	494290498.	101366919.
2 7 1970	11.54	27.21	102696643.	113293583.
3 7 1970	10.94	22.02	1164890060.	12904423 1.
4 7 1970	9.54	22.20	296959081.	123710477.
5 7 1970	6.95	23.68	48399098.	109128809.
6 7 1970	9.95	25.08	31753850.	126779100.
7 7 1970	12.13	26.24	1584634525.	122638437.
8 7 1970	12.21	23.35	562996460.	136805816.
9 7 1970	8.64	26.73	11272375.	128926946.
10 7 1970	10.86	27.98	27111484.	124368236.
11 7 1970	13.01	27.76	1748051.	117971001.
12 7 1970	12.78	26.03	380240367.	108031468.
13 7 1970	14.81	24.67	524417932.	121916339.
14 7 1970	15.50	25.07	879256446.	127208440.
15 7 1970	13.56	22.15	1222093884.	129618132.
16 7 1970	11.37	25.95	549939387.	128580771.
17 7 1970	12.12	23.14	33250583.	125246710.
18 7 1970	6.21	20.39	454181072.	115619364.
19 7 1970	8.27	17.58	1841628820.	119084098.
20 7 1970	6.25	22.02	20189885.	142670945.
21 7 1970	7.19	24.19	0.	138363088.
22 7 1970	9.46	25.51	0.	132793213.
23 7 1970	11.32	25.97	0.	129311278.
24 7 1970	10.84	24.16	270148611.	130202758.
25 7 1970	14.12	27.75	21150467.	123224917.
26 7 1970	15.27	30.11	117869993.	111104627.
27 7 1970	15.89	27.71	521246398.	117369047.
28 7 1970	12.93	28.28	3309081.	120053559.
29 7 1970	14.32	28.04	595787288.	118687259.
30 7 1970	16.83	27.55	397482394.	119089972.
31 7 1970	14.90	26.10	520595329.	114961792.
1 8 1970	12.52	24.95	48745822.	112940301.
2 8 1970	12.73	22.40	113875546.	102309484.
3 8 1970	8.61	18.74	57209367.	100326439.
4 8 1970	4.63	21.04	0.	104223050.
5 8 1970	9.37	24.62	4119528.	107554893.
6 8 1970	10.31	26.92	130975935.	108115512.
7 8 1970	12.40	27.28	33533622.	106441630.
8 8 1970	13.54	27.68	617512341.	98834814.
9 8 1970	13.61	28.11	0.	89327963.
10 8 1970		28.27	73440427.	95853616.
11 8 1970	14.26	27.95	99978856.	95522388.
12 8 1970	14.12	27.75	180577468.	97944232.
13 8 1970	15.31	29.91	2733175.	95710012.
14 8 1970	16.79	30.07	400660891.	91079342.
15 8 1970	16.16	26.13	759316861.	94860558.
16 8 1970	12.51	21.12	346434985.	90828833.
17 8 1970	8.49	20.86	0.	94318385.

18	8	1970	10.42	25.28	174192853.	91853584.
19	8	1970	14.88	23.26	564052007.	89561949.
20	8	1970	9.71	21.10	284402837.	90238404.
21	8	1970	5.08	20.92	95171523.	92184994.
22	8	1970	9.98	19.33	843774484.	87619657.
23	8	1970	11.83	20.13	173585922.	87404158.
24	8	1970	9.92	22.81	127686126.	87373182.
25	8	1970	9.57	24.85	93648896.	92808489.
26	8	1970	9.53	21.55	96972364.	90272703.
27	8	1970	10.08	20.13	918959849.	90256905.
28	8	1970	8.64	20.98	2064412.	93072072.
29	8	1970	4.00	18.98	439076465.	70909598.
30	8	1970	8.35	17.65	469548009.	73483505.
31	8	1970	2.54	19.61	1572731.	91997190.
1	9	1970	2.93	21.37	39164808.	90429458.
2	9	1970	8.50	19.85	2094468259.	89685082.
3	9	1970	14.10	21.22	1018362617.	92901248.
4	9	1970	12.39	20.04	459438434.	90058176.
5	9	1970	8.26	22.53	1798696.	8302,253.
6	9	1970	11.44	23.99	107846400.	75360275.
7	9	1970	15.66	23.95	947263751.	66374333.
8	9	1970	10.05	22.63	177278448.	8277831,.
9	9	1970	9.58	23.25	1940866112.	98611116.
10	9	,970	7.04	16.66	1456189518.	101403132.
11	9	1970	4.02	16.20	244673457.	107906703.
12	9	1970	4.98	15.26	905603614.	105519393.
13	9	,970	.31	10.76	32357221.	103746613.
14	9	1970	.00	10.30	74844534.	105045830.
15	9	1970	1.55	9.13	954054347.	108576004.
16	9	1970	4.14	13.88	82916742.	109825634.
17	9	1970	5.23	16.43	20665432.	107944414.
18	9	1970	6.72	17.08	9613777.	108236728.
19	9	1970	7.45	22.35	0.	105268500.
20	9	1970	11.76	23.68	1010675300.	100707789.
21	9	1970	13.39	22.03	1312122345.	115590438.
22	9	1970	7.96	16.40	61060310.	130745774.
23	9	1970	3.86	14.74	128288185.	129328122.
24	9	1970	6.69	12.79	844140045.	129669261.
25	9	1970	7.63	12.72	818024224.	132682019.
26	9	1970	5.62	11.99	533429294.	132424583.
27	9	1970	2.28	9.21	60717057.	130057958.
28	9	1970	-1.28	10.02	321140916.	130888197.
29	9	1970	1.74	13.95	272524555.	13123,171.
30	9	1970	2.37	11.94	104633.	130105504.
1	10	1970	2.51	16.16	141844981.	127529937.
2	10	1970	5.09	13.11	409314244.	119972112.
3	10	,970	.66	7.09	317372858.	121848400.
4	10	1970	-.81	10.41	54188425.	120907053.
5	10	1970	.27	17.34	0.	116629620.
6	10	1970	6.64	19.39	141511490.	117718251.
7	10	1970	8.19	16.48	1100867042.	121769047.
8	10	1970	6.39	11.75	2260804634.	137562124.
9	10	1970	6.90	16.76	1594204290.	156824861.
10	10	,970	1.65	10.50	296167556.	165510983.

11 10 1970	-1.23	8.72	459461225.	153127156.
12 10 1970	2.82	12.41	241245251.	161625976.
13 10 1970	3.21	11.61	308709721.	156314195.
14 10 1970	.55	7.67	34270963.	155063352.
15 10 1970	-3.29	4.58	40899722.	146600270.
16 10 1970	-4.09	9.45	5538115.	144267765.
17 10 1970	-1.87	14.76	0.	138685280.
18 10 1970	-1.95	10.72	0.	128468772.
19 10 1970	-4.13	13.13	0.	136451130.
20 10 1970	.57	14.40	7061921.	121293690.
21 10 1970	3.56	12.00	172968565.	122968117.
22 10 1970	3.16	12.32	116847333.	121876805.
23 10 1970	6.80	12.63	95484476.	124860180.
24 10 1970	7.47	11.34	1027435280.	127134442.
25 10 1970	7.62	13.14	247169355.	125088848.
26 10 1970	6.14	11.99	393868356.	128664654.
27 10 1970	6.00	11.31	2222562966.	181616416.
28 10 1970	5.97	10.30	2686008436.	251444726.
29 10 1970	2.60	8.66	748498209.	275700882.
30 10 1970	1.16	9.76	516809563.	262133567.
31 10 1970	2.33	8.91	1304243874.	266187318.
1 11 1970	.93	5.85	213053035.	257715824.
2 11 1970	-.20	6.81	107645495.	249657696.
3 11 1970	-.96	6.09	54938783.	236211197.
4 11 1970	-2.68	7.79	19833877.	225755270.
5 11 1970	-.89	6.63	6975571.	215065027.
6 11 1970	-2.82	7.25	8516767.	202912230.
7 11 1970	-5.55	5.74	916013.	195228561.
8 11 1970	-4.21	3.77	81528654.	184714095.
9 11 1970	.10	5.65	1672615208.	187538535.
10 11 1970	.45	4.90	276671515.	217490911.
11 11 1970	-.87	3.33	940119288.	237895576.
12 11 1970	-5.30	.28	148607233.	241221313.
13 11 1970	-9.19	-3.41	24806198.	227673615.
14 11 1970	-10.44	-3.44	15793027.	210224048.
15 11 1970	-10.66	-.13	12441474.	197760922.
16 11 1970	-3.86	1.43	52006826.	193546389.
17 11 1970	-3.27	.67	103352681.	183673164.
18 11 1970	-2.72	3.44	711628044.	175965084.
19 11 1970	-.48	2.97	363574884.	176583006.
20 11 1970	-1.19	2.00	787332325.	180673867.
21 11 1970	-7.39	-1.42	170929277.	180330913.
22 11 1970	-12.68	-5.44	1438875094.	173972698.
23 11 1970	-12.63	-8.32	285884810.	167062762.
24 11 1970	-15.96	-5.27	338805938.	167583382.
25 11 1970	-11.44	-.89	375375007.	171115058.
26 11 1970	-9.84	-2.84	278577782.	171152979.
27 11 1970	-19.24	-4.69	56876503.	167092601.
28 11 1970	-16.32	.22	149424676.	163772632.
29 11 1970	-10.04	2.06	266503581.	162010785.
30 11 1970	-14.56	1.18	195530574.	160483275.
1 12 1970	-4.18	4.67	1736107159.	170814436.
2 12 1970	-9.80	-1.82	55308943.	195299627.
3 12 1970	-15.28	-6.70	393280336.	203880612.

4	12	1970	-14.32	-4.19	595981734.	190155836.
5	12	1970	-13.62	-4.13	420726633.	179991224.
6	12	1970	-19.21	-11.27	80080619.	173532175.
7	12	1970	-23.14	-4.85	518624544.	170833353.
8	12	1970	-11.74	-3.04	411104892.	164667236.
9	12	1970	-12.54	-5.17	169509869.	165442466.
10	12	1970	-19.03	-8.84	17764287.	161987406.
11	12	1970	-20.62	-6.47	4537348.	160414172.
12	12	1970	-16.45	-2.77	0.	158448191.
13	12	1970	-1 1.87	-3.28	355322263.	153107025.
14	12	1970	-15.83	-8.17	46725517.	153002224.
15	12	1970	-16.35	-3.84	285939045.	151657064.
16	12	1970	-10.50	-1.73	102388489.	152727221.
17	12	1970	-9.33	-3.45	190337322.	145874143.
18	12	1970	-9.11	-2.95	332622206.	146903823.
19	12	1970	-18.50	-10.34	91866770.	144800782.
20	12	1970	-25.16	-15.05	64972405.	139261305.
21	12	1970	-30.22	-15.17	75142698.	139760970.
22	12	1970	-20.38	-9.20	707445270.	138612429.
23	12	1970	-14.79	-6.37	663024960.	136081966.
24	12	1970	-16.54	-7.69	323976136.	125357208.
25	12	1970	-21.18	-13.23	106700486.	105888002.
26	12	1970	-22.69	-9.37	304493868.	122030198.
27	12	1970	-19.66	-10.51	110597178.	129902641.
28	12	1970	-21.04	-10.38	41377426.	131777076.
29	12	1970	-24.60	-9.46	93722488.	132076692.
30	12	1970	-19.26	-5.29	60971648.	129090491.
31	12	1970	-9.11	-3.20	166969702.	126151931.

C.2 Monthly Hydrometeorological Data (MDATA, complete listing)

COMBINED SUBBASINS: 1111111111111111111111
109 MONTHLY RECORDS STARTING 12 1969
(1X,I3,I5,2X,I3,5X,F10.2,2F20.0)

MT"	YEAR	DAYS/M	AVGTEMP(C)	PRECIP(M3/M)	FLOW(M3/M)
12	1969	31	-8.65	7323862639.	3147396941.
1	1970	31	-16.29	6201424206.	3112539339.
2	1970	28	-15.17	3977251909.	2749860251.
3	1970	31	-7.48	3646386125.	2863523614.
4	1970	30	1.66	8199777905.	5876491509.
5	1970	31	7.19	16697269286.	9495577425.
6	1970	30	14.74	9100620696.	5752134095.
7	1970	31	18.47	12679540062.	3807171333.
8	1970	31	17.16	7153823302.	2915227839.
9	1970	30	11.71	15929633031.	3226123019.
10	1970	31	7.25	16945358851.	4735845929.
11	1970	30	-2.53	9159140140.	5882083415.
12	1970	31	-11.60	8527622241.	4699529926.
1	1971	31	-17.21	7244105438.	3697789637.
2	1971	28	-12.61	8407211503.	3250116039.
3	1971	31	-7.64	5755529793.	4072301034.
4	1971	30	1.89	4377398481.	10322146905.
5	1971	31	7.48	14293789811.	10278602704.
6	1971	30	15.11	9777880661.	6601431327.
7	1971	31	15.02	10081670509.	3794552755.
8	1971	31	15.17	7400918436.	3050061820.
9	1971	30	13.00	13514213901.	2642753058.
10	1971	31	8.69	15985789127.	4684515460.
11	1971	30	-2.62	10712132625.	6371727609.
12	1971	31	-10.21	7976228893.	4457489151.
1	1972	31	-17.39	10072206993.	3577998869.
2	1972	29	-15.90	5423797431.	3211963899.
3	1972	31	-9.64	8021947648.	3509511143.
4	1972	30	-.27	3703020725.	6554839122.
5	1972	31	10.93	6573265510.	11175484341.
6	1972	30	13.44	7699854798.	4602812802.
7	1972	31	15.38	16378385150.	4210169030.
8	1972	31	15.50	15827502437.	5390660434.
9	1972	30	9.71	13510970862.	4391347506.
10	1972	31	3.50	6436038053.	4425503856.
11	1972	30	-3.45	6664663091.	4233935087.
12	1972	31	-14.58	8187124206.	2891535108.
1	1973	31	-11.73	4150393969.	2867535520.
2	1973	28	-12.93	4240131196.	2407428707.
3	1973	31	-1.36	6375732502.	4917381998.
4	1973	30	2.08	6480826066.	6728572041.
5	1973	31	7.82	11011827994.	8469325144.
6	1973	30	13.92	13530688892.	4531810109.
7	1973	31	16.97	11243728829.	3710284514.

8	1973	31	17.89	13845010023.	3704085107.
9	1973	30	11.31	11494673400.	3408806945.
10	1973	31	8.31	7725218939.	4231127331.
11	1973	30	-2.35	7945447375.	3753480432.
12	1973	31	-11.96	6238871541.	3115609429.
1	1974	31	-16.06	7009343585.	2536722465.
2	1974	28	-15.31	3846087475.	2279490001.
3	1974	31	-8.61	5053842908.	2535.937375.
4	1974	30	.86	9678036024.	6731012834.
5	1974	31	6.65	11022932912.	9156156069.
6	1974	30	13.49	11287224941.	7154288631.
7	1974	31	17.83	10980170607.	4254235668.
8	1974	31	15.41	16763232896.	3960015655.
9	1974	30	8.43	10479770859.	3656333275.
10	1974	31	4.42	8711495632.	4424326060.
11	1974	30	-1.66	9870435662.	4711842321.
12	1974	31	-7.16	4427570103.	3528476423.
1	1975	31	-12.83	10815731655.	3507353051.
2	1975	28	-11.54	4423776360.	2933310555.
3	1975	31	-8.08	6533139492.	3194632452.
4	1975	30	-. 93	5115779098.	7239048609.
5	1975	31	11.63	6972698725.	9404935553.
6	1975	30	14.75	14965951396.	5480322502.
7	1975	31	18.56	8508748851.	3323726610.
8	1975	31	16.35	7094216835.	2248434935.
9	1975	30	9.87	10089071761.	2477223717.
10	1975	31	6.43	8434574508.	2550667670.
11	1975	30	-1.31	12760693687.	3442916373.
12	1975	31	-11.81	6425658632.	3231732344.
1	1976	31	-16.36	9127686983.	2658552459.
2	1976	29	-9.28	6431880818.	2502672761.
3	1976	31	-7.81	12516232005.	3856376722.
4	1976	30	3.60	5607620558.	12122170464.
5	1976	31	8.52	2652565643.	6352364971.
6	1976	30	16.02	13146408529.	3742319834.
7	1976	31	17.30	8549283475.	2683855765.
8	1976	31	16.85	5413585133.	2112531819.
9	1976	30	10.59	6151474534.	1819149725.
10	1976	31	2.87	5313169943.	1918722660.
11	1976	30	-5.42	6005922291.	2001493222.
12	1976	31	-16.95	7656582588.	1761884847.
1	1977	31	-17.93	5923829897.	1388030459.
2	1977	28	-10.68	6485497782.	1284055352.
3	1977	31	-2.08	12907347146.	3045613774.
4	1977	30	3.77	6965720508.	7071988313.
5	1977	31	12.95	7081643997.	4014709740.
6	1977	30	13.22	14050584713.	2683441266.
7	1977	31	17.11	11184502109.	2465765038.
8	1977	31	13.53	17162088227.	2122578630.
9	1977	30	11.43	16121574852.	6535466997.
10	1977	31	6.07	8187569399.	6321726720.
11	1977	30	-1.30	10346631787.	5217429084.
12	1977	31	-11.22	9077847920.	3959452759.
1	1978	31	-16.16	4061884335.	3236606047.

2	1978	28	-14.31	2165518645.	2638776758.
3	1978	31	-7.42	3786463323.	2689962962.
4	1978	30	.98	4457998897.	5673173449.
5	1978	31	10.72	11872752676.	6411670319.
6	1978	30	12.94	10561592174.	5303165497.
7	1978	31	16.28	15314726821.	4208644733.
8	1978	31	16.24	15072970274.	3539859702.
9	1978	30	12.07	8661599593.	3134950834.
10	1978	31	3.62	6765103095.	2892379553.
11	1978	30	-4.00	8013199654.	2617680763.
12	1978	31	-13.65	7417705050.	2755849806.

Appendix D.--EXAMPLE APPLICATION INPUT PARAMETER FILES (PARM and MPARM)

D.l Example Input for Simulation Program Using Daily Meteorological Data (PARM)

```
SUPERIOR: ALL BASINS 1-22
  .128925E+12
     630
01121969
31121978
        7
  .190E+01
  .300E+09
  .270E+01
  .100E-09
  .600E-02
  .170E-01
  .930E-03
  .350E-02
  .170E+00
```

D.2 Example Input for Simulation Program Using Monthly Meteorological Data (MPARM)

```
SUPERIOR: ALL BASINS 1-22
 .128925E+12
     21
 121969
 121978
 .820E+00
 .710E+09
 .360E+01
 .590E-08
 .200E-02
 .800E-02
 .480E-03
 .210E-02
 .310E+00
```

Appendix E.--EXAMPLE APPLICATION OUTPUT (SUMARY AND MSUM)

E.1 Example Output From Simulation Program Using Daily Meteorological Data (SUMARY)

COMBINED SUBBASINS: 11111111111111111111

FROM DAY 630 TO DAY 3318 IN 7-DAY GROUPS

CONSTANT	ALBEDS	TBASE(C)	AREA(M2)
.128195E+15	.300000E+09	.190000E+01	.128925E+12

DAILY AVERAGES

TEMPERATURE (C):	.211964E+01
PRECIPITATION (CM.):	.226879E+00
FLOW (CM.):	.106093E+00
HEAT LOSS, WATER EQU. (CM.):	.721731E+00
NET SUPPLY (CM.):	.222599E+00
EVAPOTRANSPIRATION (CM.):	.116506E+00
POT. EVAPOTRANSPIRATION (CM.):	.605225E+00

USZC(M3)	ALPPER(D-1)	ALPUEV(M-3)	ALPDPR(D-1)	ALPINT(D-1)
.257850E+10	.270000E+01	.100000E-09	.170000E-01	.600000E-02

ALPLEV m-3)	ALPGW(D-1)	ALPGEV(M-3)	ALPSF(D-1)	ALPSEV(M-3)
.930000E-03	.350000E-02	0.	.170000E+00	0.

7-DAY STATISTICS

FLOW MEAN (CM.):	.742652E+00
FLOW STD. DE". (CM.):	.426877E+00
MODEL 1 MEAN (CM.):	.754461E+00
EVAPOTRANSPIRATION (CM.):	.812313E+00
MEAN SS (CM.):	.635045E+00
MEAN USZM (CM.):	.729089E-01
MEAN LSZM (CM.):	.370796E+01
MEAN GZM (CM.):	.184510E+02
RMSE (CM.):	.194003E+00
COEFFICIENT OF CORRELATION:	.891248E+00

FLOW RATES AND NET SUPPLY IN CUBIC METERS PER 7 DAYS. STORAGES IN CENTIMETERS OVER THE BASIN ON 7TH DAY

ACTUAL FLOW	MODEL FLOW	NET SUPPLY	USZM	LSZM	GZM	SS	SNOW WATER
.635346E+09	.669567E+09	.161307E+10	.636169E-01	.912749E-06	.177885E+02	.420118E+00	0.
.626529E+09	.659481E+09	.294254E+10	.853416E-01	.258755E-07	.173579E+02	.435581E+00	0.
.572990E+09	.671835E+09	.268868E+10	.100435E+00	.248463E-06	.169378E+02	.438547E+00	0.
.623705E+09	.635404E+09	.135790E+10	.542169E-01	.381194E+00	.165604E+02	.397357E+00	0.
.625429E+09	.631448E+09	.223559E+10	.877230E-01	.171832E+01	.162853E+02	.428954E+00	0.
.717676E+09	.111731E+10	.812089E+10	.285673E+00	.433709E+01	.162608E+02	.963627E+00	0.
.971774E+09	.122851E+10	.208189E+10	.819391E-01	.520660E+01	.164400E+02	.690218E+00	0.
.885206E+09	.100861E+10	.246506E+10	.962939E-01	.603292E+01	.167036E+02	.641361E+00	0.
.106061E+10	.994563E+09	.271275E+10	.105459E+00	.649926E+01	.170367E+02	.657033E+00	0.
.142003E+10	.117850E+10	.520933E+10	.193142E+00	.846998E+01	.175048E+02	.861703E+00	0.
.175139E+10	.130678E+10	.349412E+10	.133803E+00	.959245E+01	.181477E+02	.850872E+00	.382934E+00

.129753E+10	.124024E+10	.154156E+10	.613248E-01	.929586E+01	.188217E+02	.778551E+00	0.
.162536E+10	.125646E+10	.348224E+10	.133379E+00	.101808E+02	.195091E+02	.856933E+00	.519657E+00
.134381E+10	.124662E+10	0.	.825886E-09	.878129E+01	.201558E+02	.776155E+00	.140665E+01
.115673E+10	.114945E+10	0.	.511393E-17	.747535E+01	.206211E+02	.725104E+00	.212150E+01
.108129E+10	.108128E+10	0.	.316657E-25	.636350E+01	.209334E+02	.685737E+00	.450647E+01
.103806E+10	.102582E+10	0.	.196075E-33	.541718E+01	.211175E+02	.652287E+00	.640112E+01
.908091E+09	.977612E+09	0.	.121411E-41	.461160E+01	.211944E+02	.622678E+00	.703145E+01
.841039E+09	.934517E+09	0.	.751782E-50	.392581E+01	.211820E+02	.596001E+00	.830097E+01
.847505E+09	.895498E+09	0.	.465507E-58	.334200E+01	.210955E+02	.571745E+00	.952806E+01
.823564E+09	.859906E+09	0.	.288244E-66	.284502E+01	.209477E+02	.549552E+00	.120363E+02
.797126E+09	.827259E+09	0.	.178482E-74	.242193E+01	.207495E+02	.529144E+00	.140824E+02
.789393E+09	.797166E+09	0.	.110517E-82	.206177E+01	.205102E+02	.510287E+00	.156403E+02
.779753E+09	.769301E+09	0.	.684326E-91	.175517E+01	.202376E+02	.492788E+00	.161284E+02
.766238E+09	.743384E+09	0.	.423738E-99	.149415E+01	.199383E+02	.476477E+00	.166041E+02
.768553E+09	.719180E+09	0.	[illegible]	.127194E+01	.196179E+02	.461213E+00	.187323E+02
.779251E+09	.696486E+09	0.	[illegible]	.108279E+01	.192812E+02	.446874E+00	.195040E+02
.778371E+09	.675127E+09	0.	*************	.921772E+00	.189321E+02	.433354E+00	.211249E+02
.775230E+09	.654955E+09	0.	*************	.784679E+00	.185739E+02	.420563E+00	.224214E+02
.773512E+09	.642400E+09	.640435E+09	.259421E-01	.109863E+01	.182343E+02	.418455E+00	.224345E+02
.818696E+09	.636885E+09	0.	.160635E-09	.957450E+00	.179150E+02	.410885E+00	.247696E+02
.825708E+09	.622350E+09	0.	.994659E-18	.814773E+00	.175853E+02	.400195E+00	.257333E+02
.841060E+09	.605370E+09	0.	.615898E-26	.693577E+00	.172481E+02	.388972E+00	.261705E+02
.920251E+09	.903340E+09	.639089E+10	.231871E+00	.445684E+01	.171297E+02	.762783E+00	.223999E+02
.191423E+10	.156982E+10	.855599E+10	.298692E+00	.895396E+01	.175086E+02	.123265E+01	.168936E+02
.264180E+10	.245037E+10	.112732E+11	.375731E+00	.140978E+02	.184460E+02	.188535E+01	.816824E+01
.409204E+10	.335012E+10	.124826E+11	.407820E+00	.190737E+02	.199570E+02	.242282E+01	0.
.285812E+10	.285853E+10	.263580E+09	.107590E-01	.166043E+02	.215866E+02	.147353E+01	0.
.213799E+10	.193531E+10	.261119E+09	.106590E-01	.110892E+02	.226680E+02	.109052E+01	0.
.140317E+10	.142074E+10	.118110E+10	.473247E-01	.163675E+01	.226778E+02	.767188E+00	0.
.146542E+10	.109712E+10	.305506E+10	.117982E+00	.223058E+01	.223579E+02	.685103E+00	0.
.107046E+10	.921610E+09	.133872E+10	.534006E-01	.421643E-05	.218168E+02	.540823E+00	0.
.105590E+10	.798985E+09	.194447E+10	.766761E-01	.980826E-05	.212888E+02	.506041E+00	0.
.105645E+10	.816907E+09	.334194E+10	.128334E+00	.103854E-03	.207735E+02	.550669E+00	0.
.852835E+09	.775059E+09	.109456E+10	.414335E-01	.722225E-07	.202708E+02	.471655E+00	0.
.762929E+09	.721594E+09	.211470E+10	.829902E-01	.380814E-05	.197802E+02	.468892E+00	0.
.753616E+09	.840801E+09	.473574E+10	.172629E+00	.647724E-06	.193014E+02	.604773E+00	0.
.111626E+10	.120701E+10	.774000E+10	.263853E+00	.629791E-06	.188343E+02	.915688E+00	0.
.122427E+10	.108579E+10	.134817E+10	.523821E-01	.197100E-06	.183785E+02	.562265E+00	0.
.909733E+09	.765544E+09	.166372E+10	.653687E-01	.677997E-06	.179337E+02	.455029E+00	0.
.910060E+09	.695374E+09	.263652E+10	.101604E+00	.100907E-05	.174996E+02	.451751E+00	0.
.138861E+10	.950100E+09	.688466E+10	.231135E+00	.306297E-06	.170761E+02	.740509E+00	0.
.162825E+10	.104667E+10	.454259E+10	.164971E+00	.481576E-06	.166628E+02	.638033E+00	0.
.112348E+10	.791821E+09	.475657E+09	.173371E-01	.160447E-07	.162595E+02	.431618E+00	0.
.877379E+09	.695783E+09	.332260E+10	.127654E+00	.170994E+01	.159730E+02	.481856E+00	0.
.864656E+09	.751334E+09	.274152E+10	.106518E+00	.281981E+01	.158582E+02	.500157E+00	0.
.120254E+10	.859559E+09	.403652E+10	.152985E+00	.450765E+01	.159085E+02	.613064E+00	0.
.118254E+10	.965469E+09	.335260E+10	.128733E+00	.606679E+01	.161492E+02	.648891E+00	0.
.113082E+10	.982556E+09	.233000E+10	.912587E-01	.658986E+01	.165052E+02	.637666E+00	0.
.101486E+10	.961570E+09	.158918E+10	.631596E-01	.671558E+01	.168894E+02	.620710E+00	0.
.928790E+09	.948849E+09	.144773E+10	.577000E-01	.672621E+01	.172710E+02	.618158E+00	0.
.923608E+09	.938491E+09	.907575E+09	.365654E-01	.636538E+01	.176229E+02	.606137E+00	0.
.104762E+10	.924695E+09	.951922E+09	.383179E-01	.608468E+01	.179276E+02	.599852E+00	.945041E+00
.118662E+10	.102540E+10	.370536E+10	.141321E+00	.756238E+01	.182936E+02	.729306E+00	.504015E-01
.941228E+09	.105949E+10	0.	.875064E-09	.655908E+01	.186863E+02	.659388E+00	.430295E+00

.851432E+09	.977223E+09	0.	.541844E-17	.558333E+01	.189459E+02	.617095E+00	.911919E+00
.760681E+09	.921425E+09	0.	.335512E-25	.475302E+01	.190934E+02	.585184E+00	.179750E+01
.666196E+09	.876644E+09	0.	.207751E-33	.404621E+01	.191472E+02	.558227E+00	.310307E+01
.682088E+09	.837778E+09	0.	.128640E-41	.344451E+01	.191230E+02	.534331E+00	.417657E+01
.641313E+09	.802930E+09	0.	.796547E-50	.293226E+01	.190341E+02	.512710E+00	.484743E+01
.609494E+09	.771229E+09	0.	.493226E-58	.249621E+01	.188917E+02	.492952E+00	.800372E+01
.645053E+09	.742162E+09	0.	.305408E-66	.212499E+01	.187054E+02	.474779E+00	.920467E+01
.652667E+09	.715358E+09	0.	.189110E-74	.180898E+01	.184833E+02	.457978E+00	.968456E+01
.630699E+09	.690519E+09	0.	.117098E-82	.153972E+01	.182323E+02	.442371E+00	.101372E+02
.662698E+09	.667395E+09	0.	.725075E-91	.131056E+01	.179582E+02	.427812E+00	.110762E+02
.630757E+09	.645784E+09	0.	.448970E-99	.111564E+01	.176658E+02	.414180E+00	.117791E+02
.620919E+09	.625512E+09	0.	[illegible]	.949732E+00	.173593E+02	.401368E+00	.120289E+02
.607465E+09	.606422E+09	0.	[illegible]	.808481E+00	.170423E+02	.389281E+00	.127286E+02
.583982E+09	.588383E+09	0.	*************	.688252E+00	.167176E+02	.377840E+00	.135861E+02
.553480E+09	.578128E+09	.659474E+09	.267031E-01	.102890E+01	.164132E+02	.377409E+00	.140778E+02
.770662E+09	.809021E+09	.538761E+10	.199094E+00	.421715E+01	.163221E+02	.658014E+00	.132202E+02
.150266E+10	.953054E+09	.219705E+10	.862762E-01	.518785E+01	.164871E+02	.598912E+00	.130297E+02
.111311E+10	.917633E+09	.221590E+10	.869841E-01	.593238E+01	.167431E+02	.602711E+00	.113219E+02
.141781E+10	.113980E+10	.553060E+10	.203840E+00	.851542E+01	.171863E+02	.861856E+00	.720330E+01
.125252E+10	.123973E+10	.216627E+10	.851190E-01	.883125E+01	.177964E+02	.771898E+00	.623829E+01
.972075E+09	.138671E+10	.575874E+10	.211360E+00	.111042E+02	.185357E+02	.101737E+01	.366738E+01
.213870E+10	.185653E+10	.764240E+10	.271122E+00	.139144E+02	.195606E+02	.136508E+01	0.
.196012E+10	.178717E+10	.782010E+07	.320882E-03	.120791E+02	.206255E+02	.102154E+01	0.
.200749E+10	.164009E+10	.485989E+10	.181361E+00	.132924E+02	.216113E+02	.112239E+01	0.
.259056E+10	.169594E+10	.346542E+10	.132777E+00	.136120E+02	.226725E+02	.109710E+01	0.
.183455E+10	.158578E+10	.663897E+09	.268798E-01	.120882E+02	.236369E+02	.983905E+00	0.
.146774E+10	.147421E+10	.154422E+10	.614274E-01	.106373E+02	.243953E+02	.940416E+00	0.
.124898E+10	.142359E+10	.173832E+10	.688826E-01	.984085E+01	.250064E+02	.917130E+00	0.
.120373E+10	.145700E+10	.357082E+10	.136540E+00	.830906E+01	.254577E+02	.967669E+00	0.
.104767E+10	.145741E+10	.312390E+10	.120480E+00	.697767E+01	.257343E+02	.930681E+00	0.
.960497E+09	.133434E+10	.156268E+10	.621391E-01	.502040E+01	.258087E+02	.816354E+00	0.
.970293E+09	.127190E+10	.403047E+10	.152773E+00	.223938E+01	.255618E+02	.826746E+00	0.
.950937E+09	.108715E+10	.125925E+10	.425326E-01	.241718E-07	.249431E+02	.625272E+00	0.
.834450E+09	.899782E+09	.136229E+10	.523225E-01	.138699E-06	.243394E+02	.558428E+00	0.
.756235E+09	.863952E+09	.252762E+10	.917092E-01	.124463E-06	.237504E+02	.565472E+00	0.
.788486E+09	.100567E+10	.525992E+10	.179961E+00	.211316E-06	.231755E+02	.719410E+00	0.
.797262E+09	.990952E+09	.228081E+10	.860552E-01	.226186E-06	.226146E+02	.591845E+00	0.
.958899E+09	.966639E+09	.466156E+10	.150799E+00	.937415E-07	.220673E+02	.657144E+00	0.
.873429E+09	.102366E+10	.455876E+10	.155929E+00	.157745E-06	.215332E+02	.672505E+00	0.
.811215E+09	.890652E+09	.841124E+09	.324373E-01	.743331E-07	.210121E+02	.515414E+00	0.
.739750E+09	.806352E+09	.407531E+10	.860791E-01	.107709E-07	.205035E+02	.532252E+00	0.
.871997E+09	.781857E+09	.221685E+10	.818238E-01	.132523E-06	.200073E+02	.492563E+00	0.
.720166E+09	.711774E+09	.104222E+10	.418662E-01	.180763E-04	.195231E+02	.442461E+00	0.
.691112E+09	.747223E+09	.324009E+10	.124682E+00	.207133E+01	.191729E+02	.531404E+00	0.
.904402E+09	.870185E+09	.324051E+10	.124697E+00	.346441E+01	.190393E+02	.598836E+00	0.
.769830E+09	.865926E+09	.607328E+09	.246176E-01	.301058E+01	.189625E+02	.537121E+00	0.
.118174E+10	.975843E+09	.482649E+10	.180227E+00	.421449E+01	.189283E+02	.719033E+00	0.
.109534E+10	.993893E+09	.594732E+09	.241132E-01	.410876E+01	.189671E+02	.597404E+00	0.
.831656E+09	.877052E+09	.627774E+09	.254358E-01	.371480E+01	.189669E+02	.552049E+00	0.
.809127E+09	.863587E+09	.197569E+10	.779222E-01	.447608E+01	.189881E+02	.576138E+00	.485459E-01
.727996E+09	.862684E+09	0.	.482498E-09	.387721E+01	.190224E+02	.549305E+00	.990138E+00
.745029E+09	.828608E+09	.464140E+09	.188683E-01	.361356E+01	.190009E+02	.532478E+00	.132691E+01
.109597E+10	.105746E+10	.564408E+10	.207588E+00	.655264E+01	.191352E+02	.825506E+00	.275852E+00
.976570E+09	.114283E+10	.522111E+09	.212000E-01	.610587E+01	.194247E+02	.686830E+00	.473286E+00

.781565E+09	.100437E+10	.296337E+09	.120880E-01	.541638E+01	.196311E+02	.629596E+00	.145088E+01
.720775E+09	.938153E+09	0.	.748493E-10	.462130E+01	.197451E+02	.595046E+00	.210631E+01
.663800E+09	.891097E+09	0.	.463471E-18	.393408E+01	.197688E+02	.567361E+00	.318685E+01
.613048E+09	.851612E+09	0.	.286983E-26	.334903E+01	.197174E+02	.543274E+00	.489668E+0 1
.603085E+09	.816602E+09	0.	.177701E-34	.285101E+01	.196037E+02	.521600E+00	.537649E+01
.612275E+09	.784841E+09	0.	.110034E-42	.242704E+01	.194387E+02	.501806E+00	.588518E+01
.570531E+09	.755712E+09	0.	.681333E-51	.206610E+01	.192317E+02	.483585E+00	.789842E+01
.533479E+09	.728818E+09	0.	.421885E-59	.175884E+01	.189905E+02	.466716E+00	.938901E+01
.540561E+09	.703862E+09	0.	.261233E-67	.149728E+01	.187218E+02	.451026E+00	.105575E+02
.552737E+09	.680600E+09	0.	.161757E-75	.127462E+01	.184312E+02	.436370E+00	.110818E+02
.561235E+09	.658829E+09	0.	.100161E-83	.108508E+01	.181235E+02	.422625E+00	.124802E+02
.591745E+09	.638372E+09	0.	.620199E-92	.923709E+00	.178026E+02	.409686E+00	.130882E+02
.581202E+09	.619080E+09	0.	.384030E*00	.786161E+00	.174720E+02	.397461E+00	.141569E+02
.606667E+09	.611137E+09	.865147E+09	.348858E-01	.124849E+01	.171678E+02	.401094E+00	.142354E+02
.587675E+09	.610884E+09	0.	.216014E-09	.109273E+01	.168914E+02	.394239E+00	.148867E+02
.554210E+09	.597057E+09	0.	.133757E-17	.930229E+00	.166012E+02	.383836E+00	.157714E+02
.544422E+09	.580413E+09	0.	.828231E-26	.791780E+00	.163004E+02	.372789E+00	.165949E+02
.563736E+09	.563578E+09	0.	.512845E-34	.673862E+00	.159918E+02	.361958E+00	.188022E+02
.887931E+09	.781611E+09	.541943E+10	.200152E+00	.391176E+01	.158709E+02	.640626E+00	.167713E+02
.189059E+10	.153442E+10	.946430E+10	.325245E+00	.890120E+01	.162436E+02	.128608E+01	.110144E+02
.263861E+10	.272194E+10	.128851E+11	.418220E+00	.147797E+02	.172494E+02	.215347E+01	.242914E+01
.246402E+10	.275055E+10	.535302E+10	.197942E+00	.161956E+02	.186654E+02	.154744E+01	0.
.200237E+10	.207464E+10	.292027E+10	.113070E+00	.158183E+02	.200988E+02	.121971E+01	0.
.227870E+10	.174912E+10	.208743E+10	.821484E-01	.148856E+02	.214168E+02	.108445E+01	0.
.192594E+10	.161521E+10	.223421E+10	.876714E-01	.126814E+02	.225120E+02	.102270E+01	0.
.169798E+10	.152300E+10	.182279E+10	.721090E-01	.118281E+02	.234068E+02	.970123E+00	0.
.164138E+10	.155409E+10	.473166E+10	.176999E+00	.625764E+01	.238422E+02	.101880E+01	0.
.230989E+10	.150210E+10	.389935E+10	.148171E+00	.760326E+01	.240844E+02	.959275E+00	0.
.158910E+10	.134705E+10	.118047E+10	.473001E-01	.577614E+01	.242848E+02	.811496E+00	0.
.115122E+10	.105913E+10	.138517E+10	.542287E-01	.293796E-06	.236970E+02	.606680E+00	0.
.103774E+10	.945972E+09	.375275E+10	.125159E+00	.876681E-07	.231235E+02	.624183E+00	0.
.107176E+10	.878358E+09	.167322E+10	.465642E-01	.113701E-07	.225639E+02	.534578E+00	0.
.929803E+09	.797997E+09	.188711E+10	.653820E-01	.482214E-07	.220178E+02	.508949E+00	0.
.856971E+09	.791422E+09	.256863E+10	.932391E-01	.128733E-06	.214849E+02	.519552E+00	0.
.885645E+09	.911560E+09	.465874E+10	.174509E+00	.174234E+00	.209839E+02	.647678E+00	0.
.878952E+09	.907885E+09	.260418E+10	.938500E-01	.118251E-06	.204760E+02	.549910E+00	0.
.874778E+09	.810714E+09	.255669E+10	.966491E-01	.313361E-06	.199804E+02	.512346E+00	0.
.881068E+09	.917991E+09	.529686E+10	.187319E+00	.388910E-06	.194969E+02	.660190E+00	0.
.911017E+09	.923940E+09	.285899E+10	.110829E+00	.545664E+00	.190757E+02	.561151E+00	0.
.748356E+09	.761231E+09	.334776E+09	.136453E-01	.150711E+00	.186495E+02	.448076E+00	0.
.851499E+09	.844150E+09	.491003E+10	.183061E+00	.293828E+01	.183817E+02	.644641E+00	0.
.908450E+09	.937827E+09	.218497E+10	.858221E-01	.398157E+01	.183505E+02	.591573E+00	0.
.896247E+09	.917527E+09	.245215E+10	.958135E-01	.492715E+01	.184316E+02	.608434E+00	0.
.973764E+09	.986832E+09	.311947E+10	.120319E+00	.625022E+01	.186437E+02	.676014E+00	0.
.102360E+10	.100340E+10	.107893E+10	.433197E-01	.606552E+01	.189199E+02	.637655E+00	0.
.104640E+10	.100735E+10	.238616E+10	.933556E-01	.674918E+01	.192140E+02	.675957E+00	.791639E-01
.968419E+09	.100695E+10	.249213E+09	.101755E-01	.596951E+01	.194993E+02	.638948E+00	0.
.109581E+10	.109156E+10	.397997E+10	.151003E+00	.751221E+01	.198161E+02	.777620E+00	0.
.104460E+10	.114011E+10	.112542E+10	.451439E-01	.725854E+01	.202096E+02	.717749E+00	0.
.117111E+10	.110044E+10	.179289E+10	.709683E-01	.739599E+01	.205808E+02	.719655E+00	.181284E+01
.109112E+10	.107555E+10	0.	.439439E-09	.635668E+01	.208927E+02	.683267E+00	.319987E+01
.983933E+09	.102293E+10	0.	.272103E-17	.541134E+01	.210771E+02	.650802E+00	.413727E+01
.879043E+09	.975626E+09	0.	.168487E-25	.460653E+01	.211543E+02	.621518E+00	.468982E+01
.812375E+09	.932844E+09	0.	.104328E-33	.392143E+01	.211423E+02	.594963E+00	.558308E+01

.789812E+09	.893956E+09	0.	.646005E-42	.333827E+01	.210563E+02	.570767E+00	.694054E+01
.713215E+09	.858436E+09	0.	.400009E-50	.284164E+01	.209090E+02	.548611E+00	.752352E+01
.720690E+09	.825839E+09	0.	.247688E-58	.241903E+01	.207114E+02	.528232E+00	.847530E+01
.788698E+09	.795789E+09	0.	.153369E-66	.205911E+01	.204727E+02	.509402E+00	.114481E+02
.845407E+09	.767961E+09	0.	.949671E-75	.175290E+01	.202007E+02	.491927E+00	.123590E+02
.804985E+09	.742083E+09	0.	.588041E-83	.149223E+01	.199021E+02	.475642E+00	.153293E+02
.765870E+09	.717918E+09	0.	.364118E-91	.127032E+01	.195824E+02	.460403E+00	.159854E+02
.754619E+09	.695261E+09	0.	.225463E-99	.108141E+01	.192463E+02	.446088E+00	.167420E+02
.728392E+09	.673938E+09	0.	*************	.920593E+00	.188979E+02	.432590E+00	.175601E+02
.718535E+09	.653798E+09	0.	*************	.783443E+00	.185404E+02	.419817E+00	.180946E+02
.729684E+09	.634709E+09	0.	[illegible]	.666869E+00	.181767E+02	.407695E+00	.195035E+02
.716235E+09	.616569E+09	0.	[illegible]	.567671E+00	.178092E+02	.396159E+00	.198514E+02
.698979E+09	.599283E+09	0.	*************	.483217E+00	.174398E+02	.385152E+00	.204644E+02
.736416E+09	.633836E+09	.229193E+10	.898346E-01	.190452E+01	.171562E+02	.442128E+00	.194352E+02
.731375E+09	.662917E+09	0.	.556260E-09	.169840E+01	.169570E+02	.423078E+00	.226531E+02
.722805E+09	.636962E+09	0.	.344439E-17	.144583E+01	.167310E+02	.407636E+00	.226921E+02
.730326E+09	.614672E+09	0.	.213278E-25	.123063E+01	.164830E+02	.393864E+00	.226921E+02
.151591E+10	.112647E+10	.856041E+10	.298824E+00	.604024E+01	.165070E+02	.102114E+01	.175263E+02
.295937E+10	.197144E+10	.966783E+10	.331082E+00	.108883E+02	.171099E+02	.149642E+01	.112199E+02
.346224E+10	.324835E+10	.146457E+11	.462161E+00	.172311E+02	.183549E+02	.259678E+01	.258224E+01
.302839E+10	.309979E+10	.374816E+10	.142836E+00	.171970E+02	.199495E+02	.162070E+01	0.
.186207E+10	.209608E+10	.895313E+09	.360802E-01	.145413E+02	.213312E+02	.118217E+01	0.
.150159E+10	.148337E+10	.190813E+10	.753581E-01	.544737E+00	.212405E+02	.763053E+00	0.
.111797E+10	.100781E+10	.201807E+10	.795272E-01	.659122E+00	.207994E+02	.584427E+00	0.
.972691E+09	.886702E+09	.284533E+10	.110329E+00	.213391E+01	.204649E+02	.582039E+00	0.
.111418E+10	.125963E+10	.749968E+10	.266734E+00	.495448E+01	.203961E+02	[illegible]	
.181294E+10	.124289E+10	.283751E+10	.106090E+00	.289374E-06	.199025E+02	.666800E+00 101194E+01	0. 0.
.124601E+10	.863687E+09	.900053E+09	.307900E-01	.182718E-07	.194208E+02	.490479E+00	0.
107656E+10	.721967E+09	.225478E+10	.650500E-01	.185903E-07	189508E+02	.456286E+00	0.
: 824826E+09	.684065E+09	.190675E+10	.721925E-01	.173244E-06	: 184921E+02	.437475E+00	0.
.658123E+09	.657185E+09	.244866E+10	.467886E-01	.458394E-08	.180446E+02	.420312E+00	0.
596778E+09	.663657E+09	.266762E+10	.978149E-01	.163084E-06	.176079E+02	.440971E+00	0.
: 510945E+09	.628450E+09	.104808E+10	.155167E-01	.953124E-09	.171817E+02	.386613E+00	0.
.496957E+09	.571469E+09	.404519E+09	.150106E-01	.165257E-07	.167659E+02	.361552E+00	0.
.533981E+09	.552051E+09	.114965E+10	.429712E-01	.621213E-07	.163601E+02	.357688E+00	0.
.518536E+09	.608609E+09	.317959E+10	.119717E+00	.520586E-06	.159641E+02	.424607E+00	0.
.533797E+09	.603910E+09	.131379E+10	.510467E-01	.187500E-06	.155778E+02	.370318E+00	0.
.521290E+09	.712002E+09	.466759E+10	.174812E+00	.159302E+01	.153148E+02	.542337E+00	0.
.608981E+09	.755394E+09	.161078E+10	.639903E-01	.241309E+01	.151872E+02	.460178E+00	0.
.581171E+09	.732772E+09	.275797E+10	.107123E+00	.329863E+01	.151569E+02	.495968E+00	0.
.605091E+09	.721331E+09	.563772E+09	.228723E-01	.315667E+01	.151734E+02	.451017E+00	0.
.531009E+09	.681315E+09	.960329E+09	.386497E-01	.309232E+01	.151725E+02	.439289E+00	0.
.5 19094E+09	.674101E+09	.112015E+10	.449372E-01	.323253E+01	.151771E+02	.440373E+00	0.
542817E+09	.688455E+09	.146688E+10	.584408E-01	.372637E+01	.152191E+02	.457653E+00	0.
: 600529E+09	.885048E+09	.482499E+10	.180176E+00	.617106E+01	.154315E+02	.679487E+00	0.
.677657E+09	.954867E+09	.552145E+09	.224059E-01	.575306E+01	.157661E+02	.580762E+00	0.
.536249E+09	.897566E+09	.216394E+10	.850310E-01	.619617E+01	.160847E+02	.593455E+00	0.
.956412E+09	.973426E+09	.318779E+10	.122793E+00	.738642E+01	.164941E+02	.671977E+00	0.
937834E+09	.102372E+10	.196469E+10	.775052E-01	.767536E+01	.169829E+02	.666066E+00	.159017E+01
: 852675E+09	.986911E+09	0.	.479916E-09	.660045E+01	.174130E+02	.622830E+00	.422208E+01
.905519E+09	.928776E+09	0.	.29 7166E-17	.561877E+01	.177080E+02	.588965E+00	.510454E+01
.744858E+09	.880867E+09	0.	.184007E-25	.478320E+01	.178893E+02	.559975E+00	.698399E+01
.735592E+09	.839031E+09	0.	.113938E-33	.407190E+01	.179755E+02	.534262E+00	.851190E+01
.600957E+09	.801604E+09	0.	.705509E-42	.346637E+01	.179824E+02	.511097E+00	.902600E+01

.586646E+09	.767733E+09	0.	.436854E-50	.295083E+01	.179235E+02	.490049E+00	.103594E+02
.631727E+09	.736865E+09	0.	.270502E-58	.251202E+01	.178100E+02	.470812E+00	.119192E+02
.600433E+09	.708581E+09	0.	.167496E-66	.213846E+01	.176516E+02	.453141E+00	.128586E+02
.583834E+09	.682540E+09	0.	.103714E-74	.182045E+01	.174565E+02	.436832E+00	.145353E+02
.591381E+09	.658452E+09	0.	.642205E-83	.154973E+01	.172316E+02	.421713E+00	.164156E+02
.594115E+09	.636072E+09	0.	.397656E-91	.131927E+01	.169828E+02	.407636E+00	.172862E+02
.588201E+09	.615192E+09	0.	.246231E-99	.112293E+01	.167149E+02	.394473E+00	.188349E+02
.608298E+09	.595628E+09	0.	*************	.955804E+00	.164323E+02	.382117E+00	.204468E+02
.621399E+09	.600695E+09	.144710E+10	.576757E-01	.177196E+01	.161935E+02	.403053E+00	.201524E+02
.631534E+09	.611823E+09	0.	.357131E-09	.155797E+01	.159999E+02	.393786E+00	.221932E+02
.610052E+09	.595185E+09	0.	.221137E-17	.132629E+01	.157818E+02	.381943E+00	.242786E+02
.659567E+09	.673166E+09	.329674E+10	.126724E+00	.323789E+01	.156654E+02	.493269E+00	.232101E+02
.108839E+10	.822323E+09	.329328E+10	.126599E+00	.496515E+01	.157716E+02	.575070E+00	.225354E+02
.201786E+10	.109667E+10	.566677E+10	.208335E+00	.779914E+01	.161415E+02	.832328E+00	.204858E+02
.214852E+10	.131626E+10	.454146E+10	.170491E+00	.964148E+01	.167811E+02	.885718E+00	.171885E+02
.320412E+10	.359181E+10	.198835E+11	.579550E+00	.179316E+02	.179962E+02	.345283E+01	.410290E+01
.384820E+10	.417061E+10	.704080E+10	.252474E+00	.199071E+02	.198032E+02	.221237E+01	0.
.239226E+10	.269626E+10	.946803E+09	.381157E-01	.177795E+02	.215459E+02	.144037E+01	0.
.185318E+10	.196300E+10	.379979E+09	.154735E-01	.153840E+02	.229705E+02	.116169E+01	0.
.145714E+10	.168854E+10	.113002E+10	.453242E-01	.134850E+02	.241059E+02	.105283E+01	0.
.128268E+10	.155272E+10	.197883E+09	.808816E-02	.115321E+02	.249911E+02	.976073E+00	0.
.100379E+10	.144175E+10	.262389E+09	.107106E-01	.871494E+01	.255672E+02	.901096E+00	0.
.826771E+09	.115959E+10	.137894E+09	.564311E-02	.598547E-02	.250060E+02	.642897E+00	0.
.727212E+09	.981108E+09	.341399E+10	.120338E+00	.137309E-06	.244008E+02	.639537E+00	0.
.100784E+10	.121638E+10	.672271E+10	.242373E+00	.715542E-04	.238102E+02	.903746E+00	0.
.929064E+09	.115608E+10	.200243E+10	.730953E-01	.944943E-07	.232340E+02	.646257E+00	0.
.802750E+09	.890177E+09	.994925E+09	.376993E-01	.646939E-07	.226717E+02	.533325E+00	0.
.662683E+09	.815866E+09	.250337E+10	.855387E-01	.614462E-07	.221229E+02	.530209E+00	0.
.589110E+09	.775440E+09	.119288E+10	.459605E-01	.121488E-06	.215875E+02	.486341E+00	0.
.555103E+09	.791744E+09	.332879E+10	.113001E+00	.863998E-07	.210651E+02	.536791E+00	0.
.521849E+09	.775741E+09	.156318E+10	.583405E-01	.928864E-07	.205552E+02	.481877E+00	0.
.485437E+09	.735890E+09	.217386E+10	.824884E-01	.240186E-06	.200577E+02	.477120E+00	0.
.486624E+09	.704448E+09	.141754E+10	.508143E-01	.471992E-07	.195723E+02	.444902E+00	0.
.476563E+09	.655523E+09	.617354E+09	.134618E-01	.166496E-08	.190986E+02	.413619E+00	0.
.463007E+09	.623922E+09	.836077E+09	.272654E-01	.121503E-07	.186364E+02	.400560E+00	0.
.419944E+09	.612981E+09	.119065E+10	.476193E-01	.300941E-05	.181853E+02	.397652E+00	0.
.393558E+09	.597093E+09	.684763E+09	.259575E-01	.407007E-07	.177452E+02	.381822E+00	0.
.434341E+09	.610590E+09	.220759E+10	.864657E-01	.373065E-05	.173157E+02	.409108E+00	0.
.451831E+09	.648158E+09	.229200E+10	.898372E-01	.154652E+01	.169906E+02	.439356E+00	0.
.428745E+09	.648539E+09	.989497E+08	.405261E-02	.117042E+01	.167418E+02	.408033E+00	0.
.401515E+09	.625194E+09	.122140E+10	.488999E-01	.156965E+01	.164969E+02	.409478E+00	0.
.409566E+09	.638995E+09	.136727E+10	.545808E-01	.222471E+01	.163218E+02	.424519E+00	.253971E+00
.441271E+09	.652477E+09	.802173E+09	.323876E-01	.247729E+01	.162047E+02	.426537E+00	.139353E+01
.495421E+09	.686674E+09	.192210E+10	.758887E-01	.339393E+01	.161572E+02	.468086E+00	.175699E-03
.485267E+09	.716610E+09	.856098E+09	.345272E-01	.352515E+01	.161751E+02	.466599E+00	.156118E+00
.467650E+09	.706286E+09	0.	.213794E-09	.303047E+01	.161698E+02	.453148E+00	.122193E+01
.462775E+09	.682693E+09	0.	.132382E-17	.257944E+01	.161074E+02	.436677E+00	.201785E+01
.449061E+09	.657292E+09	0.	.819718E-26	.219581E+01	.159976E+02	.420290E+00	.368124E+01
.456578E+09	.632814E+09	0.	.507573E-34	.186928E+01	.158487E+02	.404823E+00	.511422E+01
.423148E+09	.609896E+09	0.	.314292E-42	.159130E+01	.156680E+02	.390415E+00	.751585E+01
.387381E+09	.588571E+09	0.	.194611E-50	.135464E+01	.154616E+02	.377009E+00	.821455E+01
.345138E+09	.568710E+09	0.	.120504E-58	.115320E+01	.152344E+02	.364506E+00	.949418E+01
.329640E+09	.550156E+09	0.	.746167E-67	.981707E+00	.149909E+02	.352806E+00	.101190E+02
.323775E+09	.532761E+09	0.	.462030E-75	.835719E+00	.147346E+02	.341816E+00	.114365E+02

.360276E+09	.516393E+09	0.	.286091E-83	.711441E+00	.144687E+02	.331456E+00	.120482E+02
.317720E+09	.500937E+09	0.	.177149E-91	.605643E+00	.141957E+02	.321657E+00	.131092E+02
.306777E+09	.486296E+09	0.	.109691E-99	.515577E+00	.139179E+02	.312359E+00	.143231E+02
.271722E+09	.472383E+09	0.	*************	.438902E+00	.136370E+02	.303512E+00	.152020E+02
.311312E+09	.459123E+09	0.	*************	.373386E+00	.133546E+02	.295066E+00	.162118E+02
.351884E+09	.446451E+09	0.	******SC******	.317857E+00	.130719E+02	.286988E+00	.167325E+02
.334235E+09	.434320E+09	0.	*************	.270577E+00	.127901E+02	.279247E+00	.195479E+02
.377435E+09	.422681E+09	0.	*************	.230246E+00	.125099E+02	.271811E+00	.210293E+02
.405982E+09	.114117E+10	.102199E+11	.346710E+00	.599799E+01	.125688E+02	.113522E+01	.169428E+02
.825567E+09	.136918E+10	.194676E+10	.768250E-01	.666852E+01	.130237E+02	.726175E+00	.158710E+02
.653934E+09	.110010E+10	.386338E+10	.146905E+00	.818317E+01	.135808E+02	.724939E+00	.146290E+02
.137271E+10	.124508E+10	.529627E+10	.196050E+00	.103481E+02	.143430E+02	.888197E+00	.135895E+02
.819408E+09	.126944E+10	.225651E+10	.885077E-01	.104345E+02	.152228E+02	.786378E+00	.125404E+02
.159155E+10	.280961E+10	.163251E+11	.501857E+00	.173047E+02	.164814E+02	.264818E+01	.526406E+00
.251490E+10	.317606E+10	.444875E+10	.167302E+00	.178227E+02	.181640E+02	.166940E+01	0.
.180814E+10	.213516E+10	.792388E+09	.319989E-01	.157227E+02	.196990E+02	.119536E+01	0.
. 119 849E+10	.169559E+10	.146961E+10	.585464E-01	.143207E+02	.209841E+02	.104117E+01	0.
.936456E+09	.150403E+10	.799329E+09	.322746E-01	.100580E+02	.218925E+02	.917693E+00	0.
.787543E+09	.122045E+10	.250877E+10	.979178E-01	.341809E+00	.215911E+02	.679550E+00	0.
.709230E+09	.898822E+09	.966380E+09	.374883E-01	.105830E-06	.210686E+02	.520122E+00	0.
.681327E+09	.821146E+09	.306721E+10	.118423E+00	.736362E+00	.206178E+02	.550810E+00	0.
.619591E+09	.792485E+09	.983618E+09	.395685E-01	.105198E+01	.202294E+02	.492571E+00	0.
.582519E+09	.922754E+09	.499500E+10	.185934E+00	.238546E+01	.199509E+02	.690564E+00	0.
.626563E+09	.889589E+09	.999694E+09	.395173E-01	.240233E-06	.194680E+02	.501630E+00	0.
.609677E+09	.104636E+10	.705407E+10	.250045E+00	.206423E-05	.189968E+02	.818931E+00	0.
.688163E+09	.102765E+10	.230868E+10	.833646E-01	.100535E-06	.185371E+02	.563198E+00	0.
.571176E+09	.823433E+09	.325720E+10	.116650E+00	.158568E-06	.180884E+02	.518560E+00	0.
.480108E+09	.707233E+09	.104487E+10	.268098E-01	.498748E-08	.176507E+02	.419849E+00	0.
.472180E+09	.664834E+09	.280226E+10	.107396E+00	.866165E-06	.172235E+02	.443749E+00	0.
.441970E+09	.646236E+09	.167938E+10	.660829E-01	.837476E-06	.168066E+02	.403752E+00	0.
.390175E+09	.595503E+09	.132740E+10	.525722E-01	.630055E-06	.163999E+02	.376032E+00	0.
.385788E+09	.657070E+09	.346869E+10	.132894E+00	.160141E+01	.161085E+02	.475187E+00	0.
.498095E+09	.105688E+10	.767517E+10	.272127E+00	.120933E+00	.157365E+02	.843042E+00	0.
.947671E+09	.119590E+10	.528507E+10	.195676E+00	.772119E+00	.154327E+02	.733196E+00	0.
.145365E+10	.121637E+10	.646383E+10	.234207E+00	.405319E+01	.153561E+02	.854464E+00	0.
.134478E+10	.106426E+10	.858445E+09	.346202E-01	.330251E+01	.154231E+02	.578046E+00	0.
.177935E+10	.987549E+09	.490247E+10	.182805E+00	.554716E+01	.155690E+02	.710457E+00	0.
.187206E+10	.995476E+09	.162402E+10	.644993E-01	.570249E+01	.158596E+02	.606212E+00	0.
.130693E+10	.955707E+09	.291052E+10	.112714E+00	.675022E+01	.162073E+02	.643286E+00	0.
.195026E+10	.108635E+10	.409940E+10	.155183E+00	.839433E+01	.167063E+02	.765158E+00	0.
.139740E+10	.109074E+10	.177622E+09	.726301E-02	.736170E+01	.172337E+02	.669218E+00	0.
.107002E+10	.985783E+09	.248826E+09	.101598E-01	.634898E+01	.176203E+02	.620041E+00	0.
.116580E+10	.966360E+09	.206627E+10	.813495E-01	.671600E+01	.179590E+02	.641867E+00	0.
.124539E+10	.105021E+10	.315694E+10	.121677E+00	.774990E+01	.183746E+02	.722347E+00	.210950E+00
.121930E+10	.119394E+10	.387068E+10	.147162E+00	.914463E+01	.189242E+02	.827038E+00	.647693E-01
.128790E+10	.118992E+10	0.	.911235E-09	.791108E+01	.194740E+02	.734993E+00	.133387E+01
.103223E+10	.101723E+10 .108471E+10 0. 0.		.564241E-17	.673437E+01	.198613E+02	.682694E+00	.286285E+01
.912102E+09			.349381E-25	.573292E+01	.201116E+02	.644861E+00	.509941E+01
.889888E+09	.964743E+09	0.	.216338E-33	.488015E+01	.202471E+02	.613566E+00	.647889E+01
.895741E+09	.919870E+09	0.	.133958E-41	.415426E+01	.202868E+02	.586106E+00	.790415E+01
.765722E+09	.879955E+09	0.	.829472E-50	.353649E+01	.202467E+02	.561415E+00	.879886E+01
.760293E+09	.843838E+09	0.	.513613E-58	.301058E+01	.201406E+02	.538956E+00	.105457E+02
.747168E+09	.810864E+09	0.	.318032E-66	.256288E+01	.199799E+02	.518381E+00	.108561E+02
.718416E+09	.780573E+09	0.	.196927E-74	.218176E+01	.197745E+02	.499430E+00	.110722E+02

.720959E+09	.752608E+09	0.	.121938E-82	.185731E+01	.195328E+02	.481893E+00	.116246E+02
.684166E+09	.726670E+09	0.	.755046E-91	.158111E+01	.192616E+02	.465590E+00	.122759E+02
.672310E+09	.702509E+09	0.	.467528E-99	.134598E+01	.189671E+02	.450373E+00	.124672E+02
.655861E+09	.679911E+09	0.	*************	.114582E+01	.186541E+02	.436111E+00	.127967E+02
.640643E+09	.658692E+09	0.	*************	.975422E+00	.183270E+02	.422695E+00	.132801E+02
.625127E+09	.638694E+09	0.	*************	.830369E+00	.179893E+02	.410028E+00	.134656E+02
.572423E+09	.619783E+09	0.	*************	.706799E+00	.176441E+02	.398029E+00	.135611E+02
.575948E+09	.601842E+09	0.	*************	.601676E+00	.172938E+02	.386629E+00	.149733E+02
.588023E+09	.584771E+09	0.	*************	.512018E+00	.169405E+02	.375765E+00	.158010E+02
.763677E+09	.622684E+09	.237207E+10	.928298E-01	.197952E+01	.166751E+02	.436797E+00	.147862E+02
.115350E+10	.752055E+09	.323949E+10	.124660E+00	.383447E+01	.166151E+02	.538036E+00	.140784E+02
.128233E+10	.862464E+09	.279366E+10	.108434E+00	.516888E+01	.167453E+02	.585890E+00	.129658E+02
.120945E+10	.106606E+10	.495541E+10	.184597E+00	.756041E+01	.170890E+02	.788017E+00	.934046E+01
.177267E+10	.191994E+10	.107202E+11	.360622E+00	.125829E+02	.178611E+02	.161650E+01	.103638E+01
.145114E+10	.199296E+10	.136844E+10	.546261E-01	.118972E+02	.188817E+02	.107756E+01	0.
.173609E+10	.165560E+10	.468903E+10	.175544E+00	.129304E+02	.198804E+02	.109661E+01	0.
.144219E+10	.151376E+10	.532030E+09	.215984E-01	.937826E+01	.207044E+02	.893284E+00	0.
.100300E+10	.114227E+10	.311015E+10	.118931E+00	.136144E-05	.202033E+02	.646049E+00	0.
.172762E+10	.103404E+10	.481252E+10	.179752E+00	.140930E+01	.198225E+02	.702536E+00	0.
.129311E+10	.103140E+10	.353759E+10	.135355E+00	.223907E+01	.195667E+02	.653515E+00	0.
.131856E+10	.901093E+09	.154519E+10	.614650E-01	.105284E+01	.192716E+02	.533571E+00	0.
.100799E+10	.758288E+09	.190439E+10	.746285E-01	.981093E-06	.188051E+02	.466453E+00	0.
.947243E+09	.728511E+09	.300435E+10	.107602E+00	.137392E-06	.183500E+02	.480114E+00	0.
.990142E+09	.816525E+09	.466818E+10	.155251E+00	.120785E-06	.179059E+02	.568265E+00	0.
.100536E+10	.800516E+09	.263149E+10	.101699E+00	.138194E-05	.174725E+02	.487225E+00	0.
998393E+09	.787049E+09	.415411E+10	.145610E+00	.182978E-06	.170497E+02	.531020E+00	0.
: 869358E+09	.754554E+09	.269078E+10	.974998E-01	.135478E-06	.166370E+02	.462486E+00	0.
.690519E+09	.699645E+09	.294554E+10	.113195E+00	.162727E-05	.162344E+02	.450884E+00	0.
591672E+09	.622060E+09	.862939E+09	.302583E-01	.213072E-07	.158415E+02	.372677E+00	0.
: 644612E+09	.667632E+09	.469888E+10	.137117E+00	.475656E-07	.154581E+02	.480778E+00	0.
.114450E+10	.895878E+09	.601665E+10	.217065E+00	.165802E-05	.150839E+02	.657837E+00	0.
.892661E+09	.819956E+09	.192323E+10	.729690E-01	.185904E-06	.147189E+02	.446591E+00	0.
.634018E+09	.612722E+09	.160131E+10	.614349E-01	.179331E-06	.143626E+02	.366074E+00	0.
.916997E+09	.637769E+09	.373054E+10	.142213E+00	.188566E+01	.141358E+02	.462996E+00	0.
.731780E+09	.645720E+09	.610461E+09	.247430E-01	.159854E+01	.140027E+02	.388951E+00	0.
.621181E+09	.608115E+09	.204321E+10	.804780E-01	.259939E+01	.139102E+02	.408432E+00	0.
.777990E+09	.734315E+09	.381190E+10	.145089E+00	.456584E+01	.139959E+02	.540772E+00	0.
.745490E+09	.802456E+09	.167033E+10	.662776E-01	.501644E+01	.142252E+02	.512437E+00	0.
.596562E+09	.759378E+09	.471126E+09	.191496E-01	.458447E+01	.144468E+02	.480949E+00	0.
.542664E+09	.724784E+09	.550513E+09	.223404E-01	.427819E+01	.146174E+02	.465509E+00	0.
.502515E+09	.706192E+09	.549460E+09	.222981E-01	.397725E+01	.147482E+02	.455495E+00	0.
.535506E+09	.687595E+09	.492020E+08	.201719E-02	.342972E+01	.148267E+02	.440263E+00	.620949E+00
.682979E+09	.662402E+09	0.	.124905E-10	.292112E+01	.148403E+02	.423138E+00	.310568E+01
.660148E+09	.636109E+09	0.	.773418E-19	.248672E+01	.147982E+02	.406239E+00	.425906E+01
.641684E+09	.610947E+09	0.	.478904E-27	.211692E+01	.147100E+02	.390390E+00	.614655E+01
.650197E+09	.587533E+09	0.	.296540E-35	.180211E+01	.145837E+02	.375713E+00	.722765E+01
.630647E+09	.565874E+09	0.	.183619E-43	.153411E+01	.144264E+02	.362137E+00	.817737E+01
.619608E+09	.545816E+09	0.	.113698E-51	.130597E+01	.142437E+02	.349546E+00	.100517E+02
.593203E+09	.527181E+09	0.	.704021E-60	.111176E+01	.140408E+02	.337826E+00	.115046E+02

E.2 Example Output From Simulation Program Using Daily Meteorological Data (MSUM)

```
 COMBINED SUBBASINS:  1111111111111111111111

FROM MONTH AND YEAR 121969 TO MONTH AND YEAR 121978 IN CALENDAR MONTH GROUPS

     CONSTANT       Al.8 EDS      TBASE(C)      AREA(M2)
  .857945E+11  .710000E+09  .820000E+00  .128925E+12

CALENDAR MONTH AVERAGES
                         TEMPERATURE (C):  .201761E+01
                     PRECIPITATION (CM.):  .691433E+01
                              FLOW (CM.):  .323379E+01
            HEAT LOSS, WATER EQU. (CM.):  .246607E+02
                        NET SUPPLY (CM.):  .677832E+01
              EVAPOTRANSPIRATION (CM.):  .354454E+01
         POT. EVAPOTRANSPIRATION (CM.):  .211161E+02

     USZC(M3)  ALPPER(D-1)  ALPUEV(M-3)  ALPDPR(D-1)  ALPINT(D-1)
  .257850E+10  .360000E+01  .590000E-08  .800000E-02  .200000E-02

  ALPLEV (M-3)   ALPGW(D-1)  ALPGEV(M-3)   ALPSF(D-1)  ALPSEV(M-3)
  .480000E-03  .210000E-02 0.            .310000E+00 0.

CALENDAR MONTH STATISTICS
                         FLOW MEAN (CM.):  .323379E+01
                  FLOW STD. DE". (lx.):  .159509E+01

          MODEL 1            MEAN (CM.):  .322526E+01
              EVAPOTRANSPIRATION (CM.):  .352256E+01
                          MEAN SS (CM.):  .346486E+00
                        MEAN USZM (CM.):  .501341E-01
                        MEAN LSZM (CM.):  .901951E+01
                         MEAN GZM (CM.):  .341700E+02
                              RMSE (CM.):  .875349E+00
            COEFFICIENT OF CORRELATION:  .836002E+00
```

FLOW RATES AND NET SUPPLY IN CUBIC METERS PER CALENDAR MONTH				STORAGES IN CENTIMETERS OVER THE BASIN ON THE END OF THE MONTH			
ACTUAL FLOW	MODEL FLOW	NET SUPPLY	USZM	LSZM	GZM	SS	SNOW WATER
.264275E+10	.361580E+10	.135142E+11	.925656E-01	.101256E+02	.314700E+02	.326332E+00	0.
.468452E+10	.455534E+10	.159858E+11	.105257E+00	.175142E+02	.328588E+02	.397667E+00	0.
.637173E+10	.401765E+10	0.	.131356E-47	.130530E+02	.343875E+02	.319188E+00	.830881E+01
.445749E+10	.383600E+10	0.	.447904E-96	.957372E+01	.349104E+02	.300187E+00	.144955E+02
.357800E+10	.360616E+10	0.	**************	.702181E+01	.346833E+02	.282089E+00	.223080E+02
.321196E+10	.317545E+10	0.	**************	.525417E+01	.340041E+02	.265993E+00	.265149E+02
.350951E+10	.319357E+10	0.	**************	.385365E+01	.329438E+02	.249680E+00	.327371E+02
.655484E+10	.290337E+10	0.	**************	.285486E+01	.317055E+02	.234758E+00	.356093E+02
.111755E+11	.110920E+11	.524826E+11	.308501E+00	.314434E+02	.340122E+02	.106608E+01	0.
.460281E+10	.623639E+10	.769985E+10	.538117E-01	.272223E+02	.387509E+02	.455086E+00	0.
.421017E+10	.593500E+10	.163784E+11	.107703E+00	.168188E+02	.413608E+02	.463098E+00	0.

.539066E+10	.521699E+10	.158275E+11	.104270E+00	.694351E+01	.412085E+02	.393660E+00	0.
.439135E+10	.474674E+10	.135110E+11	.925444E-01	.137733E+02	.411512E+02	.415173E+00	0.
.442550E+10	.479120E+10	.643604E+10	.437533E-01	.143356E+02	.419416E+02	.387094E+00	0.
.423394E+10	.442525E+10	0.	.546018E-48	.106526E+02	.422657E+02	.357349E+00	.516941E+01
.289154E+10	.429243x+10	0.	.186184E-96	.781312E+01	.417974E+02	.335741E+00	.115197E+02
.286754E+10	.403164E+10	0.	*************	.573051E+01	.407733E+02	.315252E+00	.147389E+02
.240743E+10	.342884E+10	0.	*************	.433103E+01	.395308E+02	.297702E+00	.180278E+02
.491738E+10	.357339E+10	0.	• *************	.317658E+01	.379320E+02	.279311E+00	.229731E+02
.672857E+10	.766015E+10	.360989E+11	.229507E+00	.236167E+02	.388537E+02	.746325E+00	0.
.846933E+10	.609691E+10	.110118E+11	.737138E-01	.245041E+02	.422051E+02	.473988E+00	0.
.453181E+10	.602293E+10	.135307E+11	.926732E-01	.244847E+02	.453234E+02	.515069E+00	0.
.371028E+10	.403673E+10	.112437E+11	.124382E-01	.291561E-07	.424668E+02	.295298E+00	0.
.370409E+10	.350707E+10	.138450E+1 1	.411255E-02	.226175E-08	.397903E+02	.273684E+00	0.
.340881E+10	.381604E+10	.114947E+11	.792811E-01	.724393E+01	.382505E+02	.340022E+00	0.
.423113E+10	.410878E+10	.772522E+10	.522883E-01	.103475E+02	.379778E+02	.338492E+00	0.
.375348E+10	.381456E+10	0.	.652529E-48	.770442E+01	.377454E+02	.307402E+00	.616284E+01
.311561E+10	.369164E+10	0.	.222503E-96	.565079E+01	.369544E+02	.288688E+00	.110020E+02
.253672E+10	.346601E+10	0.	*************	.414455E+01	.357899E+02	.270978E+00	.164388E+02
.227949E+10	.294694E+10	0.	• *************	.313238E+01	.345315E+02	.255831E+00	.194220E+02
.253584E+10	.307047E+10	0.	• *************	.229744E+01	.330007E+02	.239976E+00	.233419E+02
.673101E+10	.564720E+10	.279960E+11	.182698E+00	.186254E+02	.335159E+02	.548889E+00	.913368E+01
.915616E+10	.648834E+10	.227985E+11	.146822E+00	.277738E+02	.370460E+02	.556810E+00	0.
715429E+10	.581398E+10	.112872E+11	.779060E-01	.265332E+02	.410968E+02	.484250E+00	0.
: 425424E+10	.364395E+10	.109802E+11	.379771E-02	.244954E-08	.385066E+02	.264327E+00	0.
.396002E+10	.380271E+10	.167632E+11	.872166E-01	.386188E-05	.360797E+02	.305076E+00	0.
.365633E+10	.351753E+10	.104798E+11	.725350E-01	.677545E+01	.347140E+02	.306945E+00	0.
.442433E+10	.384546E+10	.871150E+10	.587677E-01	.106185E+02	.346446E+02	.321384E+00	0.
.471184E+10	.357638E+10	0.	.733390E-48	.791006E+01	.346714E+02	.287769E+00	.765595E+01
.352848E+10	.345626E+10	0.	.250075E-96	.580161E+01	.341165E+02	.270310E+00	.110902E+02
. 350735E+10	.324566E+10	0.	*************	.425518E+01	.331620E+02	.253772E+00	.194793E+02
.293331E+10	.275999E+10	0.	*************	.321599E+01	.320746E+02	.239616E+00	.229106E+02
.319463E+10	.287602E+10	0.	*************	.235876E+01	.307158E+02	.224790E+00	.279780E+02
.723905E+10	.261335E+10	0.	*************	.174741E+01	.293137E+02	.211263E+00	.319461E+02
.940494E+10	.967206E+10	.481592E+11	.286730E+00	.284692E+02	.312722E+02	.933720E+00	0.
.548032E+10	.614100E+10	.149660E+11	.102002E+00	.244244E+02	.354822E+02	.461227E+00	0.
.332373E+10	.318992E+10	.850875E+10	.115519E-02	.283058E-09	.332459E+02	.227161E+00	0.
.224843E+10	.275784E+10	.709422E+10	.118061E-01	.460442E-07	.311505E+02	.215839E+00	0.
.247722E+10	.301379E+10	.100891E+11	.699253E-01	.646553E+01	.300406E+02	.270991E+00	0.
.255067E+10	.341544E+10	.843457E+10	.569528E-01	.102163E+02	.301794E+02	.287184E+00	0.
.344292E+10	.319039E+10	0.	.710741E-48	.761072E+01	.303978E+02	.256680E+00	.989777E+01
.323173E+10	.308318E+10	0.	.242352E-96	.558206E+01	.300505E+02	.241155E+00	.148818E+02
.265855E+10	.289582E+10	0.	*************	.409414E+01	.293070E+02	.226435E+00	.219616E+02
.250267E+10	.254819E+10	0.	• *************	.306350E+01	.283742E+02	.213390E+00	.269505E+02
.38 5638E+10	.256135E+10	0.	*************	.224691E+01	.272173E+02	.200204E+00	.366586E+02
. 121222E+11	.108342E+11	.528698E+11	.319120E+00	.312410E+02	.296249E+02	.108412E+01	0.
.635236E+10	.585843E+10	.265257E+10	.182675E-01	.248827E+02	.344808E+02	.397159E+00	0.
.374232E+10	.346481E+10	.131464E+11	.898821E-01	.341400E-03	.323758E+02	.270103E+00	0.
.268386E+10	.273177E+10	.854928E+10	.503225E-02	.573898E-08	.303352E+02	.208638E+00	0.
.211253E+10	.249663E+10	.541359E+10	.521093E-02	.103280E-07	.284233E+02	.194997E+00	0.
.181915E+10	.251211E+10	.615147E+10	.432244E-01	.396400E+01	.271744E+02	.218934E+00	0.
.191872E+10	.276041E+10	.531317E+10	.362582E-01	.639172E+01	.267239E+02	.228761E+00	0.
.200149E+10	.261195E+10	0.	.452483E-48	.476204E+01	.263818E+02	.210816E+00	.465846E+01
.176188E+10	.253143E+10	0.	.154290E-96	.349270E+01	.257006E+02	.197937E+00	.105973E+02
.138803E+10	.237624E+10	0.	• *************	.256171E+01	.248006E+02	.185762E+00	.151920E+02

.128406E+10	.202007E+10	0.	*************	.193610E+01	.238698E+02	.175356E+00	.202225E+02
.304561E+10	.210450E+10	0.	*************	.142003E+01	.227644E+02	.164471E+00	.302340E+02
.707199E+10	.859308E+10	.459449E+11	.283241E+00	.272993E+02	.248701E+02	.867952E+00	0.
.401471E+10	.516607E+10	.708164E+10	.480368E-01	.241021E+02	.294727E+02	.367980E+00	0.
.268344E+10	.505992E+10	.140506E+11	.960630E-01	.258032E+02	.334856E+02	.445573E+00	0.
.246577E+10	.307133E+10	.111845E+11	.102355E-01	.191910E-07	.313752E+02	.218625E+00	0.
.212258E+10	.379214E+10	.171621E+11	.112567E+00	.924036E+01	.306258E+02	.340157E+00	0.
.653547E+10	.436872E+10	.161216E+11	.109447E+00	.169478E+02	.318574E+02	.392631E+00	0.
.632173E+10	.442477E+10	.818757E+10	.553311E-01	.177784E+02	.340305E+02	.361510E+00	0.
.521743E+10	.406809E+10	0.	.690503E-48	.132117E+02	.355307E+02	.328009E+00	.802531E+01
.39 5945E+10	.394194E+10	0.	.235451E-96	.969005E+01	.360143E+02	.308470E+00	.150665E+02
.323661E+10	.370558E+10	0.	• [illegible]	.710714E+01	.357416E+02	.289860E+00	.182171E+02
.263878E+10	.315353E+10	0.	*************	.537146E+01	.350472E+02	.273869E+00	.198967E+02
.268996E+10	.328810E+10	0.	*************	.393968E+01	.339454E+02	.257069E+00	.228337E+02
.567317E+10	.540084E+10	.253320E+11	.166762E+00	.183649E+02	.345517E+02	.518338E+00	.664289E+01
.641167E+10	.616814E+10	.204371E+11	.132623E+00	.261730E+02	.377832E+02	.526863E+00	0.
.530317E+10	.567802E+10	.105616E+11	.730806E-01	.255552E+02	.414936E+02	.475969E+00	0.
.420864E+10	.405810E+10	.153147E+11	.603755E-01	.104559E-05	.388784E+02	.302491E+00	0.
.353986E+10	.344071E+10	.150730E+11	.312985E-01	.167647E-06	.364281E+02	.267493E+00	0.
.313495E+10	.333700E+10	.866160E+10	.603302E-01	.535615E+01	.348715E+02	.290152E+00	0.
.289258E+10	.359997E+10	.676510E+10	.459390E-01	.834696E+01	.343428E+02	.297443E+00	0.
.261768E+10	.337000E+10	0.	.573294E-48	.621771E+01	.339297E+02	.271736E+00	.621540E+01
.275585E+10	.326298E+10	0.	.195485E-96	.456036E+01	.330728E+02	.255142E+00	.119689E+02

Appendix F.--CALIBRATION PROGRAMS (CALIB AND MMCAL)

F.1 Instructions for Calibration Programs

Appendices C and F-H illustrate the calibration of parameters for the Large Basin Runoff Model. This appendix contains instructions on program use and requirements; it also contains source code listings (ANSI Ver. X3.9-1966 FORTRAN) for two versions of the model. The first, CALIB, uses daily hydrometeorological data and allows the user to specify the mass-balance computation interval, which is then fixed throughout the calibration. The second, MMCAL, uses monthly hydrometeorological data; the mass-balance interval automatically varies between 28-31 days, depending on the month and year. Appendix C contains example input files of daily and monthly hydrometeorological data (the files called DATA and MDATA, respectively). Appendix G contains two example parameter files. The first file is used to start the calibration; initial parameter values are chosen by the user. The second file is a result of the calibration; it contains the optimized parameter values, i.e., the parameters that produce the lowest root-mean-square error between actual and model flows. Appendix H is an example calibration for the lumped-parameter 7-d model as applied to the entire Lake Superior Basin; it uses the example input parameter and daily data files (PARAM and DATA, respectively) presented herein.

F.1.1 Comments on Source Code

The following comments apply for both source code listings in this appendix (both CALIB and MMCAL). No changes to the source code are required for application to the basins of Lakes Superior, Michigan, or Ontario. Lines 00310-00315 describe dimension requirements for an array defined in line 00230. Line 00205 creates arrays for the January through December average midmonth cloudless day insolation (10 langleys/d), which are specified in lines 00494-00500 for applications to Lake Ontario (by using insolation at Ithaca and Toronto), Lake Superior (by using insolation at Sault St. Marie), and Lake Michigan (by using insolation at Madison), respectively. The appropriate insolation array is chosen in lines 00507-00519 based on the parameter input file heading. Use of the model for other areas hence requires modification of these program elements to agree with the intended application. Also, if evapotranspiration from the groundwater zone or evaporation from surface storages is considered to be important, lines 00600 and 00610, respectively, may be changed.

F.1.2 Model Using Daily Hydrometeorological Data (CALIB)

The calibration program CALIB requires two input files, one containing initial user-chosen parameter values and other application-specific information (the file called PARAM) and one containing daily hydrometeorological data (the file called DATA).

F.1.2.1 <u>Input Initial Parameter File (PARAM)</u>. The initial parameter file contains 15 lines. The first line is a header indicating the specific lake and basin application; the first four characters are used in selecting the proper insolation array within CALIB. The second line is the watershed area in square meters. Line 3 defines the number of days to be used to initialize the model storages prior to actual calibration, with respect to the starting date specified on the next line. Lines 4 and 5 indicate the first and last dates (DDMMYYYY), respectively, of that portion of the data set to be used in calibration including the initialization period. Line 6 is the mass-balance computation interval. Lines 7-15 provide initial parameter values, each with an associated figure indicating the number of significant figures on which the optimization should initially operate. Thus, when the calibration begins, the initial parameter values are rounded based on the number of significant figures specified, then each parameter, in rotation, is systematically varied in the least significant digit. The parameters are listed in this order: T_b, a, α_{per}, β_{eu}, α_{int}, α_{dp}, β_{el}, α_{gw}, α_{sf}. Line 16 specifies the parameter with which to begin the optimization. For example, a 1 would indicate that the optimization begins with the first parameter, which is currently .170E+01. The last line indicates the maximum number of significant figures to use in the optimization for all parameters. When there is no change in any parameter to the specified number of significant digits given with each parameter, all such numbers are incremented by one and the optimization continues until the maximum number of significant digits is reached. When all parameters have been calibrated at this level of optimization, the program terminates automatically. If the user wants to set a parameter's value as a constant and have it unchanged in the optimization, then he or she can simply set the number of significant digits for that parameter to zero in the initial parameter set.

F.1.2.2 Input Data File (DATA). A partial listing of DATA is given in appendix C; it contains the date, minimum daily air temperature, maximum daily air temperature, daily precipitation volume over the watershed, and daily basin outflow volume from the watershed, each in the units indicated in the file. The first four lines are header information skipped over by the program. Missing data is denoted by "-9999." and is subsequently filled in by the model, which uses the value for the previous day.

F.1.2.3 Output Calibration Session (RESULT). An example of a typical calibration session is given in appendix H. The calibration program may require operator intervention to control the behavior of parameter values. Since the program continually updates the parameter values in a separate file, the user has a potential initial parameter set for the next run if program execution is terminated. Depending on the selection of initial values, it is possible for parameters to reach an obvious local optimum. For example, setting a parameter initially to a very large or very small value may restrict the search such that the parameter value stays near the limit. Determination of good initial values depends on operator experience. This particular example was run as a batch job; there are no computational changes for interactive use. An asterisk does not appear, however, next to the current parameter being optimized. Also, the program CALIB must have the variable of line number 00560 set to 0 to run the program interactively. The program is listed in this fashion; in batch mode, it is set to 1. The terminal output documents the systematic search of the parameter space for each parameter selected in rotation. Each line contains the nine parameter values used for a single iteration, followed by the calculated correlation coefficient and root-mean-square error between actual outflow volumes and model outflow volumes;

root-mean-square error is expressed as depth in centimeters over the basin area. In this particular example, the optimization began on the first significant figure; as a result, the given initial values were rounded. After several iterations on the nine parameters, the optimum for a single significant figure is reached. At this point, the optimization moves automatically to the second significant figure. After several more cycles of the parameter set, the optimum for two significant figures is reached. Since a maximum of two significant figures was specified, the program automatically terminates. The final line is the optimized parameter set, correlation coefficient, and root-mean-square error expressed as depth in centimeters over the basin area. It should be pointed out that the parameter values are limited to the range of .lOE-09 to .99E+9 (except for parameter 2, a, which has no set upper limit). Thus, the fourth parameter was never reduced during the example optimization.

F.1.2.4 Output Final Parameter File (PARAM). During the calibration process, the parameter file (PARAM) is constantly updated. If the calibration is interrupted, computations can resume from the break since the parameter file is continually being rewritten by the program. The final PARAM file resulting from the described calibration is given in appendix G. As before, the first six lines contain the heading for the specific lake and basin application, watershed area, initialization period, first and last dates of the calibration period, and mass-balance interval, respectively. The nine subsequent lines contain optimum parameter values, each with its current significant figure increment. Line 16 indicates on which parameter the calibration ended. Line 17 indicates the present limit on the number of digits used in convergence. The last line contains the correlation coefficient and the minimum root-mean-square error (expressed as centimeters over the basin), respectively, between actual outflow volumes and model outflow volumes. As mentioned in appendix B, this parameter file can be used unchanged in the simulation model.

F.1.3 Model Using Monthly Hydrometeorological Data (MMCAL)

The calibration program, MMCAL, is also presented in this appendix, but no example calibration session is provided since it appears similar to appendix H. Subroutines OUTFLOW, UPDATE, and WRT are identical to those in CALIB and are omitted from the source code listing for brevity. Using monthly hydrometeorological data to calculate the model is not illustrated herein; it is similar to that in the previous section except for the input file contents. MMCAL requires two input files, one containing initial user-chosen parameter values and other application-specific information (the file called MPAR) and one containing monthly hydrometeorological data (the file called MDATA).

F.1.3.1 Input Initial Parameter File (MPAR). MPAR differs from PARAM in only three respects. Line 3 defines the number of months to be used to initialize the model storages prior to actual calibration, with respect to the starting date specified on the next line. Lines 4 and 5 still indicate the first and last dates, respectively, of that portion of the data set to be used in calibration, including the initialization period; the format, however, is MMYYYY . The mass-balance computation interval (line 6 in PARAM) is eliminated, since the monthly simulation program automatically varies the mass-balance interval based on the specific month.

F.1.3.2 Input Data File (MDATA)

A complete listing of MDATA is given in appendix C; it contains the date (month and year), number of days in the specific month, average monthly air temperature, monthly precipitation volume over the watershed, and monthly basin outflow volume from the watershed, each in the units indicated in the file. The first four lines are header information skipped over by the program. There should be no missing temperature or precipitation data. Missing data for flow are denoted by "-9999."

F.2 Source Code for Calibration Program Using Daily Data (CALIB)

```
      PROGRAM CALIB(DATA,TAPE5=DATA,OUTPUT,TAPE6=OUTPUT,
+                     RESULT,TAPE8=RESULT,PARAM,TAPE7=PARAM)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
      COMMON/OTPT/AREA,ISTART,INODAYS,INDPGOD,IPARM,PARM,IXRC,INOCHNG,
+                 S,EXVAS,IFDMR,ILDMR,IHEAD1,IHEAD2,IHEAD3,IHEAD4
      COMMON/OTPT2/TBASE,ALBEDS,EXVA,SSQERR
      DIMENSION ONTI(12),ONTT(12),SUP(12),MICH(12)
      DIMENSION R(14),INDPM(13)
      DIMENSION PARM(9),IXRC(9)
      DIMENSION DATA(8,5313)
      DIMENSION INAME(8)
      DIMENSION IERR(6)
      DATA IERR/6*0/
      DATA INDPM/0,31,59,90,120,151,181,212,243,273,304,334,366/
CC*****
CC***** PROGRAM FOR INTERACTIVE INVESTIGATION OF MODEL
CC*****
CC        NOTE -- THE ARRAY 'DATA' SHOULD BE DIMENSIONED AS:
CC                DATA(8,NUMBER OF DAYS IN DATA SET)
CC*****
CC  AREA    = WATERSHED AREA, SQ. M.
CC  FLOW    = ACTUAL BASIN OUTFLOW VOLUME, CUB. M.
CC  ID      = CALENDAR DAY OF THE YEAR
CC IFDMR = FIRST DAY FOR MODEL RUN (DDMMYYYY)
CC ILDMR = LAST DAY FOR MODEL RUN (DDMMYYYY)
CC  IM      = CALENDAR MONT" OF THE YEAR
CC INDPGOD= NUMBER OF DAYS PER GROUP OF DAYS, DAYS
CC INODAYS= NUMBER OF DAYS TO BE CONSIDERED IN DATA SET, DAYS
CC  IY      = CALENDAR YEAR
CC  PRECIP  = DAILY PRECIPITATION VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  R       = AVERAGE MID-MONTH CLOUDLESS-DAY INSOLATION, LANGLEYS/DAY
CC            (INPUT IN "NITS OF 10*LANGLEYS/DAY)
CC  RR      = DAILY SURFACE INSOLATION, CAL.
CC  SNW     = SNOWPACK VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  TA      = AVERAGE DAILY AIR TEMPERATURE, DEG. C.
CC  TMAX    = MAXIMUM DAILY AIR TEMPERATURE, DEG. C.
CC  TMIN    = MINIMUM DAILY AIR TEMPERATURE, DEG. C.
CC*****
CC*****
CC***** INPUT CONSTANTS
CC*****
      DATA ONTI/20.,33.,46.,59.,69.,74.,70.,62.,51.,38.,24.,18./
      DATA ONTT/20.,31.,46.,60.,70.,74.,71.,61.,48.,34.,22.,18./
```

```
      DATA SUP/19.,33.,49.,64.,77.,79.,77.,67.,51.,36.,20.,15./
      DATA MICH/22.,34.,48.,62.,70.,73.,70.,61.,49.,36.,24.,19./
      REWIND 7
      READ(7,2000) ILAKE
 2000 FORMAT(A4)I=1,12
      IF(ILAKE.EQ.4HIONT) R(I)=ONTI(I)
      IF(ILAKE.EQ.4HTONT) R(I)=ONTT(I)
      IF(ILAKE.EQ.4HSUPE) R(I)-SUP(I)
      IF(ILAKE.EQ.4HMICH) R(I)=MICH(I)
   45 CONTINUE
CC*****
CC        NOTE -- SYSTEM SPECIFIC PROCEDURE SUPPLIES ZERO
CC                WHEN EXPONENTIAL UNDERFLOW OCCURS
CC*****
      CALL SYSTEMC(115,IERR)
CC*****
      REWIND 7
      READ(7,3000)IHEAD1,IHEAD2,IHEAD3,IHEAD4
 3000 FORMAT(4A10)
CC*****
CC***** IBATCH = 1 FOR BATCH JOB; = 0 FOR INTERACTIVE JOB
CC*****
      IBATCH=0
      EPSILON-l.E-7
      DPSILON=1.E-200
      GPSILON=1.E-3
      ALPGEV=0.
      ALPSEV=0.
      R(14)=R(1)*10.
      DO 33 IXY=1,12
   33 R(14-IXY)=R(13-IXY)*10.
      R(1)=R(13)
      READ(7,559) AREA
      READ(7,560) ISTART
  560 FORMAT(I8)
      READ(7,560) IFDMR
      READ(7.560) ILDMR
      READ(7,560) INDPGOD
      CALL LENGTH(IFDMR,ILDMR,INODAYS)
      DAY=FLOAT(INDPGOD)
      IIST=ISTART/INDPGOD
CC*****
CC***** SYSTEMATIC PARAMETER SEARCH
CC*****
      IFTFG=1
      IRTN=0
      ICNT=0
      IRPTFG=1
      IUPDN=1
      IOPTFG=-1
      USZC=AREA*0.02
      DO 36 I=1,9
      READ(7.557) PARM(I),IXRC(I)
```

```
      IF(PARM(I).LT..1E-9) PARM(I)=.1E-9
      XRCC=10.**(1-IXRC(I)+INT(ALOG10(PARM(I)*.99999)))
      IF(PARM(I).LT.1.00001)XRCC=XRCC/10.
      PARM(I)=PARM(I)+XRCC/2.
      XRCC=10.**(1-IXRC(I)+INT(ALOG10(PARM(I)*.99999)))
      IF(PARM(I).LT.1.00001)XRCC=XRCC/10.
      PARM(I)=INT(PARM(I)*1.00001/XRCC)*XRCC
   36 CONTINUE
      READ(7,560, IPARM
      READ(7,560) INOCHNG
      IF(INOCHNG.LT.1.OR.INOCHNG.GT.2) I=IFTFG/IRTN
      DO 37 I=1,9
      IF(IXRC(I).GT.INOCHNG) IXRC(I)=INOCHNG
   37 CONTINUE
CC*****
CC*****       INPUT AND FILL IN DAILY DATA
CC*****
      REWIND 5
      READ(5,1000) INAME
      REWIND 8
      IF(IBATCH.EQ.0)GOTO 996
      WRITE(8,1060) INAME
 1060 FORMAT(3X,22HCALIBRATION RUN FOR    ,8A10)
      WRITE(8,1070) AREA,ISTART,INODAYS,INDPGOD
 1070 FORMAT(/,3X, 7HAREA = ,E13.6E2,
+           /,3X,36HLASTDAY OF INITIALIZATION PERIOD = ,I5,
+           /,3X,43HTOTAL NUMBER OF DAYS USED IN CALIBRATION = ,I5,
+           /,3X,31HMASS-BALANCE INTERVAL (DAYS)  = ,I5,//)
  996 CONTINUE
      READ (5,1000)
      READ (5,1000)
      READ(5,1000)
   15 READ(5,1010) ID,IM,IY,TMIN,TMAX,PRECIP,FLOW
      IF(ID*1000000+IM*10000+IY.NE.IFDMR)GOTO 15
      BACKSPACE 5
      DO 600 I=1,INODAYS
      READ(5,1010) ID,IM,IY,NTMIN,NTMAX,NPRECIP,FLOW
 1010 FORMAT(1X,I3,I3,I5,5X,2F10.2,2F20.0)
      IF(NTMIN.GT.NTMAX.OR.NTMIN.LT.-900..OR.NTMAX.LT.-900.) GOTO 920
      GOTO 921
  920 NTMIN=TMIN
      NTMAX=TMAX
  921 TMIN=NTMIN
      TMAX=NTMAX
      IF(NPRECIP.LT.-900.) NPRECIP=PRECIP
      PRECIP=NPRECIP
CC*****
CC*****       COMPUTE DAILY INSOLATION
CC*****
      X=(TMAX-TMIN)/15.
      X=AMIN1(X,1.0)
      IF(ID.GT.15) GOTO 203
      IF(IM.EQ.1) GOTO 200
      II=INDPM(IM)-INDPM(IM-1)
```

```
      IF(II.NE.28) GOTO 201
      IF(INT((FLOAT(IY)+.5)/4.)*4.NE.IY) GOTO 201
      II-29
      GOTO 201
  200 II-31
  201 NDYS=FLOAT(II)
      NDY=NDYS-15.+FLOAT(ID)
      RR=(R(IM+1)-R(IM))/NDYS*NDY+R(IM)
      GOTO 204
  203 II=INDPM(IM+1)-INDPM(IM)
      IF(II.NE.28) GOTO 202
      IF(INT((FLOAT(IY)+.5)/4.)*4.NE.IY) GOTO 202
      II-29
  202 NDYS=FLOAT(II)
      NDY=FLOAT(ID)-15.
      RR=(R(IM+2)-R(IM+1))/NDYS*NDY+R(IM+1)
  204 RR=RR*(0.355+0.68*X)*10000.*AREA
      DATA(2,I)=TMAX
      DATA(8,I)=TMIN
      DATA(3,I)=FLOW
      DATA(5,I)=PRECIP
      DATA(6,I)=RR
  600 CONTINUE
      REWIND 5
CC*****
CC*****  GROUP FLOW BY THE NUMBER OF DAYS PER GROUP OF DAYS (INDPGOD)
CC*****
      IKNTR=0
      INMP=0
      AVGF -0.
      "AR-0.
      MEAN=0.
      FLOW=0.
      II=0
      III-0
      INVD=0
      DO 610 I=1,INODAYS
      IF(DATA(3,I).LT.-900.)GOTO 620
      IF(I.LE.ISTART) GOTO 620
      AVGF = AVGF + DATA(3,I)
      IKNTR = IKNTR + 1
  620 CONTINUE
      IF(DATA(3,I).LT.-900.)GOTO 621
      FLOW = FLOW + DATA(3,I)
      INVD=INVD+1
  621 II=II+1
      IF(II.NE.INDPGOD) GOTO 610
        III = III + 1
        IF(INVD.LT.INDPGOD)GOTO 622
        FLOW=FLOW*II/INVD
        GOTO 623
  622   FLOW=-9999.
  623   DATA(3,III)=FLOW
        IF(III.LE.IIST) GOTO 630
```

```
           IF(FLOW.LT.-900.)GOTO 630
           "AR = "AR + FLOW**2
           MEAN = MEAN + FLOW
           INMP=INMP+1
  630  FLOW = 0.
         II = 0
         INVD=0
  610 CONTINUE
      FI=FLOAT(INMP)
      "AR = VAR/FI
      MEAN = MEAN/FI
      VAR = VAR - MEAN**2
      AVGF = AVGF/FLOAT(IKNTR)
CC*****
CC*****
CC*****
      TBASE =PARM(1)
      ALBEDS=PARM(2)
      ALPPER=PARM(3)
      ALPUEV=PARM(4)
      ALPINT=PARM(5)
      ALPDPR=PARM(6)
      ALPLEV=PARM(7)
      ALPGW =PARM(8)
      ALPSF =PARM(9)
      IF(IBATCH.EQ.0)GOTO = 990
      IBATCH=2
  990 CALL WRT(IBATCH)
      IF(IBATCH.EQ.0)GOTO 991
      IBATCH=1
  991 S=0.1E+99
      GOTO 26
   20 XRCC=10.**(1-IXRC(IPARM)+INT(ALOG10(PARM(IPARM)*.99999)))
      IF(PARM(IPARM).LT.1.00001)XRCC=XRCC/10.
      IF(INT(PARM(IPARM)/XRCC*1.00001).NE.10**IXRC(IPARM))GOTO 21
      IF(IUPDN.NE.1)GOTO 21
      XRCC=XRCC*10.
   21 PARM(IPARM)=(INT(PARM(IPARM)*1.00001/XRCC)+IUPDN)*XRCC
      IF(PARM(IPARM).LT..99999E-10.OR.(IPARM.NE.2.AND.
     +   PARM(IPARM).GT..99999E+9))GOTO 22
      TBASE  = PARM(1)
      ALBEDS = PARM(2)
      ALPPER = PARM(3)
      ALPUEV = PARM(4)
      ALPINT = PARM(5)
      ALPDPR = PARM(6)
      ALPLEV = PARM(7)
      ALPGW  = PARM(8)
      ALPSF  = PARM(9)
      IF(IRPTFG.EQ.0) GOTO 554
      IRPTFG=0
      IF(IPARM.LE.2) IRPTFG=1
CC*****
CC***** FIND SUM OF SQUARED ERRORS
```

```
CC*****
      IF(IPARM.NE.2.AND.IPARM.NE.3.AND.IFTFG.EQ.0)GOTO 310
      SNW=0.
      AVGRR=0.
      IFTFG = 0
CC*****
CC***** DAILY LOOP - DATA PREPERATION (BEGINNING)
CC*****
      DO 300 I=1.INODAYS
CC*****
CC*****       HEAT BALANCE
CC*****
      TMAX=DATA(2,I)
      TMIN=DATA(8,I)
      TA=(TMAX+TMIN)/2.
      RR = DATA(6,I)
      PRECIP = DATA(5,I)
      MELT-0.
      IF(TA.LE.0.)GOTO 903
      IF(SNW.LT.1.)GOTO 904
      IF(TMIN.LT.0.)GOTO 950
      DD=TA
      GOTO 951
  950 DD=TMAX**2/(TMAX-TMIN)/2.
  951 MELT=ALBEDS*DD
      IF(MELT.LE.SNW)GOTO 904
      MELT-SW
  904 SNW=SNW-MELT
      NS=PRECIP+MELT
      GOTO 905
  903 SNW=SNW+PRECIP
      NS-0.
  905 DATA(1,I)=NS
      IF(I.LE.ISTART)GOTO 300
      AVGRR=AVGRR+RR-MELT*1000000.*79.7
  300 CONTINUE
CC*****
CC***** DAILY LOOP - DATA PREPARATION (END)
CC*****
CC*****
CC***** SUMMARY INFORMATION
CC*****
  310 AVGHPLE=0.
      DO 910 I=1,INODAYS
      TA=(DATA(2,I)+DATA(8,I))/2.
      HPLSE=EXP(TA/TBASE)
      DATA(4,I)=HPLSE
      IF(I.LE.ISTART)GOTO 910
      AVGHPLE=AVGHPLE+HPLSE
  910 CONTINUE
      CONS=AVGRR/AVGHPLE
      DO 911 I-1;INODAYS
      TA=(DATA(2,I)+DATA(8,I))/2.
      HPLSE=DATA(4,I)/(596.-.52*TA)/1000000.*CONS
```

```
  911 DATA(4,I)=HPLSE
CC*****
CC***** CONVERT TO GROUPS OF DAYS INPUTS
CC*****
      NS=0.
      HPLSE=0.
      II-0
      III-0
      DO 400 I=1,INODAYS
      NS=NS+DATA(1,I)
      HPLSE=HPLSE+DATA(4,I)
      II=II+1
      IF(II.NE.INDPGOD)GOTO 400
      III=III+1
      DATA(7,III)=NS
      DATA(4,III)=HPLSE
      IF(III.LE.IIST)GOTO 710
  710 NS-O.
      HPLSE=0.
      II-0.
  400 CONTINUE
CC*****
CC***** INPUT INITIAL VARIABLE VALUES
CC*****
  554 USZM=.00698*AREA/100.
      LSZM=.03335*AREA/100.
      GZM=0.0000*AREA/100.
      SS=.00931*AREA/100.
CC*****
CC***** INITIALIZE
CC*****
      AVGFM = 0.
      "ARM-0.
      PROD-o.
      SSQERR = 0.
      IFII=0
CC*****
CC***** DAILY LOOP (BEGINNING)
CC*****
      DO 100 I=1,III
CC*****
CC*****       INPUT DAILY PREPARED DATA
CC*****
      NS=DATA(7,I)
      HPLSE=DATA(4,I)
      FLOW   = DATA(3,I)
CC*****
CC*****       MASS BALANCE
CC*****
      CALL OUTFLOW (NS)
CC*****
      IF(FLOW.LT.-900.)GOTO 100
      IF(I.LE.IIST)GOTO 100
      AVGFM=AVGFM+NS
```

```
      VARM=VARM+NS**2
      PROD=PROD+FLOW*NS
      SSQERR=SSQERR+(FLOW-NS)**2
      IFII=IFII+1
  100 CONTINUE
CC*****
CC***** DAILY LOOP (END)
CC*****
CC*****
CC***** SUMMARY INFORMATION
CC*****
      FI=FLOAT(IFII)
      AVGFM=AVGFM/FI
      VARM=VARM/FI
      VARM=VARM-AVGFM**2
      PROD=PROD/FI
      EXVA=(PROD-MEAN*AVGFM)**2/VAR/VARM
      SSQERR=SSQERR/FI
      SSQERR=SQRT(SSQERR)/AREA*100.
      EXVA=SQRT (EXVA)
      CALL WRT(IBATCH)
  557 FORMAT(E10.3E2,2X,I1)
      CALL UPDATE(IBATCH)
      IF(SSQERR.GE.S) GOTO 22
      S=SSQERR
      EXVAS=EXVA
      IRTN=IRTN+1
      IOPTFG=IOPTFG+1
      GOTO 20
   22 PARM(IPARM)=PARM(IPARM)-XRCC*FLOAT(IUPDN)
      CALL UPDATE(IBATCH)
      IF(IOPTFG.GT.0) GOTO 23
      IOPTFG=1
      IUPDN=-1
      GOTO 20
   23 IOPTFG=0
      IUPDN=1
   27 ICNT=ICNT+1
      IF (IRTN.NE. 0)ICNT=0
      IRTN=0
      IF(ICNT.NE.8)GOTO 24
      ICNT=0
      IRELCNG=0
      DO 35 I=1,9
      IF(IXRC(I).EQ.0)GOTO 38
      IXRC(I)=IXRC(I)+1
      IF(IXRC(I).LE.INOCHNG)GOTO 35
      IXRC(I)=INOCHNG
   38 IRELCNG=IRELCNG+1
   35 CONTINUE
      IF(IRELCNG.EQ.9)GOTO 34
   24 IPARM=IPARM+1
      IPARMM=IPARM
      IF(IPARM.GE. 10)IPARM=1
```

```
      CALL UPDATE(IBATCH)
      IPARM=IPARMM
   28 IF(IPARM.LT.10)GOTO 26
      IPARM=1
      IRPTFG=1
   26 IF(PARM(IPARM).GT..1E+98.OR.IXRC(IPARM).EQ.0)GOTO 27
      GOTO 20
  559 FORMAT(6E13.6E2)
   34 WRITE(6.557)
      IF(IBATCH.EQ.1) WRITE(8,557)
      CALL UPDATE(IBATCH)
      TBASE =PARM(1)
      ALBEDS=PARM(2)
      ALPPER=PARM(3)
      ALPUEV=PARM(4)
      ALPINT=PARM(5)
      ALPDPR=PARM(6)
      ALPLEV=PARM(7)
      ALPGW =PARM(8)
      ALPSF =PARM(9)
      EXVA=EXVAS
      SSQERR=S
      IF(IBATCH.EQ.0)GOTO 992
      IBATCH=2
  992 CALL WRT(IBATCH)
      REWIND 8
      STOP
 1000 FORMAT(8A10)
      END
      SUBROUTINE OUTFLOW (NS)
      IMPLICIT REAL (A-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
CC*****
CC ALPDPR = LINEAR RESERVOIR CONSTANT FOR DEEP PERCOLATION, IN". DAYS
CC ALPGEV = PARTIAL CONSTANT OF GROUNDWATER EVAPORATION, INV. CUB. M.
CC ALPGW = LINEAR RESERVOIR CONSTANT FOR GROUNDWATER FLOW, INV. DAYS
CC ALPINT = LINEAR RESERVOIR CONSTANT FOR INTERFLOW, IN". DAYS
CC ALPLEV = PARTIAL CONSTANT OF LOWER ZONE EVAPORATION, INV. CUB. M.
CC ALPPER = LINEAR RESERVOIR CONSTANT FOR PERCOLATION, IN". DAYS
CC ALPSEV = PARTIAL CONSTANT OF SURFACE EVAPORATION, IN". CUB. M.
CC ALPSF = LINEAR RESERVOIR CONSTANT FOR SURFACE FLOW, INV. DAYS
CC ALPUEV = PARTIAL CONSTANT OF UPPER ZONE EVAP., INV. CUB. M.
CC DAY    -TIME IN ONE GROUP OF DAYS (WEEK, MONTH, ETC.), DAYS
CC EVAP   = TOTAL EVAPOTRANSPIRATION VOLUME, CUB. M.
CC EVPRP  = POTENTIAL EVAPOTRANSPIRATION RATE, CUB. M./DAY
CC GZM    = GROUNDWATER ZONE MOISTURE, CUB. M.
CC HPLSE  = TOTAL ENERGY OUT (EVAP. + POT. EVAP.) WATER EQ"., CUB. M.
CC LSZM   = LOWER SOIL ZONE MOISTURE, CUB. M.
CC NS     = NET SUPPLY VOLUME, CUB. M.
CC NS     = BASIN OUTFLOW VOLUME, CUB. M.
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CC NSR    = NET SUPPLY RATE, CUB. M./DAY
CC R      = DUMMY VARIABLE FOR STORAGE OF INTERMEDIATE RESULTS
CC SS     = SURFACE WATER STORAGE, CUB. M.
CC T      = DUMMY VARIABLE FOR STORAGE OF INTERMEDIATE RESULTS
CC USZC   = UPPER SOIL ZONE MOISTURE CAPACITY, CUB. M.
CC USZM   = UPPER SOIL ZONE MOISTURE, CUB. M.
CC VDPR   = DEEP PERCOLATION VOLUME, CUB. M.
CC VGEV   = GROUNDWATER ZONE EVAPOTRANSPIRATION VOLUME, CUB. M.
CC VGW    = GROUNDWATER ZONE OUTFLOW VOLUME, CUB. M.
CC VINF   = INFILTRATION VOLUME, CUB. M.
CC VINT   = INTERFLOW VOLUME, CUB. M.
CC VLEV   = LOWER ZONE EVAPOTRANSPIRATION VOLUME, CUB. M.
CC VPER   = PERCOLATION VOLUME, CUB. M.
CC VRUN   = SURFACE RUNOFF VOLUME, CUB. M.
CC VUEV   = UPPER ZONE EVAPOTRANSPIRATION VOLUME, CUB. M.
CC*****
      NSR=NS/DAY
      EVPRP=HPLSE/2./DAY
      IF(EVPRP.LE.DPSILON)GOTO 903
  904 B=NSR/USZC+ALPPER+ALPUEV*EVPRP
      C=NSR/B
      A=USZM-C
      USZMAVG=A/B*(1.-EXP(-B*DAY))/DAY+C
      D=ALPINT+ALPDPR+ALPLEV*EVPRP
      IF(ABS((D-B)/D).LE.EPSILON.OR.ABS(D-B).LE.DPSILON)GOTO 905
      F=ALPPER*A/(D-B)
      G=ALPPER*C/D
      E=LSZM-F-G
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/B*(1.-EXP(-B*DAY)))/DAY+G
      GOTO 906
  905 F=ALPPER*A
      G=ALPPER*C/D
      E=LSZM-G
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/D**2*(1.-(D*DAY+1.)
     +        *EXP(-D*DAY)))/DAY+G
  906 EVPRPO=EVPRP
      EVPRP=HPLSE/DAY/(1.+ALPUEV*USZMAVG+ALPLEV*LSZMAVG)
      IF(ABS((EVPRP-EVPRPO)/EVPRP).GT.EPSILON)GOTO 904
  903 B=NSR/USZC+ALPPER+ALPUEV*EVPRP
      C=ALPPER*NSR/B
      A=ALPPER*USZM-C
      T=EXP(-B*DAY)*A/ALPPER+NSR/B
      USZMAVG=(A/B*(1.-EXP(-B*DAY))/DAY+C)/ALPPER
      R=NS+USZM-T
      USZM=T
      VINF=NS-R*NSR/USZC/B
      VPER=R*ALPPER/B
      VRUN=NS-VINF
      VUEV=R-VRUN-VPER
      D=ALPINT+ALPDPR+ALPLEV*EVPRP
      IF(ABS((D-B)/D).LE.EPSILON.OR.ABS(D-B).LE.DPSILON)GOTO 100
      F=A/(D-B)
      G=C/D
      E=LSZM-F-G
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      T=E*EXP(-D*DAY)+F*EXP(-B*DAY)+G
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/B*(1.-EXP(-B*DAY)))/DAY+G
      R=VPER+LSZM-T
      IF(ALPDPR.LT.DPSILON)GOTO 910
      E=ALPDPR*E
      F=ALPDPR*F
      G=ALPDPR*G
  910 LSZM=T
      VINT=R*ALPINT/D
      VDPR=R*ALPDPR/D
      VLEV=R-VINT-VDPR
      H=ALPGW+ALPGEV*EVPRP
      IF(ABS((H-D)/H).LE.EPSILON.OR.ABS(H-D).LE.DPSILON)GOTO 200
      IF(ABS((H-B)/H).LE.EPSILON.OR.ABS(H-B).LE.DPSILON)GOTO 250
      T=(GZM-E/(H-D)-F/(H-B)-G/H)*EXP(-H*DAY)
     +E/(H-D)*EXP(-D*DAY)+F/(H-B)*EXP(-B*DAY)+G/H
      IF(ALPDPR.LT.DPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.DPSILON)GOTO 911
      L=ALPGW*(GZM-E/(H-D)-F/(H-B)-G/H)
      M=E*(ALPINT/ALPDPR+ALPGW/(H-D))
      N=A*NSR/USZC/ALPPER+F*(ALPINT/ALPDPR+ALPGW/(H-B))
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 912
  911 L=0.
      M=ALPINT*E
      N=ALPINT*F+A*NSR/USZC/ALPPER
      O=ALPINT*G+C*NSR/USZC/ALPPER
  912 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 300
      IF(ABS((P-D)/P).LE.EPSILON.OR.ABS(P-D).LE.DPSILON)GOTO 400
      IF(ABS((P-B)/P).LE.EPSILON.OR.ABS(P-B).LE.DPSILON)GOTO 500
      T=(SS-L/(P-H)-M/(P-D)-N/(P-B)-O/P)*EXP(-P*DAY)
     +L/(P-H)*EXP(-H*DAY)+M/(P-D)*EXP(-D*DAY)+N/(P-B)*EXP(-B*DAY)+O/P
  600 R=VRUN+VINT+VGW+SS-T
      NS=R*ALPSF/P
      SS=T
      EVAP=VUEV+VLEV+VGEV+R-NS
      RETURN
  500 T=(SS-L/(P-H)-M/(P-D)+N*DAY-O/P)*EXP(-P*DAY)
     +L/(P-H)*EXP(-H*DAY)+M/(P-D)*EXP(-D*DAY)+O/P
      GOTO 600
  400 T=(SS-L/(P-H)+M*DAY-N/(P-B)-O/P)*EXP(-P*DAY)
     +L/(P-H)*EXP(-H*DAY)+N/(P-B)*EXP (-B*DAY)+O/P
      GOTO 600
  300 T=(SS+L*DAY-M/(P-D)-N/(P-B)-O/P)*EXP(-P*DAY)
     +M/(P-D)*EXP(-D*DAY)+N/(P-B)*EXP(-B*DAY)+O/P
      GOTO 600
  200 T=(GZM+E*DAY-F/(H-B)-G/H)*EXP(-H*DAY)
     +F/(H-B)*EXP(-B*DAY)+G/H
      IF(ALPDPR.LT.DPSILON) T=GZM*EXP(-H*DAY)
```

```
      R=VDPR+GZM-T
      IF(ALPDPR.LT.DPSILON)GOTO 913
      L=ALPGW*(GZM-F/(H-B)-G/H)+ALPINT/ALPDPR*E
      M=ALPGW*E
      N=A*NSR/USZC/ALPPER+F*(ALPINT/ALPDPR+ALPGW/(H-B))
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 914
  913 L=ALPINT*E
      M-0.
      N=ALPINT*F+A*NSR/USZC/ALPPER
      O=ALPINT*G+C*NSR/USZC/ALPPER
  914 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 203
      IF(ABS((P-B)/P).LE.EPSILON.OR.ABS(P-B).LE.DPSILON)GOTO 204
      T=(SS-L/(P-H)+M/(P-H)**2-N/(P-B)-O/P)*EXP(-P*DAY)
       +(L/(P-H)+M/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)
       +N/(P-B)*EXP(-B*DAY)+O/P
      GOTO 600
  204 T=(SS-L/(P-H)+M/(P-H)**2+N*DAY-O/P)*EXP(-P*DAY)
       +(L/(P-H)+M/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)+O/P
      GOTO 600
  203 T=(SS+L*DAY+M/2*DAY**2-N/(P-B)-O/P)*EXP(-P*DAY)
       +N/(P-B)*EXP(-B*DAY)+O/P
      GOTO 600
  100 T=(LSZM+A*DAY-C/D)*EXP(-D*DAY)+C/D
      F-A
      G=C/D
      E=LSZM-G
      LSZMAVG=(E/D*(1.-EXP(-D*DAY))+F/D**2*(1.-(D*DAY+1.)
              *EXP(-D*DAY)))/DAY+G
      R=VPER+LSZM-T
      IF(ALPDPR.LT.DPSILON)GOTO 920
      E=ALPDPR*E
      F=ALPDPR*F
      G=ALPDPR*G
  920 LSZM=T
      VINT=R*ALPINT/D
      VDPR=R*ALPDPR/D
      VLEV=R-VINT-VDPR
      H=ALPGW+ALPGEV*EVPRP
      IF(ABS((H-D)/H).LE.EPSILON.OR.ABS(H-D).LE.DPSILON)GOTO 120
      T=(GZM-E/(H-D)+F/(H-D)**2-G/H)*EXP(-H*DAY)
       +(E/(H-D)+F/(H-D)**2*((H-D)*DAY-1))*EXP(-D*DAY)+G/H
      IF(ALPDPR.LT.DPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.DPSILON)GOTO 921
      L=ALPGW*(GZM+F/(H-D)**2-E/(H-D)-G/H)
      M=ALPGW*(E/(H-D)-F/(H-D)**2)+ALPINT/ALPDPR*E
      M=M+(NSR/USZC/ALPPER)*A
      N=F*(ALPGW/(H-D)+ALPINT/ALPDPR)
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
```

```
      GOTO 922
  921 L=0.
      M=ALPINT*E+A*NSR/USZC/ALPPER
      N=ALPINT*F
      O=ALPINT*G+C*NSR/USZC/ALPPER
  922 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 130
      IF(ABS((P-D)/P).LE.EPSILON.OR.ABS(P-D).LE.DPSILON)GOTO 140
      T=(SS-L/(P-H)-M/(P-D)+N/(P-D)**2-O/P)*EXP(-P*DAY)
     +L/(P-H)*EXP(-H*DAY)+O/P
     +(M/(P-D)+N/(P-D)**2*((P-D)*DAY-1))*EXP(-D*DAY)
      GOTO 600
  140 T=(SS-L/(P-H)+M*DAY+N/2*DAY**2-O/P)*EXP(-P*DAY)
     +L/(P-H)*EXP(-H*DAY)+O/P
      GOTO 600
  130 T=(SS+L*DAY-M/(P-D)+N/(P-D)**2-O/P)*EXP(-P*DAY)
     +(M/(P-D)+N/(P-D)**2*((P-D)*DAY-1))*EXP(-D*DAY)+O/P
      GOTO 600
  120 T=(GZM+E*DAY+F/2*DAY**2-G/H)*EXP(-H*DAY)+G/H
      IF(ALPDPR.LT.DPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.DPSILON)GOTO 923
      L=ALPGW*(GZM-G/H)+ALPINT/ALPDPR*E
      L=L+NSR/USZC/ALPPER*A
      M=ALPGW*E+ALPINT/ALPDPR*F
      N=ALPGW*F/2
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 924
  923 L=ALPINT*E+A*NSR/USZC/ALPPER
      M=ALPINT*F
      N=0.
      O=ALPINT*G+C*NSR/USZC/ALPPER
  924 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 123
      T=(SS-L/(P-H)+M/(P-H)**2-2*N/(P-H)**3-O/P)*EXP(-P*DAY)
     +(L/(P-H)+M/(P-H)**2*((P-H)*DAY-1)+N/(P-H)*DAY**2
     -2*N/(P-H)**3*((P-H)*DAY-1))*EXP(-H*DAY)+O/P
      GOTO 600
  123 T=(SS+L*DAY+M/2*DAY**2+N/3*DAY**3-O/P)*EXP(-P*DAY)+O/P
      GOTO 600
  250 T=(GZM-E/(H-D)+F*DAY-G/H)*EXP(-H*DAY)
     +E/(H-D)*EXP(-D*DAY)+G/H
      IF(ALPDPR.LT.DPSILON) T=GZM*EXP(-H*DAY)
      R=VDPR+GZM-T
      IF(ALPDPR.LT.DPSILON)GOTO 915
      L=ALPGW*(GZM-E/(H-D)-G/H)+ALPINT/ALPDPR*F
      L=L+A*NSR/USZC/ALPPER
      M=E*(ALPINT/ALPDPR+ALPGW/(H-D))
```

```
      N=ALPGW*F
      O=C*NSR/USZC/ALPPER+G*(ALPINT/ALPDPR+ALPGW/H)
      GOTO 916
  915 L=ALPINT*F+A*NSR/USZC/ALPPER
      M=ALPINT*E
      N-0.
      O=ALPINT*G+C*NSR/USZC/ALPPER
  916 GZM=T
      VGW=R*ALPGW/H
      VGEV=R-VGW
      P=ALPSF+ALPSEV*EVPRP
      IF(ABS((P-H)/P).LE.EPSILON.OR.ABS(P-H).LE.DPSILON)GOTO 255
      IF(ABS((P-D)/P).LE.EPSILON.OR.ABS(P-D).LE.DPSILON)GOTO 254
      T=(SS-L/(P-H)-M/(P-D)+N/(P-H)**2-O/P)*EXP(-P*DAY)
       +(L/(P-H)+N/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)
       +M/(P-D)*EXP(-D*DAY)+O/P
      GOTO 600
  254 T=(SS-L/(P-H)+M*DAY+N/(P-H)**2-O/P)*EXP(-P*DAY)
       +(L/(P-H)+N/(P-H)**2*((P-H)*DAY-1))*EXP(-H*DAY)+O/P
      GOTO 600
  255 T=(SS+L*DAY-M/(P-D)+N/2*DAY**2-O/P)*EXP(-P*DAY)
       +M/(P-D)*EXP(-D*DAY)+O/P
      GOTO 600
      END
      SUBROUTINE UPDATE(IBATCH)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/OTPT/AREA,ISTART,INODAYS,INDPGOD,IPARM,PARM,IXRC,INOCHNG,
                  S,EXVAS,IFDMR,ILDMR,IHEAD1,IHEAD2,IHEAD3,IHEAD4
      DIMENSION PARM(9),IXRC(9)
      IF(IBATCH.EQ.1) RETURN
      REWIND 7
      WRITE(7,3000)IHEAD1,IHEAD2,IHEAD3,IHEAD4
      WRITE(7,559) AREA
      WRITE(7,560) ISTART
      WRITE(7,560) IFDMR
      WRITE(7,560) ILDMR
      WRITE(7,560) INDPGOD
      DO 36 I=1,9
   36 WRITE(7,557) PARM(I),IXRC(I)
      WRITE(7,560) IPARM
      WRITE(7,560) INOCHNG
      WRITE(7,559) EXVAS,S
      REWIND 7
  557 FORMAT(E10.3E2,2X,I1)
  559 FORMAT(6E13.6E2)
  560 FORMAT(I8)
 3000 FORMAT(4A10)
      RETURN
      END
      SUBROUTINE WRT(IBATCH)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/OTPT/AREA,ISTART,INODAYS,INDPGOD,IPARM,PARM,IXRC,INOCHNG,
```

```
                       S,EXVAS,IFDMR,ILDMR,IHEAD1,IHEAD2,IHEAD3,IHEAD4
      COMMON/OTPT2/TBASE,ALBEDS,EXVA,SSQERR
      DIMENSION IX(9),PARM(9),IXRC(9)
      IF(IBATCH.EQ.2)GOTO 10
      IF(IBATCH.EQ.1)GOTO 20
      WRITE(6,556)TBASE,ALBEDS,ALPPER,ALPUEV,ALPINT,ALPDPR,
                       ALPLEV,ALPGW,ALPSF,EXVA,SSQERR
  556 FORMAT(E6.2E1,8E7.2E1,2X,F3.2,E12.6E2)
      RETURN
   10 WRITE(8,557)TBASE,ALBEDS,ALPPER,ALPUEV,ALPINT,ALPDPR,
                       ALPLEV,ALPGW,ALPSF,EXVA,SSQERR
  557 FORMAT(9E11.3E2,4X,2E14.6E2)
      RETURN
   20 DO 30 I=1,9
      IX(I)=1H
      IF(I.EQ.IPARM)IX(I)=1H*
   30 CONTINUE
      WRITE(8,558) IX(1),TBASE ,IX(1),IX(2),ALBEDS,IX(2),
                       IX(3),ALPPER,IX(3),IX(4),ALPUEV,IX(4),
                       IX(5),ALPINT,IX(5),IX(6),ALPDPR,IX(6),
                       IX(7),ALPLEV,IX(7),IX(8),ALPGW ,IX(8),
                       IX(9),ALPSF ,IX(9),EXVA,SSQERR
  558 FORMAT(1X,9(1X,A1,E8.3E2,A1),3X,2E14.6E2)
      RETURN
      END
CC*****
CC*****
      SUBROUTINE LENGTH(IFDP,ILDP,INODAYS)
      IMPLICIT REAL(A-H,J-Z)
      DIMENSION IMON(12)
      DATA IMON/31,28,31,30,31,30,31,31,30,31,30,31/
      IMON(2)=28
      IBD=IFDP/1000000
      ILD=ILDP/1000000
      IBM=(IFDP/10000)-IBD*100
      ILM=(ILDP/10000)-ILD*100
      IBY=IFDP-(IFDP/10000)*10000
      ILY=ILDP-(ILDP/10000)*10000
CC*****
      IF(INT((FLOAT(IBY)+.5)/4.)*4.EQ.IBY)IMON(2)=29
      INODAYS=IMON(IBM)-IBD+1
  444 IBM=IBM+1
      IF(IBM.EQ.13.AND.IBY.LT.ILY)GOTO 222
      IF(IBM.GT.ILM.AND.IBY.EQ.ILY)GOTO 555
  333 INODAYS=INODAYS+IMON(IBM)
      IF(ILD*1000000+IBM*10000+IBY.EQ.ILDP.AND.ILD.NE.IMON(IBM))
          INODAYS=INODAYS-IMON(IBM)+ILD
      GOTO 444
  222 IBM=1
      IBY=IBY+1
      IMON(2)=28
      IF(INT((FLOAT(IBY)+.5)/4.)*4.EQ.IBY)IMON(2)=29
      GOTO 333
  555 RETURN
      END
/
```

F.3 Source Code for Calibration Program Using Monthly Data (MMCAL)

```
      PROGRAM MMCAL (MDATA,TAPE5=MDATA,OUTPUT,TAPE6=OUTPUT,
+                  RES,TAPE8=RES,MPAR,TAPE7=MPAR)
      IMPLICIT REAL (A-H, J-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
      COMMON/OTPT/AREA,ISTART,INODAYS,INDPGOD,IPARM,PARM,IXRC,INOCHNG,
+                S,EXVAS,IFDMR,ILDMR,IHEAD1,IHEAD2,IHEAD3,IHEAD4
      COMMON/OTPT2/TBASE,ALBEDS,EXVA,SSQERR
      DIMENSION ONTI(12),ONTT(12),SUP(12),MICH(12)
      DIMENSION R(14),INDPM(13)
      DIMENSION PARM(9),IXRC(9)
      DMENSION DATA(9,109)
      DIMENSION INAME(8)
      DIMENSION IERR(6)
      DATA IERR/6*0/
CC*****
CC***** MONTHLY MODEL FOR MONTHLY DATA
CC***** PROGRAM POR INTERACTIVE INVESTIGATION OF MODEL
CC*****
CC         NOTE -- MONTHLY DATA SST SHOULD BE COMPLETE
CC                 (NO -9999. VALUES) FOR TEMPERATURE AND
CC                 PRECIPITATION.  FLOW DATA MAY CONTAIN
CC                 MISSING (-9999.) VALUES.
CC
CC                 THE ARRAY 'DATA' SHOULD BE DIMENSIONED AS:
CC                 DATA(9,NUMBER OF MONTHS IN DATA SET)
CC*****
CC AREA    = WATERSHED AREA, SQ. M.
CC FLOW    = ACTUAL BASIN OUTFLOW VOLUME, CUB. M.
CC IFDMR = FIRST MONTH POR MODEL RUN (MMYYYY)
CC ILDMR = LAST MONTH FOR MODEL RUN (MMYYYY)
CC  IM     = CALENDAR MONTH OF THE YEAR
CC INODAYS= NUMBER OF MONTHS TO BE CONSIDERED IN DATA SET
CC  IY     = CALENDAR YEAR
CC PRECIP = MONTHLY PRECIPITATION VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  R      = AVERAGE MID-MONTH CLOUDED-DAY INSOLATION, LANGLEYS/DAY
CC           (INPUT IN UNITS OF 10*LANGLEYS/DAY)
CC  RR     = MONTHLY SURFACE INSOLATION, CAL.
CC  SNW    = SNOWPACK VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  TA     = AVERAGE DAILY AIR TEMPERATURE, DEG. C.
CC*****
CC*****
CC***** INPUT CONSTANTS
CC*****
      DATA ONTI/20.,33.,46.,59.,69.,74.,70.,62.,51.,38.,24.,18./
```

```
      DATA ONTT/20.,31.,46.,60.,70.,74.,71.,61.,48.,34.,22.,18./
      DATA SUP/19.,33.,49.,64.,77.,79.,77.,67.,51.,36.,20.,15./
      DATA MICH/22.,34.,48.,62.,70.,73.,70.,61.,49.,36.,24.,19./
      REWIND 7
      READ(7,2000) ILAKE
 2000 FORMAT(A4)
      DO 45 I=1,12
      IF(ILAKE.EQ.4HIONT) R(I)=ONTI(I)
      IF(ILAKE.EQ.4HTONT) R(I)=ONTT(I)
      IF(ILAKE.EQ.4HSUPE) R(I)=SUP(I)
      IF(ILAKE.EQ.4HMICH) R(I)=MICH(I)
   45 CONTINUE
CC*****
CC       NOTE -- SYSTEM SPECIFIC PROCEDURE SUPPLIES ZERO
CC               WHEN EXPONENTIAL UNDERFLOW OCCURS
CC*****
      CALL SYSTEMC(115,IERR)
CC*****
      REWIND 7
      READ(7,3000)IHEAD1,IHEAD2,IHEAD3,IHEAD4
 3000 FORMAT(4A10)
CC*****
CC***** IBATCH = 1 FOR BATCH JOB; = 0 FOR INTERACTIVE JOB
CC*****
      IBATCH=0
      EPSILON=1.E-7
      DPSILON=1.E-200
      GPSILON=1.E-3
      ALPGEV=0.
      ALPSEV=0.
      DO 33 IXY=1,12
   33 R(IXY)=R(IXY)*10.
      READ(7.559) AREA
      READ(7,560) ISTART
  560 FORMAT(I8)
      READ(7,560) IFDMR
      READ(7,560) ILDMR
      CALL LENGTH(IFDMR,ILDMR,INODAYS)
      IIST=ISTART
      III-INODAYS
CC*****
CC***** SYSTEMATIC PARAMETER SEARCH
CC*****
      IFTFG=1
      IRTN=0
      ICNT=0
      IRPTFG=1
      IOPDN-1
      IOPTFG=-1
      USZC=AREA*0.02
      DO 36 I-l.9
      READ(7,557) PARM(I),IXRC(I)
      IF(PARM(I).LT..1E-9) PARM(I)=.1E-9
      XRCC=10.**(1-IXRC(I)+INT(ALOG10(PARM(I)*.99999)))
```

```
      IF(PARM(I).LT.1.00001)XRCC=XRCC/10.
      PARM(I)=PARM(I)+XRCC/2.
      XRCC=10.**(1-IXRC(I)+INT(ALOG10(PARM(I)*.99999)))
      IF(PARM(I).LT.1.00001)XRCC=XRCC/10.
      PARM(I)=INT(PARM(I)*1.00001/XRCC)*XRCC
   36 CONTINUE
      READ(7,560) IPARM
      READ(7,560) INOCHNG
      IF(INOCHNG.LT.1.OR.INOCHNG.GT.2) I=IFTFG/IRTN
      DO 37 I=1,9
      IF(IXRC(I).GT.INOCHNG) IXRC(I)=INOCHNG
   37 CONTINUE
CC*****
CC*****       INPUT AND FILL IN MONTHLY DATA
CC*****
      REWIND 5
      READ(5,1000) INAME
      REWIND 8
      IF(IBATCH.EQ.0)GOTO 996
      WRITE(8,1060) INAME
 1060 FORMAT(3X,22HCALIBRATION RUN FOR    ,3A10)
      WRITE(8,1070)    AREA,ISTART,INODAYS
 1070 FORMAT(/,3X, 7HAREA = ,E13.6E2,
+            /,3X,38HLAST MONTH OF INITIALIZATION PERIOD = ,I5,
+            /,3X,45HTOTAL NUMBER OF MONTHS USED IN CALIBRATION = ,I5,
+            /,3X,40HMASS-BALANCE INTERVAL IN CALANDER MONTHS,//)
  996 CONTINUE
      READ(5,1000)
      READ(5,1000)
      READ(5,1000)
   15 READ(5,1010)IM,IY,INDIM,TA,PRECIP,FLOW
      IF(IM*10000+IY.NE.IFDMR)GOTO 15
      BACKSPACE 5
      DO 600 I=1,INODAYS
      READ(5,1010) IM,IY,INDIM,TA,PRECIP,FLOW
 1010 FORMAT(1X,I3,I5,2X,I3,5X,F10.2,2F20.0)
CC*****
CC*****       COMPUTE MONTHLY  INSOLATION
CC*****
      DATA(3,I)=FLOW
      DATA(2,I)=TA
      DATA(9,I)=FLOAT(INDIM)
      DATA(5,I)=PRECIP
      RR=R(IM)*DATA(9,I)*10000.*AREA
      DATA(6,I)=RR
  600 CONTINUE
      REWIND 5
CC*****
CC*****
CC*****
      IKNTR=0
      AVGF=0.
      "AR-0.
      MEAN-0.
```

```
      DO 610 I=1,INODAYS
      IF(I.LE.ISTART) GOTO 610
      IF(DATA(3,I).LT.-900.)GOTO 610
      AVGF = AVGF + DATA(3,I)
      IKNTR = IKNTR + 1
         VAR = VAR + DATA(3,I)**2
         MEAN = MEAN + DATA(3,I)
  610 CONTINUE
      FI = FLOAT(IKNTR)
      VAR = VAR/FI
      MEAN = MEAN/FI
      VAR = VAR - MEAN**2
      AVGF = AVGF/FLOAT(IKNTR)
CC*****
CC*****
CC*****
      TBASE =PARM(1)
      ALBEDS=PARM(2)
      ALPPER=PARM(3)
      ALPUEV=PARM(4)
      ALPINT=PARM(5)
      ALPDPR=PARM(6)
      ALPLEV=PARM(7)
      ALPGW =PARM(8)
      ALPSF =PARM(9)
      IF(IBATCH.EQ.0)GOTO 990
      IBATCH=2
  990 CALL WRT(IBATCH)
      IF(IBATCH.EQ.0)GOTO 991
      IBATCH=1
  991 S=0.1E+99
      GOTO 26
   20 XRCC=10.**(1-IXRC(IPARM)+INT(ALOG10(PARM(IPARM)*.99999)))
      IF(PARM(IPARM).LT.1.00001)XRCC=XRCC/10.
      IF(INT(PARM(IPARM)/XRCC*1.00001).NE.10**IXRC(IPARM))GOTO 21
      IF(IUPDN.NE.1)GOTO 21
      XRCC=XRCC*10.
   21 PARM(IPARM)=(INT(PARM(IPARM)*1.00001/XRCC)+IUPDN)*XRCC
      IF(PARM(IPARM).LT..99999E-10.OR.(IPARM.NE.2.AND.
     +   PARM(IPARM).GT..99999E+9))GOTO 22
      TBASE = PARM(1)
      ALBEDS = PARM(2)
      ALPPER = PARM(3)
      ALPUEV = PARM(4)
      ALPINT = PARM(5)
      ALPDPR = PARM(6)
      ALPLEV = PARM(7)
      ALPGW = PARM(8)
      ALPSF = PARM(9)
      IF(IRPTFG.EQ.0) GOTO 554
      IRPTFG=0
      IF(IPARM.LE.2) IRPTFG=1
CC*****
CC***** FIND SUM OF SQUARED ERRORS
```

```
CC*****
      IF(IPARM.NE.2.AND.IPARM.NE.3.AND.IFTFG.EQ.0)GOTO 310
      SW-O.
      AVGRR=0.
      IFTFG = 0
CC*****
CC***** MONTHLY LOOP -DATA PREPERATION (BEGINNING)
CC*****
      DO 300 I=1,INODAYS
CC*****
CC*****      "EAT BALANCE
CC*****
      TA=DATA(2,I)
      RR = DATA(6,I)
      PRECIP = DATA(5,I)
      MELT-0.
      IF(TA.LE.0.)GOTO 903
      IF(SNW.LT.1.)GOTO 904
      DD=TA*DATA(9,I).
  951 MELT=ALBEDS*DD
      IF(MELT.LE.SNW)GOTO 904
      MELT-SW
  904 SNW=SNW-MELT
      NS=PRECIP+MELT
      GOTO 905
  903 SNW=SNW+PRECIP
      NS=0.
  905 DATA(1,I)=NS
      IF(I.LE.ISTART)GOTO 300
      AVGRR=AVGRR+RR-MELT*1000000.*79.7
  300 CONTINUE
CC*****
CC***** MONTHLY LOOP -DATA PREPARATION (END)
CC*****
CC*****
CC***** SUMMARY INFORMATION
CC*****
  310 AVGHPLE=0.
      00 910 I=1,INODAYS
      TA=DATA(2,I)
      HPLSE=EXP(TA/TBASE)
      DATA(4,I)=HPLSE
      IF(I.LE.ISTART)GOTO 910
      AVGHPLE=AVGHPLE+HPLSE
  910 CONTINUE
      CONS=AVGRR/AVGHPLE
      DO 911 I=1,INODAYS
      TA=DATA(2,I)
      HPLSE=DATA(4,I)/(596.-.52*TA)/1000000.*CONS
  911 DATA(4,I)=HPLSE
CC*****
CC*****
CC*****
      00 400 I=1,INODAYS
```

```
      DATA(7,I)=DATA(1,I)
  400 CONTINUE
CC*****
CC***** INPUT INITIAL VARIABLE VALUES
CC*****
  554 USZM=.00698*AREA/100.
      LSZM=.03335*AREA/100.
      GZM=0.0000*AREA/100.
      SS=.00931*AREA/100.
CC*****
CC***** INITIALIZE
CC*****
      AVGFM = 0.
      VARM=0.
      PROD=0.
      SSQERR = 0.
      IFII=0
CC*****
CC***** MONTHLY LOOP (BEGINNING)
CC*****
      DO 100 I=1,III
CC*****
CC*****       INPUT MONTHLY PREPARED DATA
CC*****
      NS=DATA(7,I)
      HPLSE=DATA(4,I)
      FLOW   = DATA(3,I)
      DAY=DATA(9,I)
CC*****
CC*****       MASS BALANCE
CC*****
      CALL OUTFLOW(NS)
CC*****
      IF(FLOW.LT.-900.)GOTO 100
      IF(I.LE.IIST)GOTO 100
      AVGFM=AVGFM+NS
      VARM=VARM+NS**2
      PROD=PROD+FLOW*NS
      SSQERR=SSQERR+(FLOW-NS)**2
      IFII=IFII+1
  100 CONTINUE
CC*****
CC***** MONTHLY LOOP (END)
CC*****
CC*****
CC***** SUMMARY INFORMATION
CC*****
      FI=FLOAT(IFII)
      AVGFM=AVGFM/FI
      VARM=VARM/FI
      VARM=VARM-AVGFM**2
      PROD=PROD/FI
      EXVA=(PROD-MEAN*AVGFM)**2/VAR/VARM
      SSQERR=SSQERR/FI
```

```
      SSQERR=SQRT(SSQERR)/AREA*100.
      EXVA=SQRT(EXVA)
     CALL  WRT(IBATCH)
  557 FORMAT(E10.3E2.2X.I1)
      CALL   UPDATE(IBATCH)
      IF(SSQERR.GE.S) GOT0 22
      S=SSQERR
      EXVAS=EXVA
      IRTN=IRTN+1
      IOPTFG=IOPTFG+1
      GOTO 20
   22 PARM(IPARM)=PARM(IPARM)-XRCC*FLOAT(IUPDN)
      CALL UPDATE(IBATCH)
      IF(IOPTFG.GT.0) GOT0 23
      IOPTFG=1
      IUPDN=-1
      corn 2 0
   23 IOPTFG=0
      IUPDN=1
   27 ICNT=ICNT+1
      IF(IRTN.NE.0)ICNT=0
      IRTN=0
      IF(ICNT.NE.8)GOTO 24
      ICNT=0
      IRELCNG=0
      DO 35 I=1,9
      IF(IXRC(I).EQ.0)GOTO 38
      IXRC(I)=IXRC(I)+1
      IF(IXRC(I).LE.INOCHNG)GOTO 35
      IXRC(I)=INOCHNG
   38 IRELCNG=IRELCNG+1
   35 CONTINUE
      IF(IRELCNG.EQ.9)GOTO 34
   24 IPARM=IPARM+1
      IPARMM=IPARM
      IF(IPARM.GE.10)IPARM=1
      CALL UPDATE(IBATCH)
      IPARM=IPARMM
   28 IF(IPARM.LT.10)GOTO 26
      IPARM=1
      IRPTFG=1
   26 IF(PARM(IPARM).GT..1E+98.OR.IXRC(IPARM).EQ.0)GOTO 27
      GOTO 20
  559 FORMAT(6E13.6E2)
   34 WRITE(6,557)
      IF(IBATCH.EQ.1) WRITE(8.557)
      CALL UPDATE(IBATCH)
      TBASE =PARM(1)
      ALBEDS=PARM(2)
      ALPPER=PARM(3)
      ALPUEV=PARM(4)
      ALPINT=PARM(5)
      ALPDPR=PARM(6)
      ALPLEV=PARM(7)
```

```
      ALPGW =PARM(8)
      ALPSF =PARM(9)
      EXVA=EXVAS
      SSQERR=S
      IF(IBATCH.EQ.0)GOTO 992
      IBATCH=2
  992 CALL WRT(IBATCH)
      REWIND 8
      STOP
 1000 FORMAT(8A10)
      END
      SUBROUTINE OUTFLOW (NS)
```

(SEE LISTING FOR CALIB)

```
      SUBROUTINE UPDATE(IBATCH)
```

(SEE LISTING FOR CALIB)

```
      SUBROUTINE WRT(IBATCH)
```

(SEE LISTING FOR CALIB)

```
      SUBROUTINE LENGTH(IFDP,ILDP,INODAYS)
      IMPLICIT REAL(A-H,J-Z)
      IBM=(IFDP/10000)
      ILM=(ILDP/10000)
      IBY=IFDP-(IFDP/10000)*10000
      ILY=ILDP-(ILDP/10000)*10000
CC*****
      INODAYS=12*(ILY-1)+ILM-(12*(IBY-1)+(IBM-1))
  555 RETURN
      END
```

Appendix G.--EXAMPLE CALIBRATION PARAMETER FILES (PARAM): INITIAL AND FINAL

G.1 Initial Parameter File (PARAM)

```
SUPERIOR: ALL BASINS 1-22
  .128925E+12
     630
01121969
31121978
        7
  .170E+01  1
  .290E+09  1
  .240E+01  1
  .100E-09  1
  .450E-02  1
  .980E-02  1
  .770E-03  1
  .380E-02  1
  .160E+00  1
        1
        2
```

G.2 Final Parameter File (PARAM)

```
SUPERIOR: ALL BASINS 1-22
  .128925E+12
      630
   1121969
 31121978
        7
  .190E+01  2
  .300E+09  2
  .270E+01  2
  .100E-09  2
  .600E-02  2
  .170E-01  2
  .930E-03  2
  .350E-02  2
  .170E+00  2
        7
        2
  .891248E+00  .194003E+00
```

Appendix H.--EXAMPLE CALIBRATION SESSION (RESULT)

CALIBRATION RUN FOR COMBINED SUBBASINS: 1111111111111111111111

AREA = .128925E+12
LAST DAY OF INITIALIZATION PERIOD = 630
TOTAL NUMBER OF DAYS USED IN CALIBRATION = 3318
MASS-BALANCE INTERVAL (DAYS) = 7

.200E+01	.300E+09	.200E+01	100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	-I	-1
.300E+01	.300E+09	.200E+01	100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.866557E+00	.310366E+00
.400E+01	.300E+09	.200E+01	100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.849625E+00	.395737E+00
● .2omffl1*	.300E+09	.200E+01	100E-09	.500E-02	.l00E-01	.800E-03	.400E-02	.200E+00	.884311E+00	.217741E+00
.100E+01	.300E+09	.200E+01	.100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.862373E+00	.362909E+00
.200E+01	*.400E+09*	.200E+01	100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.868016E+00	.231951E+00
.200E+01	*.200E+09*	.200E+01	100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.839636E+00	.247743E+00
.200E+01	.300E+09	*.300E+01*	.100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.886020E+00	.214288E+00
.200E+01	.300E+09	*.400E+01*	.100E-09	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.879580E+00	.229520E+00
.200E+01	.300E+09	.300E+01	● .200E-09*	.500E-02	.100E-01	.800E-03	.400E-02	.200E+00	.885562E+00	.215110E+00
.200E+01	.300E+09	.300E+01	.100E-09	*.600E-02*	.100E-01	.800E-03	.400E-02	.200E+00	.884198E+00	.212240E+00
.200E+01	.300E+09	.300E+01	.100E-09	*.700E-02*	.100E-01	.800E-03	.400E-02	.200E+00	.881267E+00	.214446E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	*.200E-01*	.800E-03	.400E-02	.200E+00	.886886E+00	.197392E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	*.300E-01*	.800E-03	.400E-02	.200E+00	.883323E+00	.208978E+00
.200E+01	.300E+09	.300E+01	.100E-09	. 600E-02	.200E-01	*.900E-03*	.400E-02	.200E+00	.886886E+00	.197392E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	*.100E-02*	.400E-02	.200E+00	.886886E+00	.197392E+00
.200E+01	.300E+09	.300E+01	.100E-09	.b00E-02	.200E-01	.900E-03	*.500E-02*	.200E+00	.884103E+00	.199575E+00
.200E+01	300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.900E-03	*.300E-02*	.200E+00	.886237E+00	.198015E+00
.200E+01	: 300E+09	.300E+01	.100E-09	. 600E-02	.200E-01	.900E-03	.400E-02	*.300E+00*	.876780E+00	.205833E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.900E-03	.400E-02	*.100E+00*	.866204E+00	.216242E+00
.300E+01	.300E+09	.300E+01	.100E-09	.b00E-02	.200E-01	. 900E-03	.400E-02	.200E+00	.867754E+00	.266083E+00
.100E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.900E-03	.400E-02	.200E+00	.850370E+00	.420786E+00
.200E+01	*.400E+09*	.300E+01	.100E-09	.600E-02	.200E-01	.900E-03	.400E-02	.200E+00	.883493E+00	.200528E+00
.200E+01	*.200E+09*	.300E+01	.l00E-09	.600E-02	.200E-01	.900E-03	.400E-02	.200E+00	.826016E+00	.241000E+00
.200E+01	.300E+09	*.400E+01*	.100E-09	.600E-02	.200E-01	.900E-03	.400E-02	.200E+00	.882209E+00	.206136E+00
.200E+01	.300E+09	*.200E+01*	.100E-09	.600E-02	.200E-01	.900E-03	.400E-02	.200E+00	.884051E+00	.214086E+00
.200E+01	.300E+09	.300E+01	*.200E-09*	.600E-02	.200E-01	.900E-03	.400E-02	.200E+00	.886697E+00	.197500E+00
.200E+01	.300E+09	.300E+01	.100E-09	*.700E-02*	.200E-01	.900E-03	.400E-02	.200E+00	.886991E+00	.197870E+00
.200E+01	.300E+09	.300E+01	.100E-09	*.500E-02*	.200E-01	.900E-03	.400E-02	.200E+00	.885245E+00	.200015E+00
.200E+01	.300E+09	.300E+01	.100E-09	.b00E-02	*.300E-01*	.900E-03	.400E-02	.200E+00	.883324E+00	.208977E+00
.200E+01	.300E+09	.300E+01	100E-09	.600E-02	*.100E-01*	.900E-03	.400E-02	.200E+00	.884197E+00	.212242E+00
.200E+01	.300E+09	.300E+01	: 100E-09	.600E-02	.200E-01	*.910E-03*	.400E-02	.200E+00	.886886E+00	.197392E+00
.200E+01	.300E+09	.300E+01	.100E-09	. 600E-02	.200E-01	*.920E-03*	.400E-02	.200E+00	.886886E+00	.197392E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.910E-03	*.410E-02*	.200E+00	.886721E+00	.197514E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.VlOE-03	*.390E-02*	.200E+00	.887019E+00	.197296E+00
.200E+01	.300E+09	.300E+01	.l00E-09	.600E-02	.200E-01	.910E-03	*.380E-02*	.200E+00	.887117E+00	.197229E+00
.200E+01	.300E+09	.300E+01	.100E-09	. 600E-02	. 200E-01	.910E-03	*.370E-02*	.200E+00	.887177E+00	.197191E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.910E-03	*.360E-02*	.200E+00	.887197E+00	.197186E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.910E-03	*.350E-02*	.200E+00	.887173E+00	.197217E+00

.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.910E-03	.360E-02	*. 210E+00*	.886562E+00	.197624E+00
.200E+01	.300E+09	.300E+01	. 100E-09	.600E-02	.200E-01	.910E-03	.360E-02	*. 190E+00*	.887634E+00	.196943E+00
.200E+01	.300E+09	.300E+01	.100E-09	.600E-02	.200E-01	.910E-03	.360E-02	*. 180E+00*	.887826E+00	196939E+00
.200E+01	.300E+09	.300E+01	100E-09	.600E-02	.200E-01	.910E-03	.360E-02	*.170E+00*	.887716E+00	: 197224E+00
.210E+01	.300E+09	.300E+01	: 100E-09	.600E-02	.200E-01	.910E-03	.360E-02	. 180E+00	.885678E+00	.198952E+00
.190E+01	.300E+09	.300E+01	. 100E-09	.600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890521E+00	.196368E+00
.180E+01	.300E+09	.300E+01	. 100E-09	.600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.892990E+00	.198926E+00
.190E+01	*. 310E+09*	.300E+01	.100E-09	.600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.889753E+00	.196918E+00
.190E+01	*.290E+09*	.300E+01	. 100E-09	. 600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890379E+00	.196688E+00
.190E+01	.300E+09	*.310E+01*	. 100E-09	. 600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890194E+00	.196888E+00
.190E+01	.300E+09	*. 290E+01*	. 100E-09	. 600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890771E+00	.196044E+00
.190E+01	.300E+09	*.280E+01*	. 100E-09	.600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890937E+00	.195954E+00
.190E+01	.300E+09	*.270E+01*	.100E-09	.600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.891018E+00	.196137E+00
.190E+01	.300E+09	.280E+01	*. 110E-09*	600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890917E+00	.195947E+00
190E+01	.300E+09	.280E+01	*.120E-09*	600E-02	.200E-01	.910E-03	360E-02	180E+00	.890897E+00	195941E+00
: 190E+01	.300E+09	.280E+01	*.130E-09*	600E-02	.200E-01	.910E-03	: 360E-02	: 180E+00	.890876E+00	: 195936E+00
.190E+01	.300E+09	.280E+01	● . 140E-09*	.600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890854E+00	.195932E+00
.190E+01	.300E+09	.280E+01	*. 150E-09*	. 600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890833E+00	.195929E+00
.190E+01	.300E+09	.280E+01	*. 160E-09*	.600E-02	.200E-01	.910E-03	.360E-02	180E+00	.890811E+00	.195927E+00
.190E+01	.300E+09	.280E+01	*.170E-09*	.600E-02	.200E-01	.910E-03	.360E-02	: 180E+00	.890788E+00	.195926E+00
.190E+01	.300E+09	.280E+01	*. 180E-09*	. 600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890765E+00	.195925E+00
.190E+01	.300E+09	.280E+01	● 190E-09*	.600E-02	.200E-01	.910E-03	.360E-02	.180E+00	.890742E+00	195926E+00
.190E+01	.300E+09	.280E+01	. 180E-09	*. 610E-02*	.200E-01	.910E-03	.360E-02	.180E+00	.890800E+00	: 195954E+00
.190E+01	.300E+09	.280E+01	.180E-09	*. 590E-02*	.200E-01	.910E-03	.360E-02	.180E+00	.890716E+00	195928E+00
.190E+01	.300E+09	.280E+01	.180E-09	.600E-02	*.210E-01*	.910E-03	.360E-02	.180E+00	.890511E+00	: 197027E+00
.190E+01	.300E+09	.280E+01	180E-09	.600E-02	*. 190E-01*	.910E-03	.360E-02	.180E+00	.890967E+00	.195013E+00
.190E+01	.300E+09	.280E+01	: 180E-09	. 600E-02	*.180E-01*	.910E-03	.360E-02	.180E+00	.890984E+00	194428E+00
.190E+01	.300E+09	.280E+01	. 180E-09	.600E-02	*.170E-01*	.910E-03	.360E-02	.180E+00	.890564E+00	: 194404E+00
.190E+01	.300E+09	.280E+01	. 180E-09	. 600E-02	*.160E-01*	.910E-03	.360E-02	.180E+00	.889909E+00	.194778E+00
.190E+01	.300E+09	.280E+01	.180E-09	.600E-02	.170E-01	*.920E-03*	.360E-02	.180E+00	.890564E+00	.194404E+00
.190E+01	.300E+09	.280E+01	.180E-09	.b00E-02	.170E-01	*. 930E-03*	.360E-02	.180E+00	.890564E+00	.194405E+00
.190E+01	.300E+09	.280E+01	.180E-09	.600E-02	.170E-01	.920E-03	*.370E-02*	.180E+00	.890556E+00	.194429E+00
.190E+01	.300E+09	.280E+01	180E-09	.600E-02	.170E-01	.920E-03	*.350E-02*	.180E+00	.890532E+00	.194412E+00
.190E+01	.300E+09	.280E+01	: 180E-09	. 600E-02	.170E-01	.920E-03	.360E-02	*. 190E+00*	.890332E+00	.194644E+00
.190E+01	.300E+09	.280E+01	.180E-09	. 600E-02	.170E-01	.920E-03	.360E-02	*.170E+00*	.890495E+00	.194454E+00
.200E+01	.300E+09	.280E+01	. 180E-09	. 600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.888788E+00	.196039E+00
.180E+01	.300E+09	.280E+01	.180E-09	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.892480E+00	.195441E+00
.190E+01	*.310E+09*	.280E+01	.180E-09	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.889889E+00	.195113E+00
.190E+01	*.290E+09*	.280E+01	.180E-09	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.890356E+00	.194528E+00
.190E+01	.300E+09	*. 290E+0 1*	.180E-09	. 600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.890113E+00	.194739E+00
.190E+01	.300E+09	*.270E+01*	.180E-09	600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.890940E+00	.194324E+00
.190E+01	.300E+09	*.260E+01*	.180E-09	. 600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891229E+00	.194551E+00
.190E+01	.300E+09	.270E+01	*.190E-09*	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	[illegible]	194345E+00
.190E+01	.300E+09	.270E+01	*.170E-09*	. 600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.890973E+00	: 194303E+00
.190E+01	.300E+09	.270E+01	*.160E-09*	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891004E+00	.194282E+00
.190E+01	.300E+09	.270E+01	*.150E-09*	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891036E+00	.194262E+00
.190E+01	.300E+09	.270E+01	*.140E-09*	. 600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891068E+00	.194243E+00
.190E+01	.300E+09	.270E+01	*.130E-09*	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891099E+00	.194224E+00

.190E+01	.300E+09	.270E+01	*.120E-09*	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891130E+00	.194205E+00
.190E+01	.300E+09	.270E+01	*.110E-09*	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891161E+00	.194187E+00
.190E+01	.300E+09	.270E+01	*.100E-09*	.600E-02	.170E-01	.920E-03	.360E-02	.180E+00	.891192E+00	.194170E+00
.190E+01	.300E+09	.270E+01	.100E-09	*.610E-02*	.170E-01	.920E-03	.360E-02	.180E+00	.891309E+00	.194187E+00
.190E+01	.300E+09	.270E+01	.100E-09	*.590E-02*	.170E-01	.920E-03	.360E-02	.180E+00	.891060E+00	.194185E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	*.180E-01*	.920E-03	.360E-02	.180E+00	.891407E+00	.194410E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	*.160E-01*	.920E-03	.360E-02	.180E+00	.890520E+00	.194524E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	*.930E-03*	.360E-02	.180E+00	.891192E+00	.194170E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	*.940E-03*	.360E-02	.180E+00	.891192E+00	.194170E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	*.370E-02*	.180E+00	.891206E+00	.194190E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	*.350E-02*	.180E+00	.891139E+00	.194181E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	*.190E+00*	.890821E+00	.194609E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	*.170E+00*	.891270E+00	.194012E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	*.160E+00*	.890984E+00	.194203E+00
.200E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	.170E+00	.889424E+00	.195402E+00
.180E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	.170E+00	.893043E+00	.195502E+00
.190E+01	*.310E+09*	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	.170E+00	.890797E+00	.194624E+00
.190E+01	*.290E+09*	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	.170E+00	.890805E+00	.194264E+00
.190E+01	.300E+09	*.280E+01*	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	.170E+00	.890758E+00	.194296E+00
.190E+01	.300E+09	*.260E+01*	.100E-09	.600E-02	.170E-01	.930E-03	.360E-02	.170E+00	.891698E+00	.194018E+00
.190E+01	.300E+09	.270E+01	*.110E-09*	.600E-02	.170E-01	.930E-03	.360E-02	.170E+00	.891239E+00	.194029E+00
.190E+01	.300E+09	.270E+01	.100E-09	*.610E-02*	.170E-01	.930E-03	.360E-02	.170E+00	.891350E+00	.194032E+00
.190E+01	.300E+09	.270E+01	.100E-09	*.590E-02*	.170E-01	.930E-03	.360E-02	.170E+00	.891176E+00	.194024E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	*.180E-01*	.930E-03	.360E-02	.170E+00	.891535E+00	.194236E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	*.160E-01*	.930E-03	.360E-02	.170E+00	.890546E+00	.194384E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	*.940E-03*	.360E-02	.170E+00	.891270E+00	.194012E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	*.920E-03*	.360E-02	.170E+00	.891270E+00	.194012E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	*.370E-02*	.170E+00	.891253E+00	.194053E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	*.350E-02*	.170E+00	.891248E+00	.194003E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	● .340E-02*	.170E+00	.891183E+00	.194028E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	*.180E+00*	.891139E+00	.194181E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	*.160E+00*	.890996E+00	.194171E+00
.200E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.889398E+00	.195427E+00
.180E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.893035E+00	.195436E+00
.190E+01	*.310E+09*	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.890733E+00	.194641E+00
.190E+01	*.290E+09*	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.890826E+00	.194231E+00
.190E+01	.300E+09	*.280E+01*	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.890762E+00	.194279E+00
.190E+01	.300E+09	*.260E+01*	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.891649E+00	.194017E+00
.190E+01	.300E+09	.270E+01	*.110E-09*	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.891216E+00	.194020E+00
.190E+01	.300E+09	.270E+01	.100E-09	*.610E-02*	.170E-01	.930E-03	.350E-02	.170E+00	.891326E+00	.194020E+00
.190E+01	.300E+09	.270E+01	.100E-09	*.590E-02*	.170E-01	.930E-03	.350E-02	.170E+00	.891155E+00	.194018E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	*.180E-01*	.930E-03	.350E-02	.170E+00	.891516E+00	.194215E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	*.160E-01*	.930E-03	.350E-02	.170E+00	.890524E+00	.194381E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	*.940E-03*	.350E-02	.170E+00	.891248E+00	.194003E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	*.920E-03*	.350E-02	.170E+00	.891248E+00	.194003E+00
.190E+01	.300E+09	.270E+01	.100E-09	.600E-02	.170E-01	.930E-03	.350E-02	.170E+00	.891248E+00	.194003E+00

Appendix I.--SEVEN-DAY MODEL STORAGES

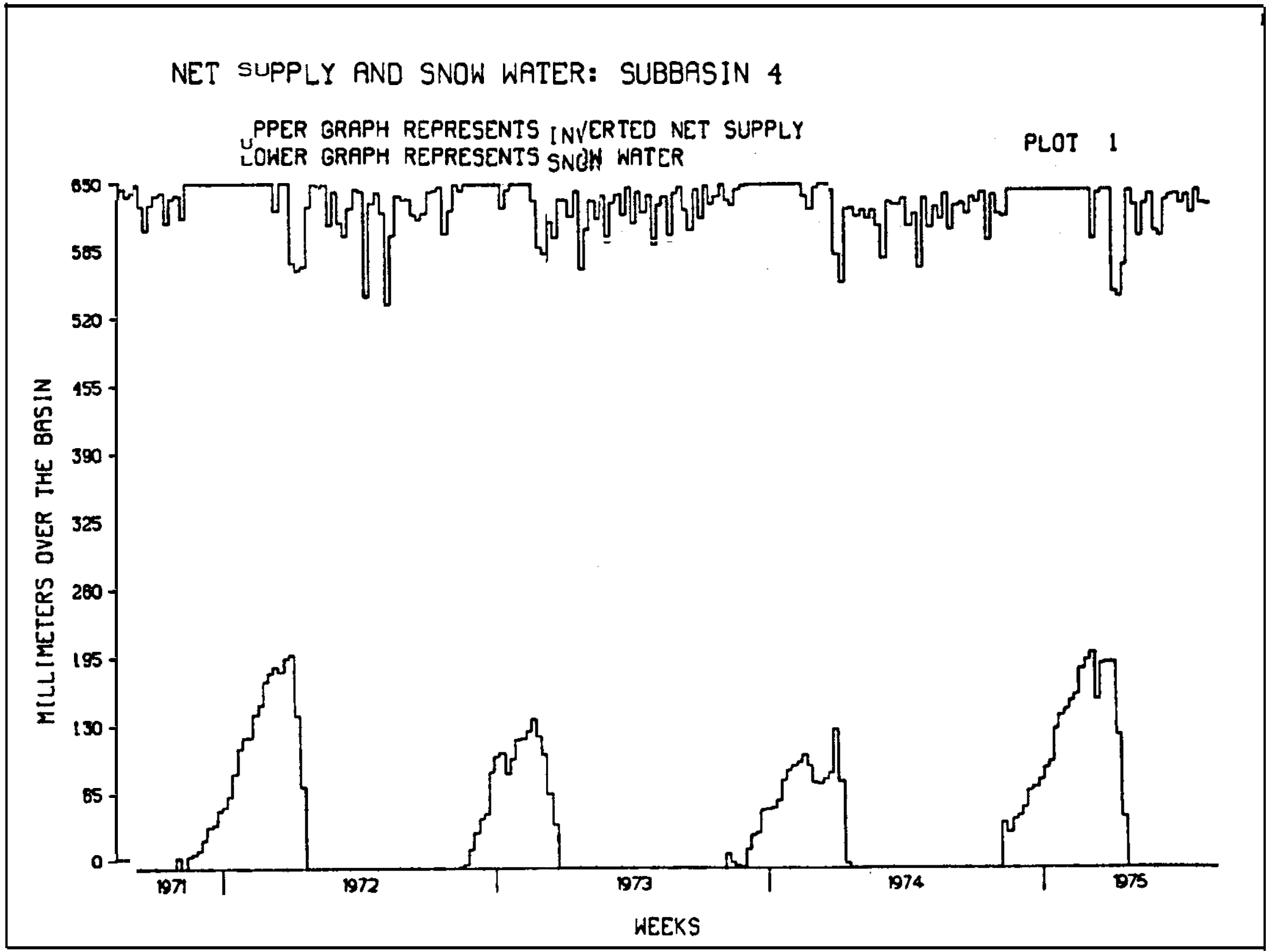


FIGURE 9.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4.*

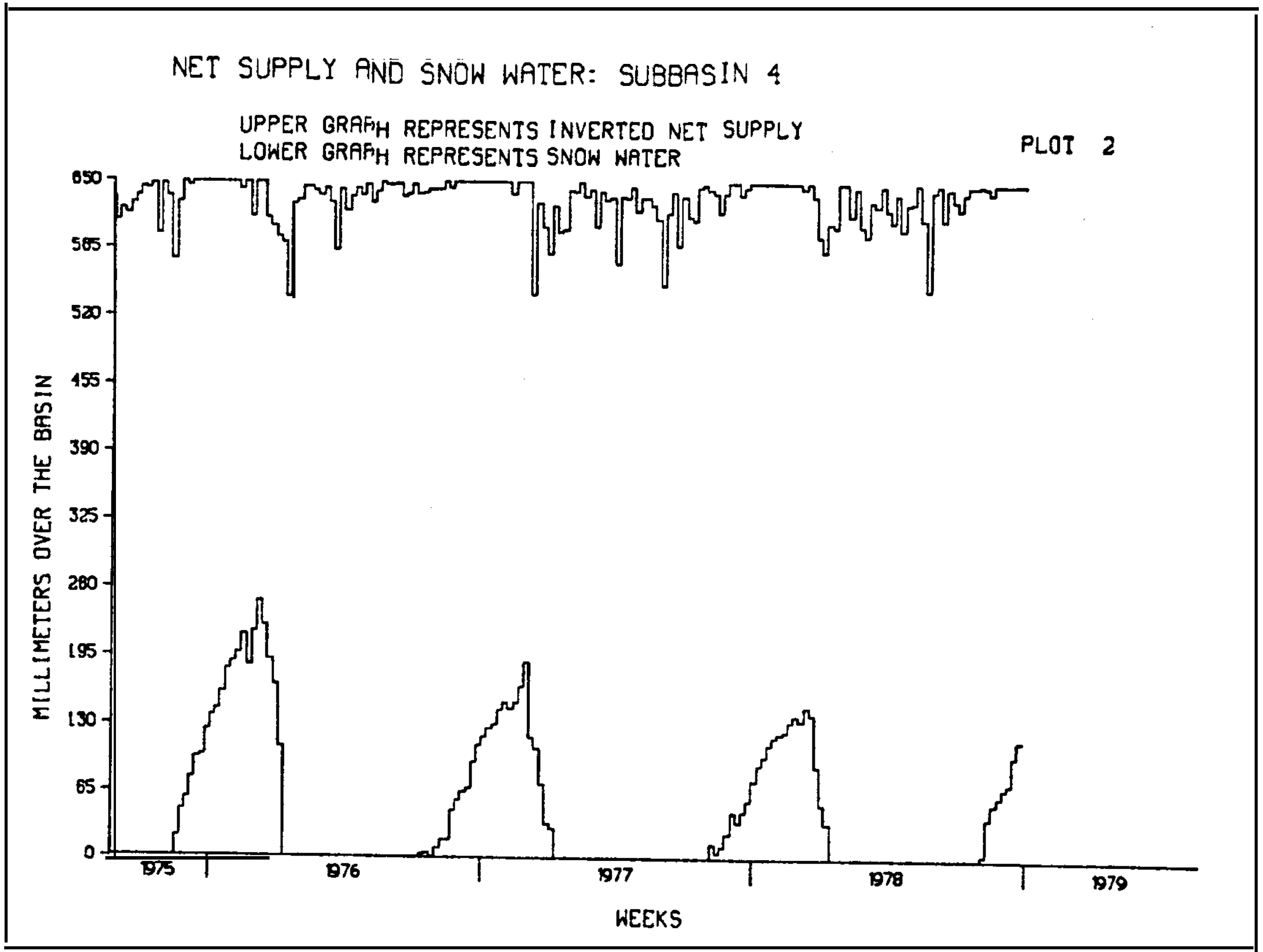


FIGURE 9.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).*

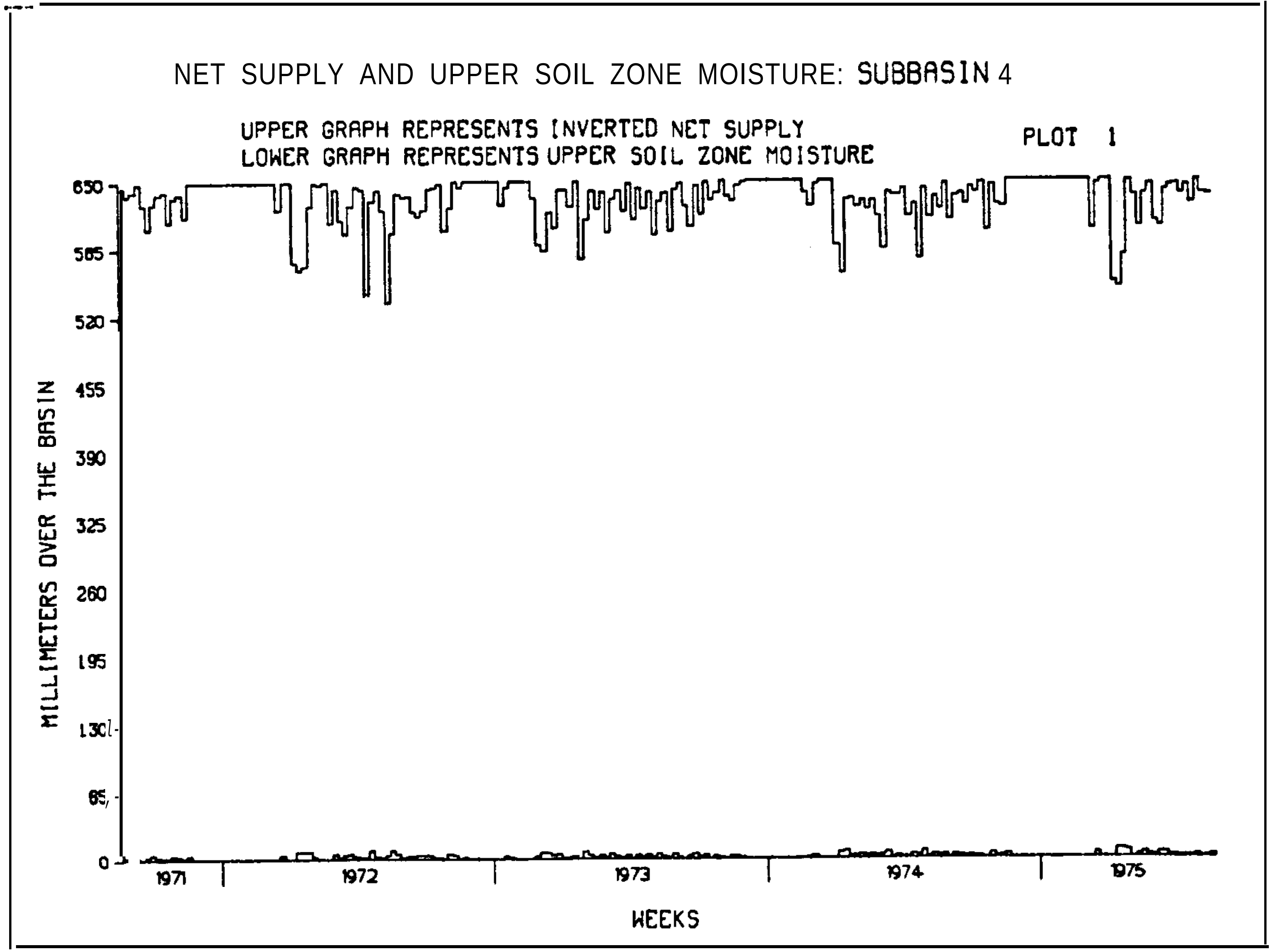


FIGURE 9.--Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).

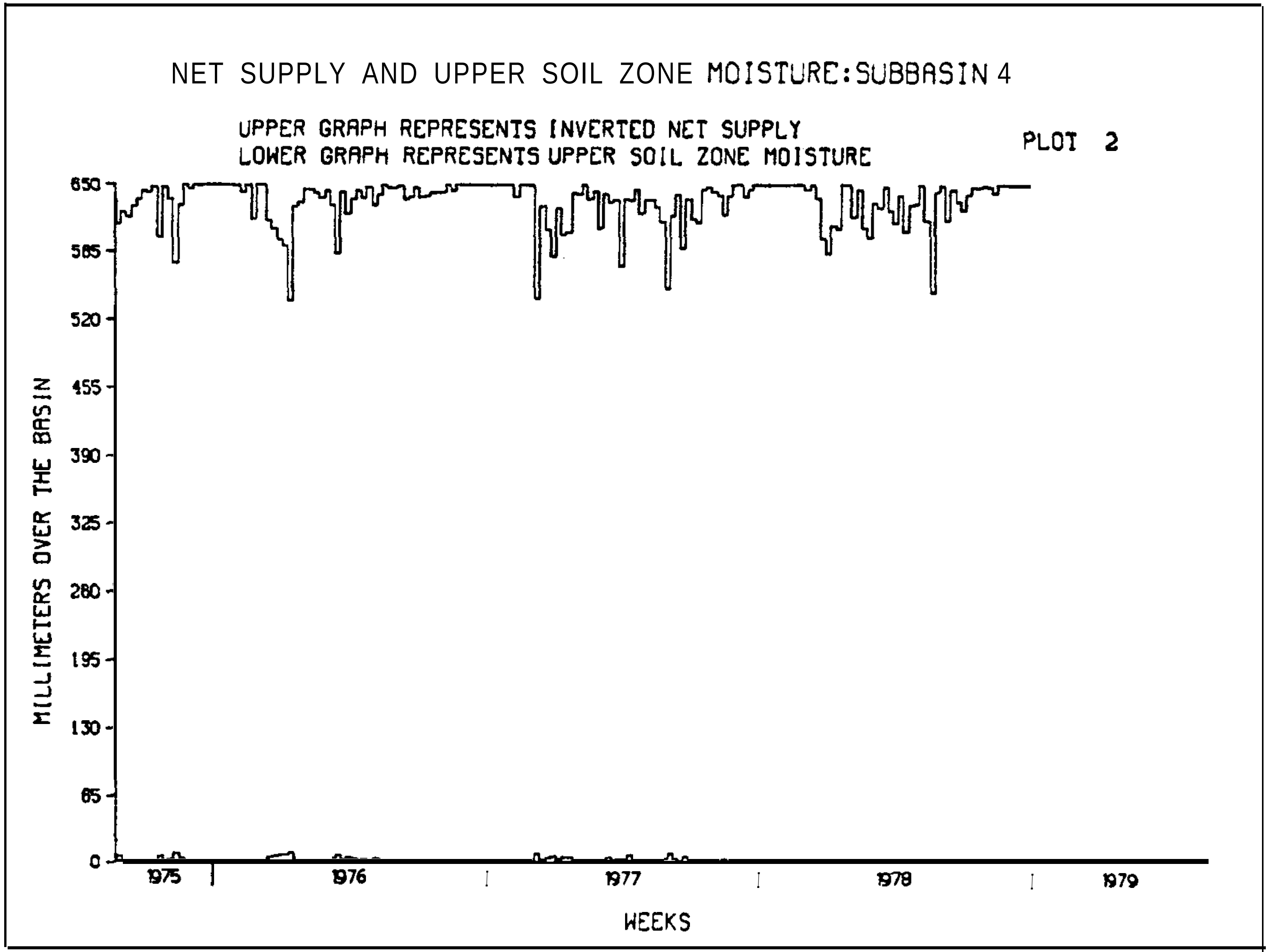


FIGURE 9.--*Seven-day net supply mte to the watershed and 7th day snowpack, soil zones, groundwater,* and surface *storages for subbasin 4 (cont.).*

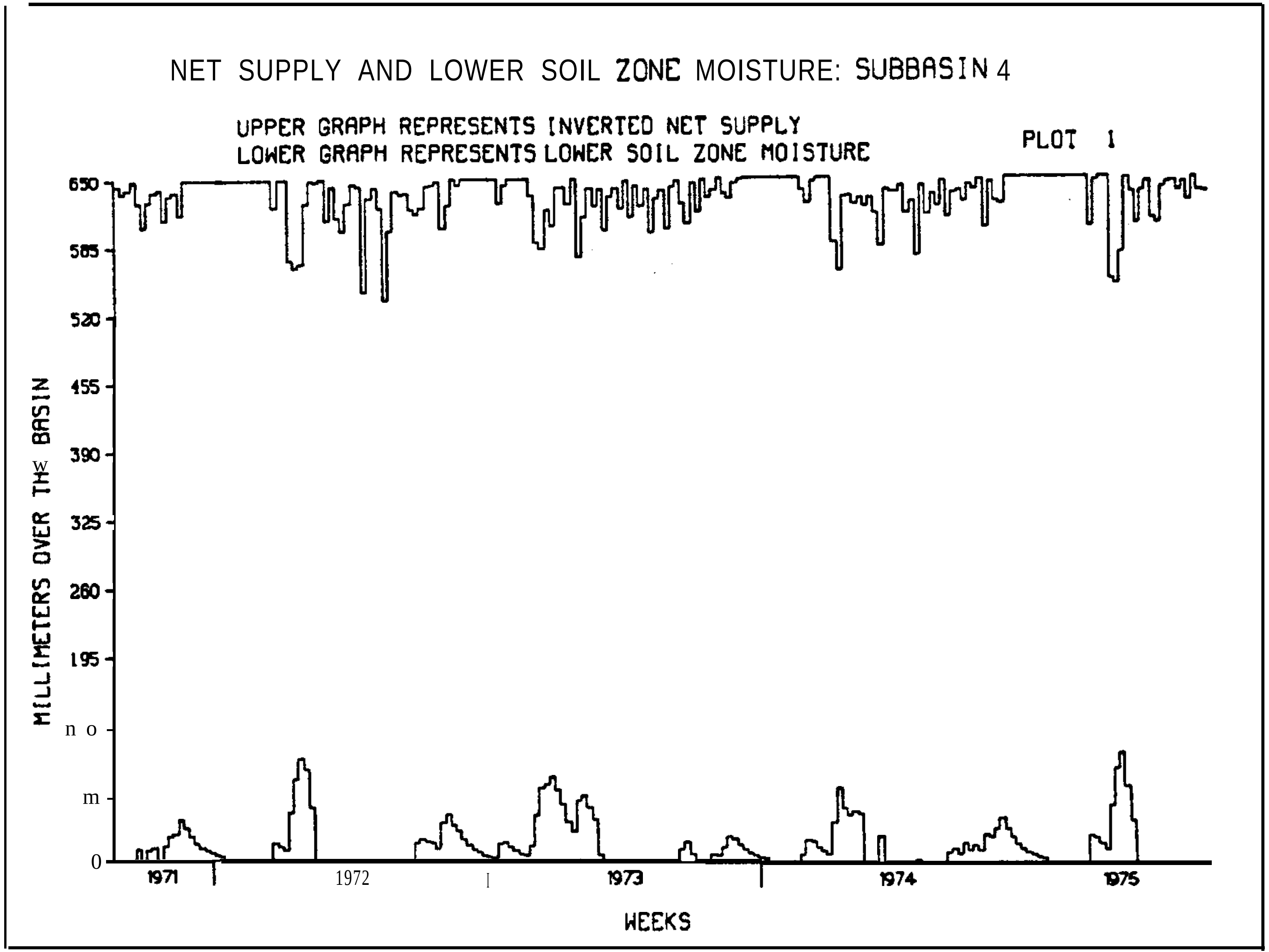


FIGURE 9.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).*

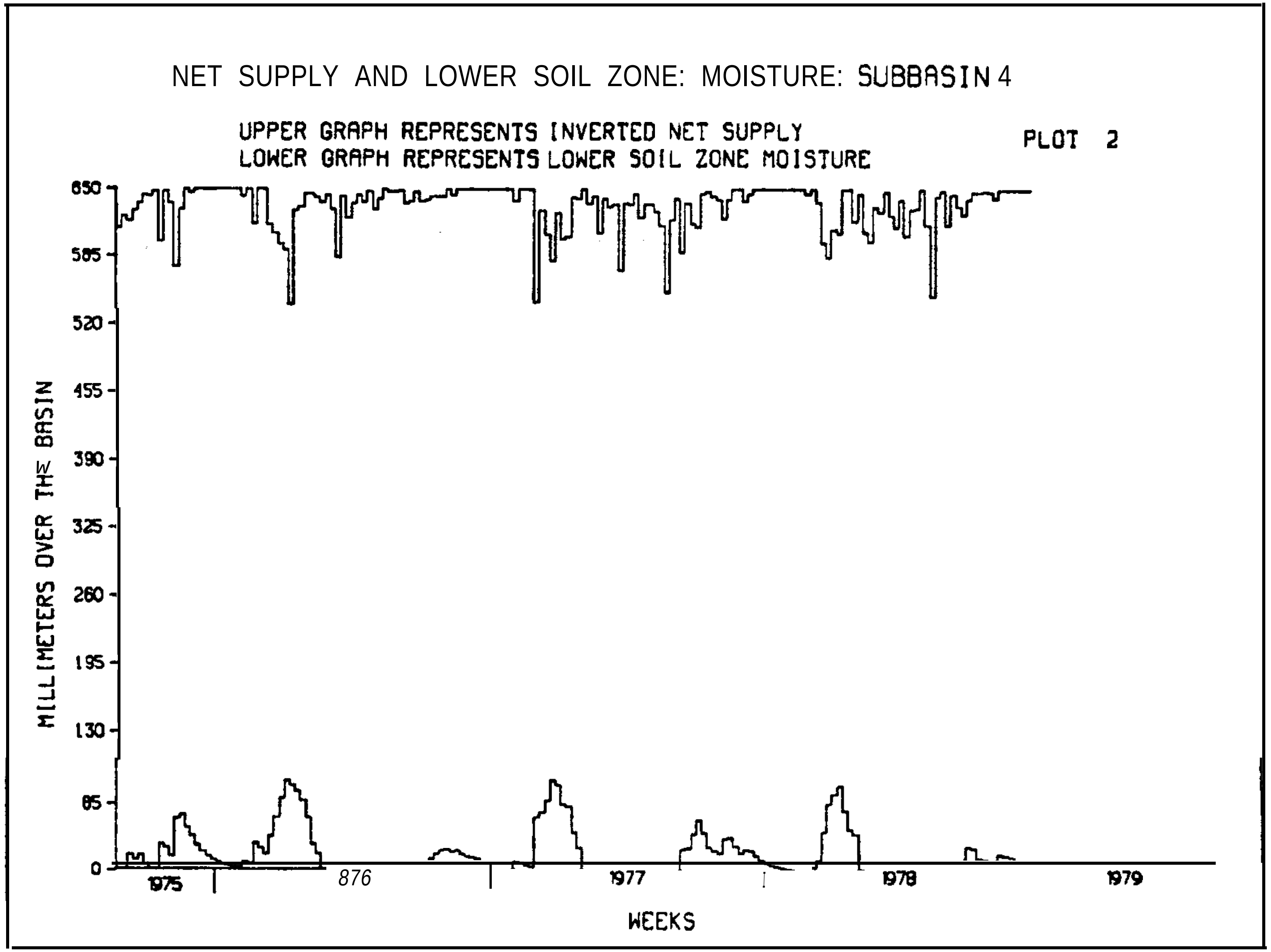


FIGURE 9.--Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).

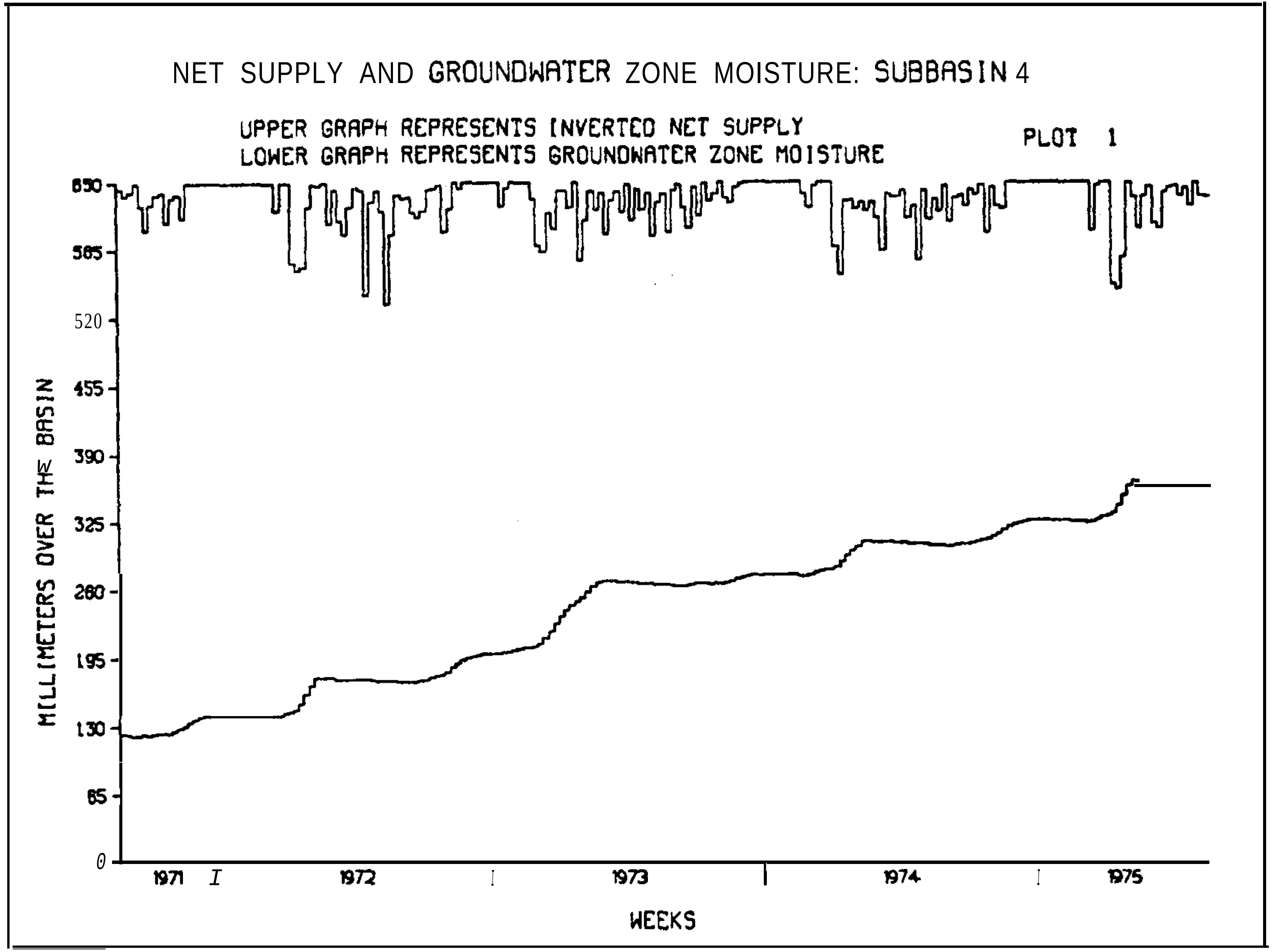


FIGURE 9.--Seven-day net supply mte to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).

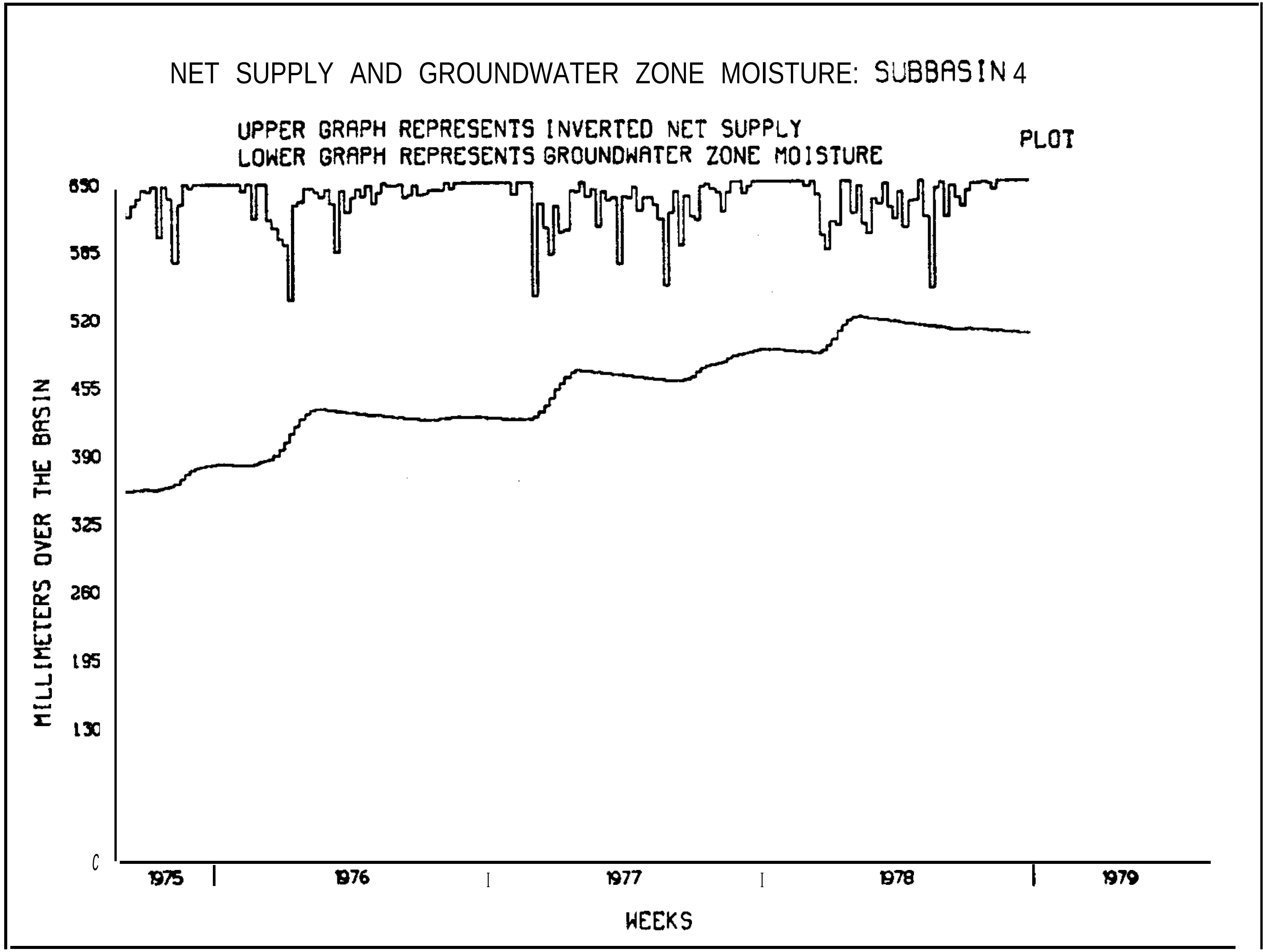


FIGURE 9.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).*

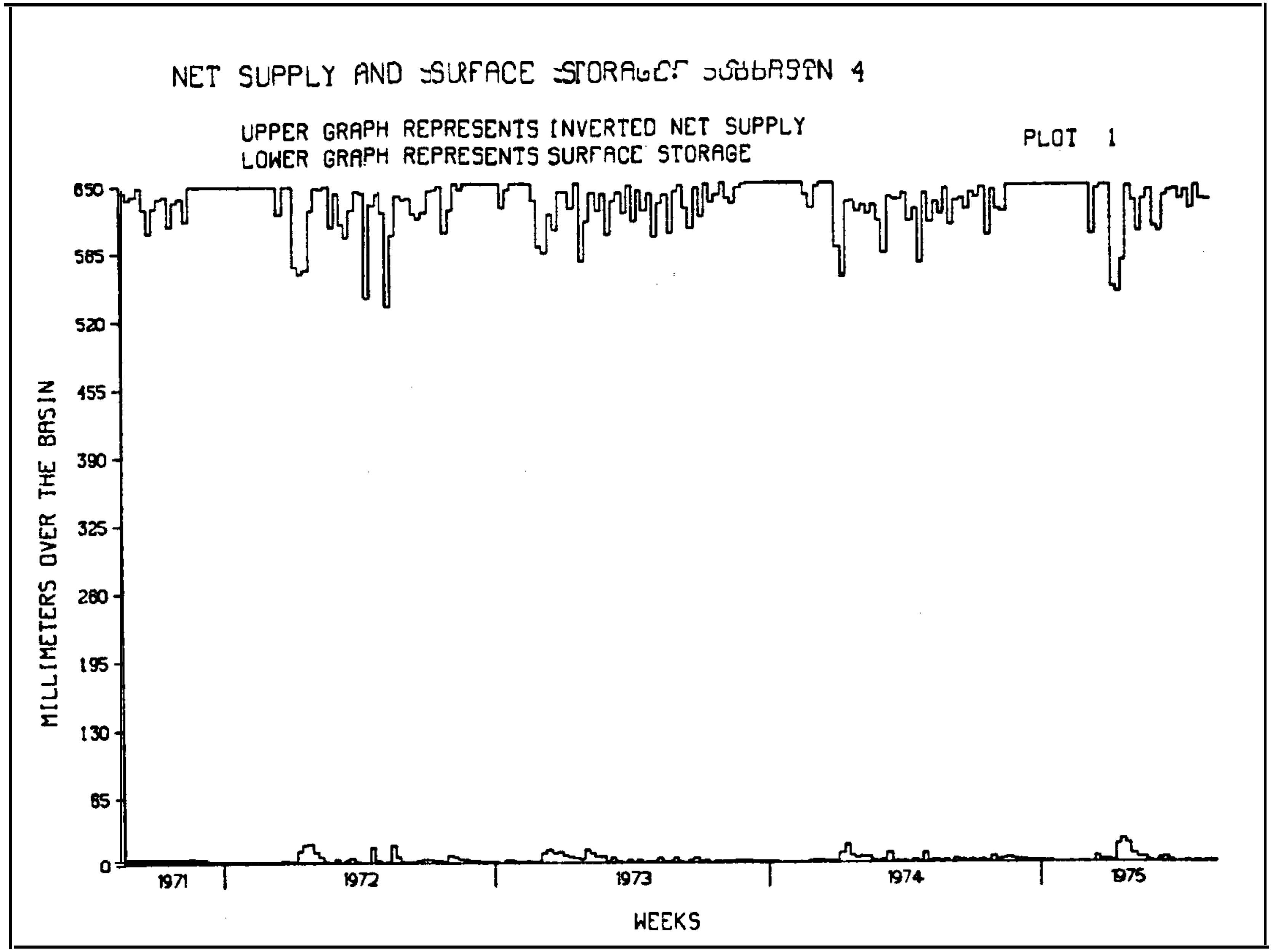


FIGURE 9.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).*

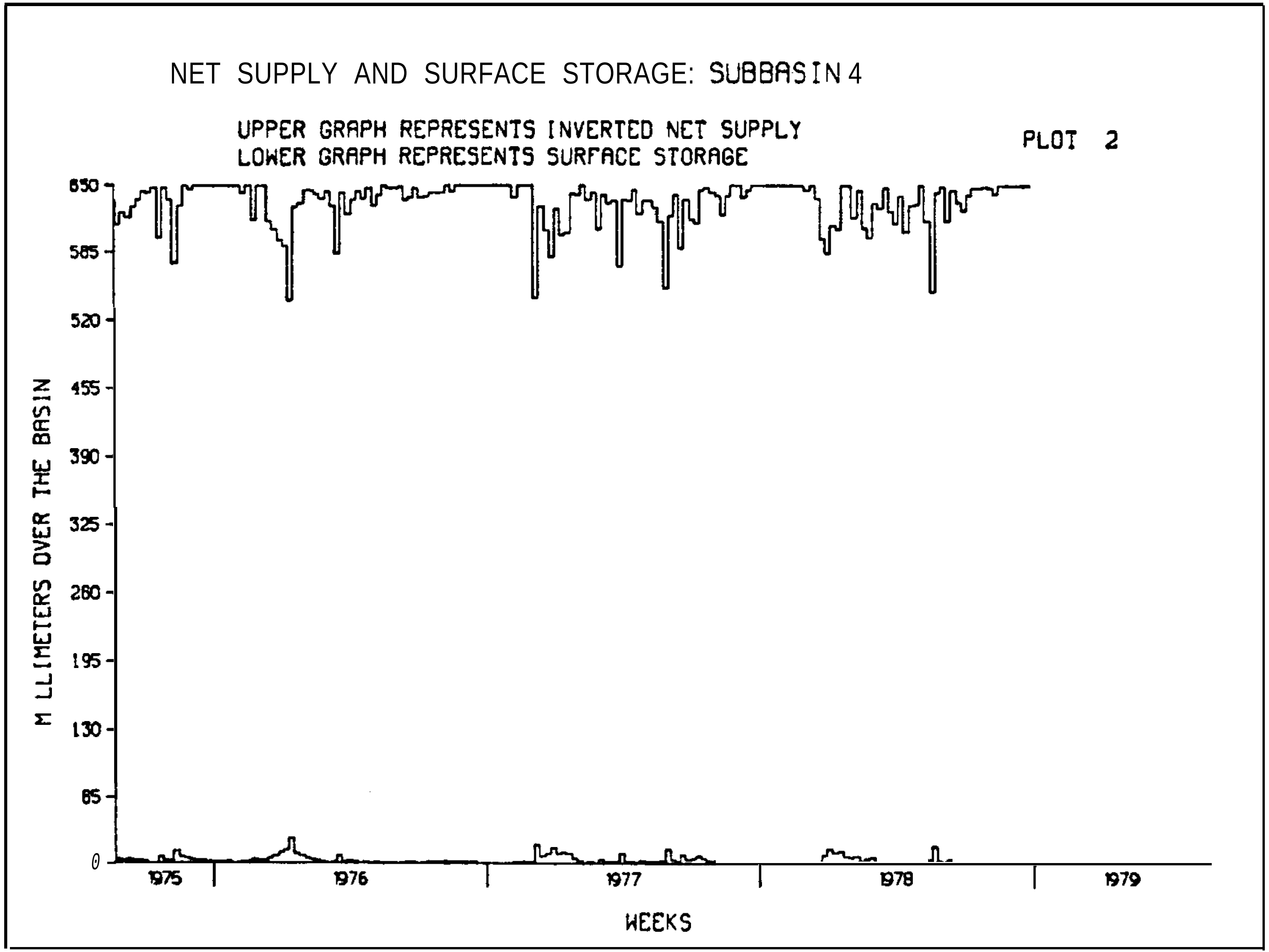


FIGURE 9.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 4 (cont.).*

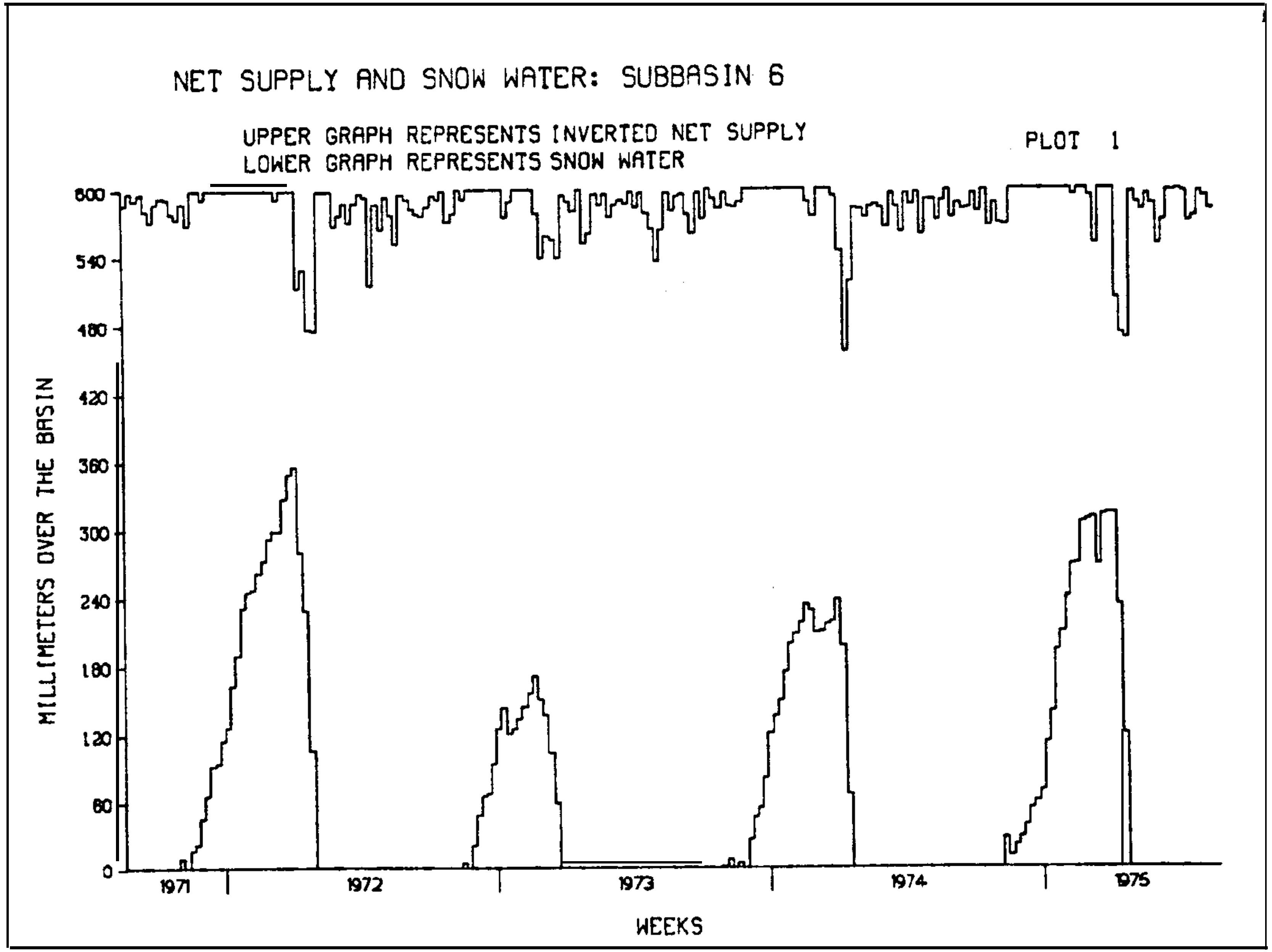


FIGURE 0.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6.*

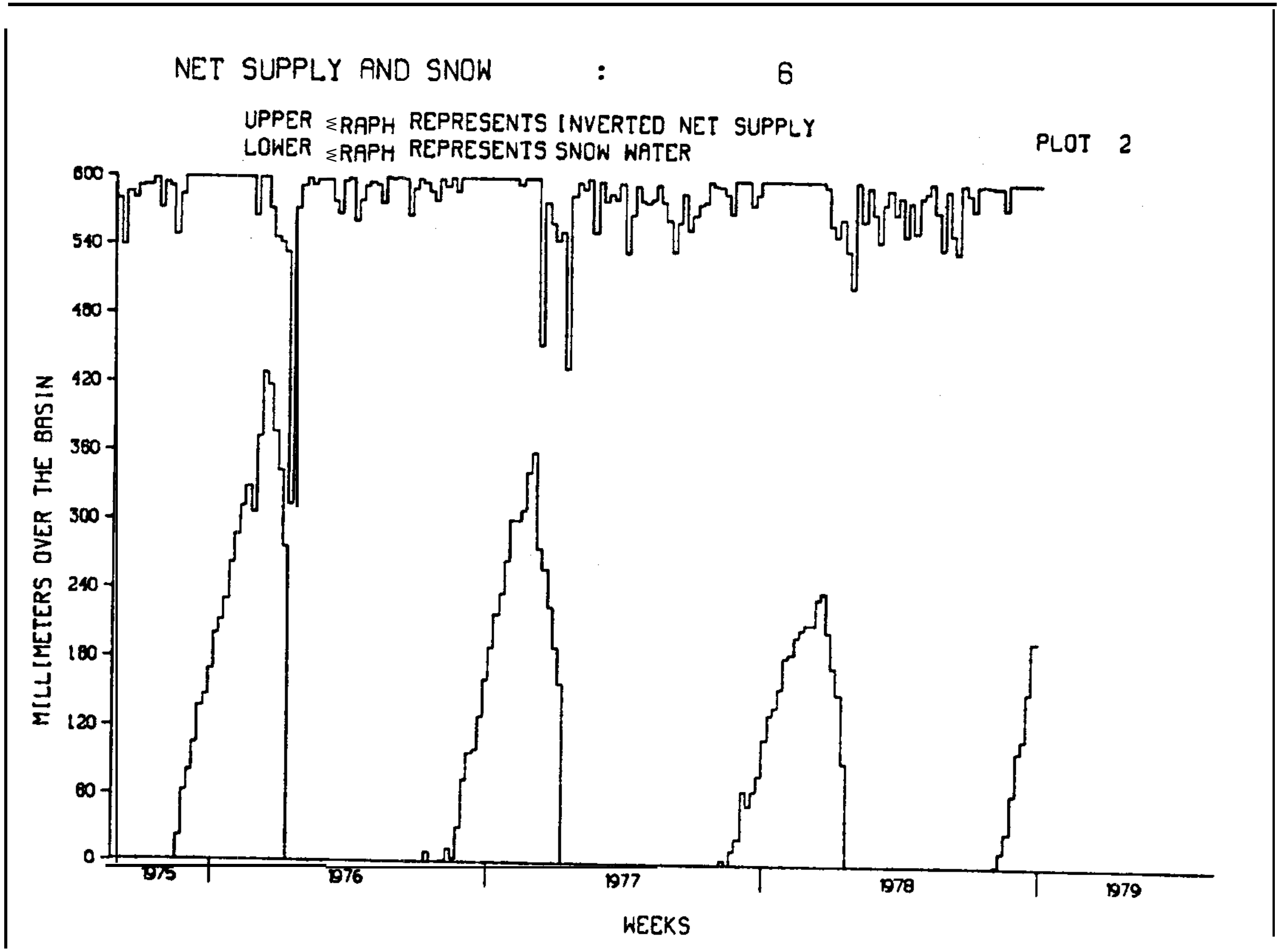


FIGURE 10.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6 (cont.).*

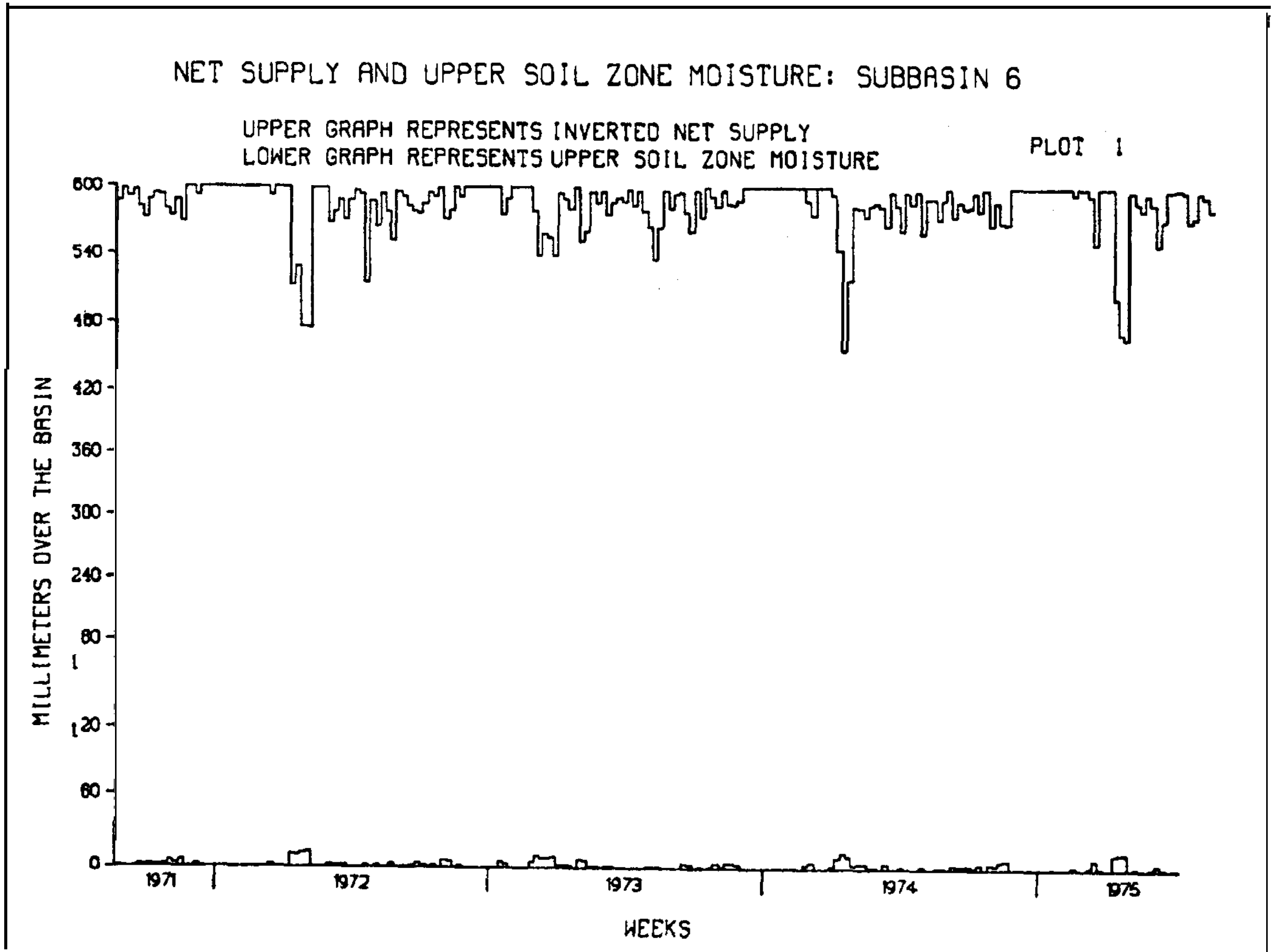


FIGURE 10.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6 (cont.).*

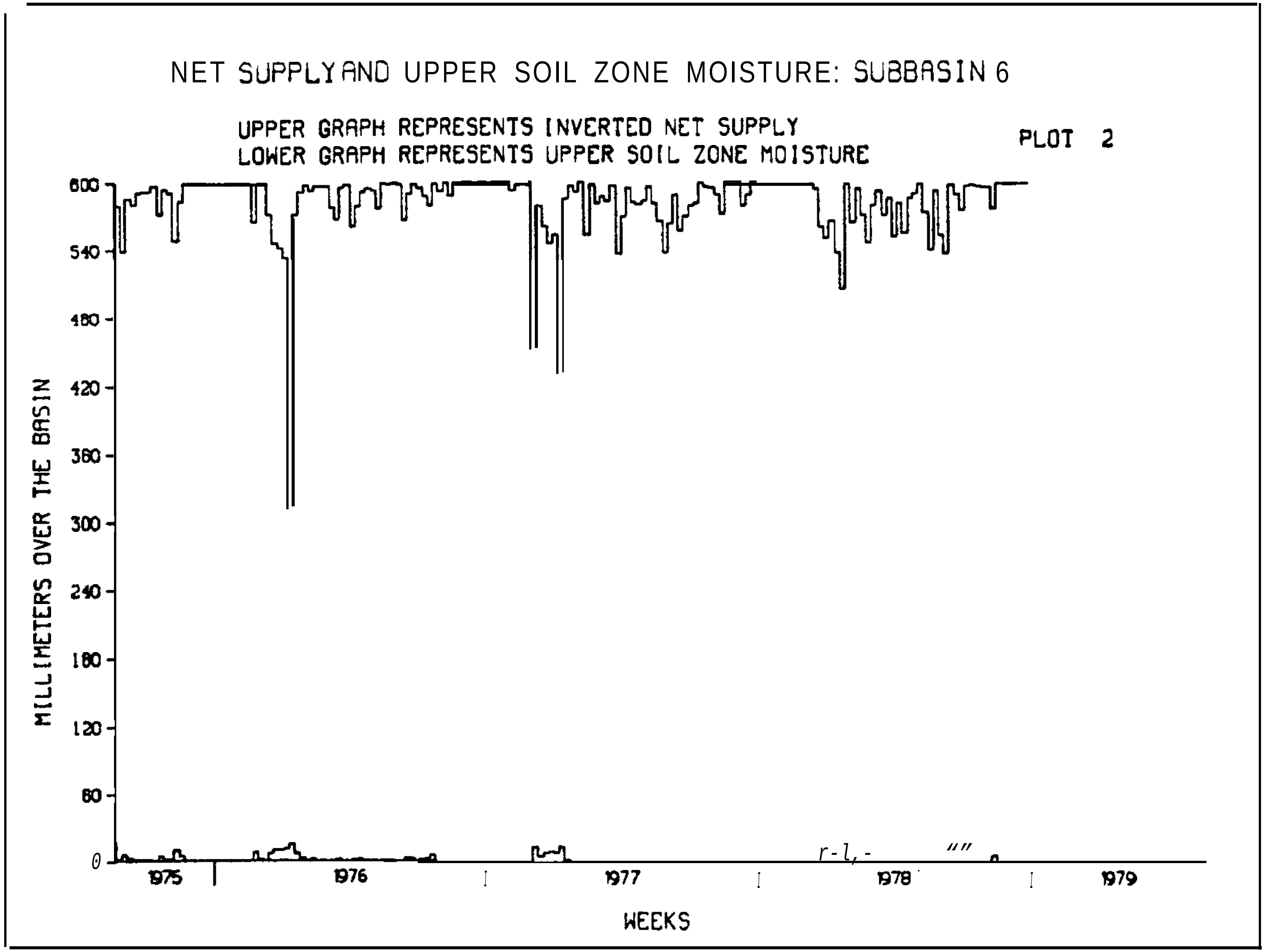


FIGURE 10.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6 (cont.).*

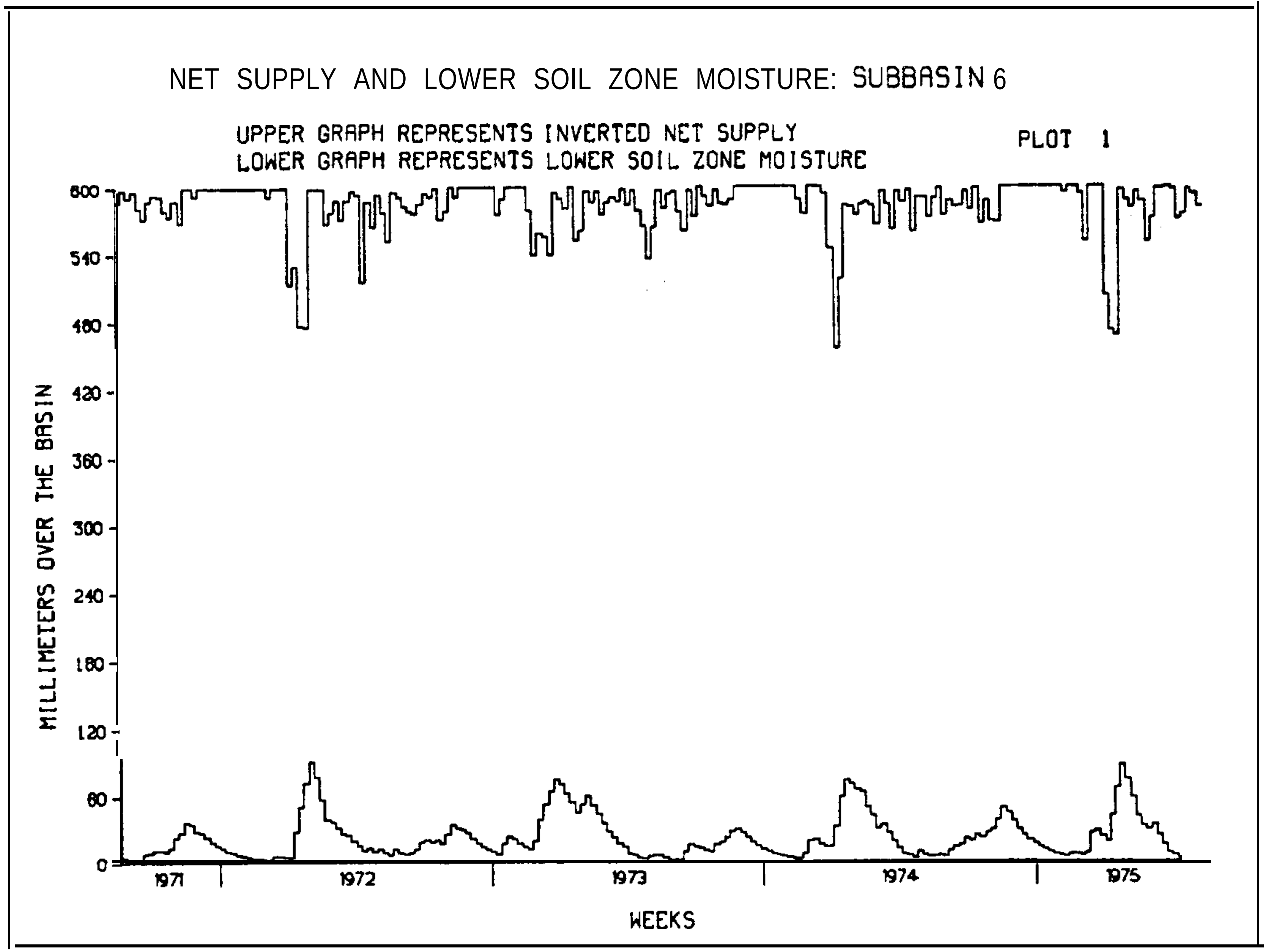


FIGURE 10.--*Seven-day* net supply *rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6 (cont.).*

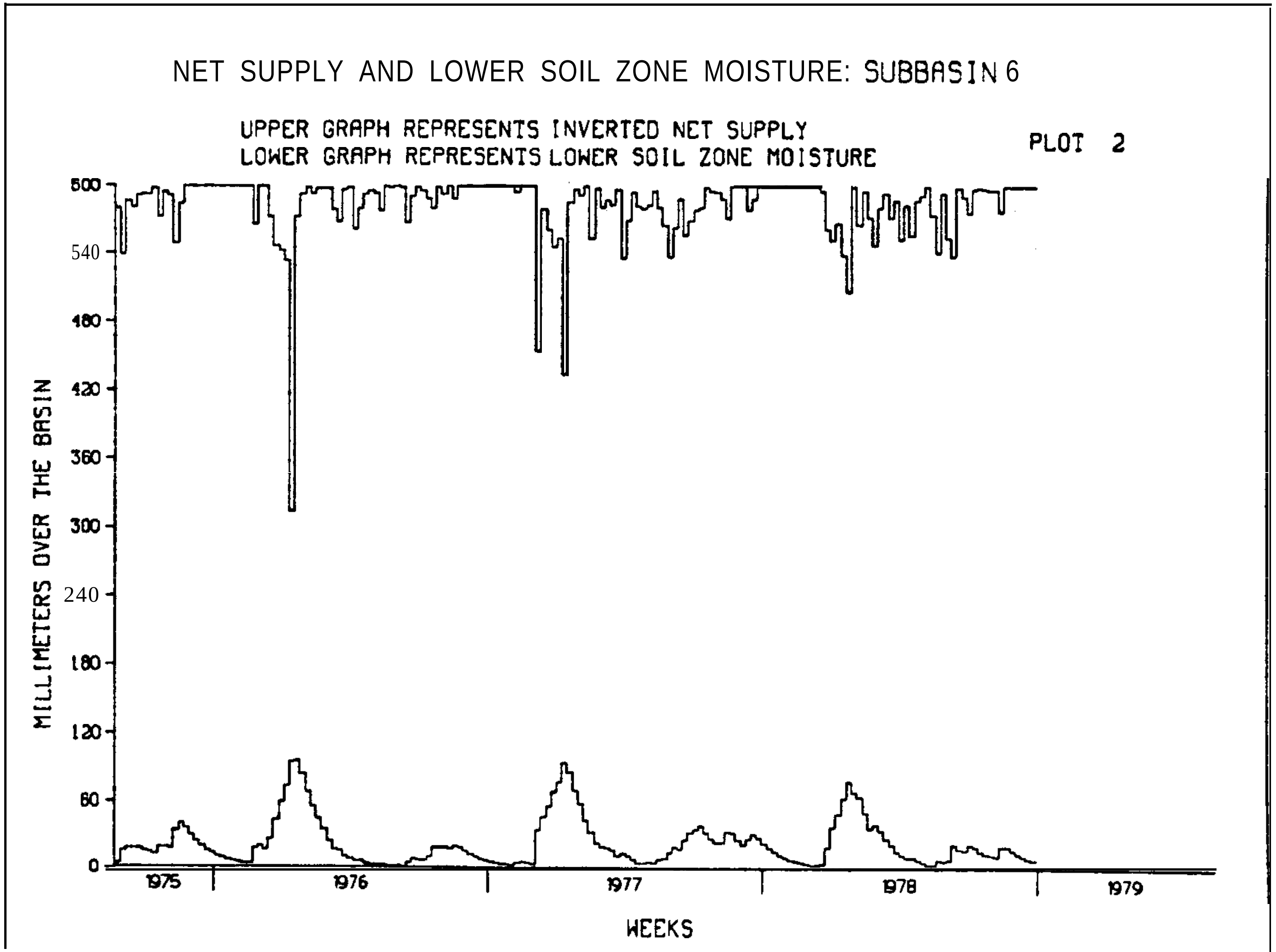


FIGURE 10.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface stomps for subbasin 6 (cont.).*

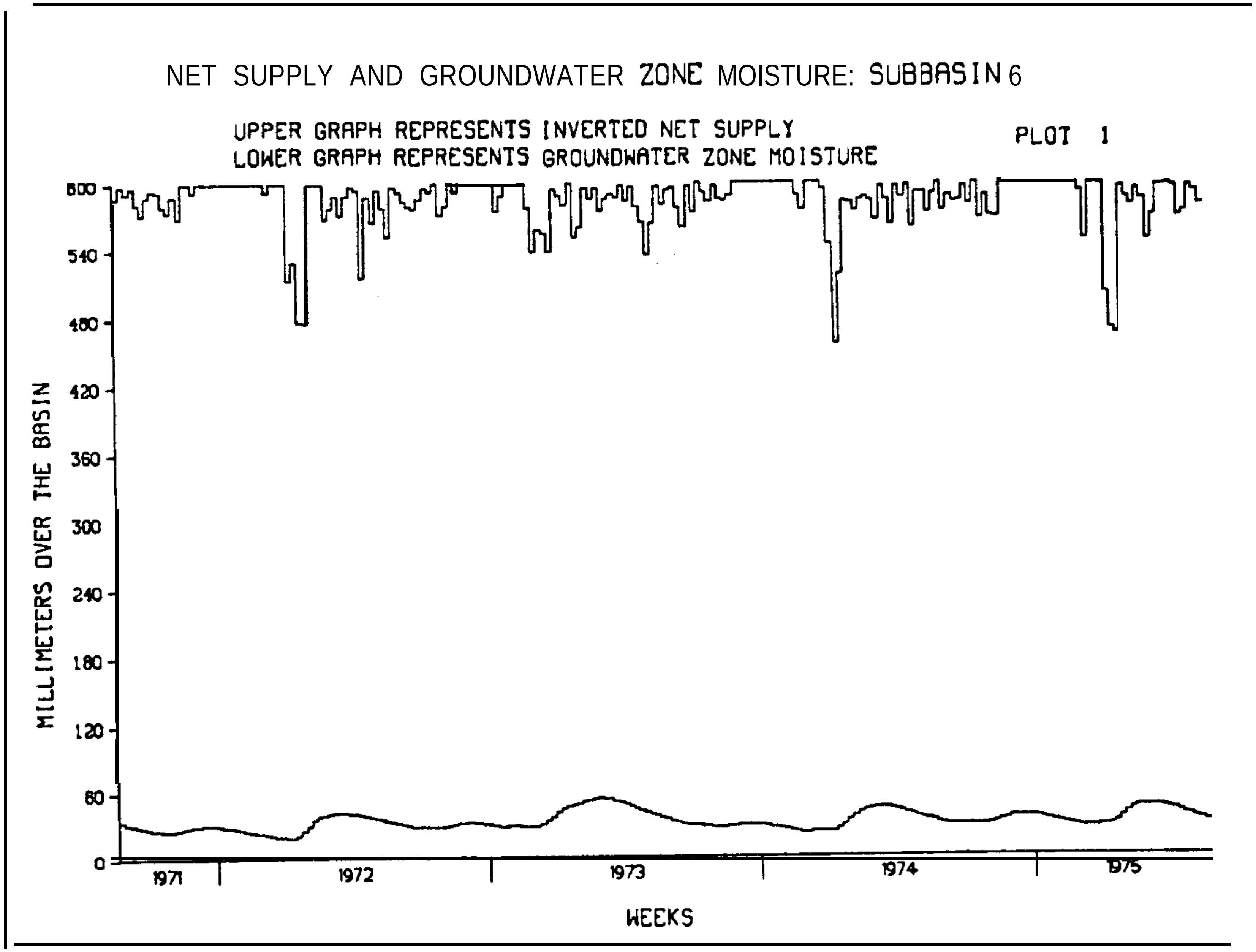


FIGURE 10.--*Seven-day net supply mte to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6 (cont.).*

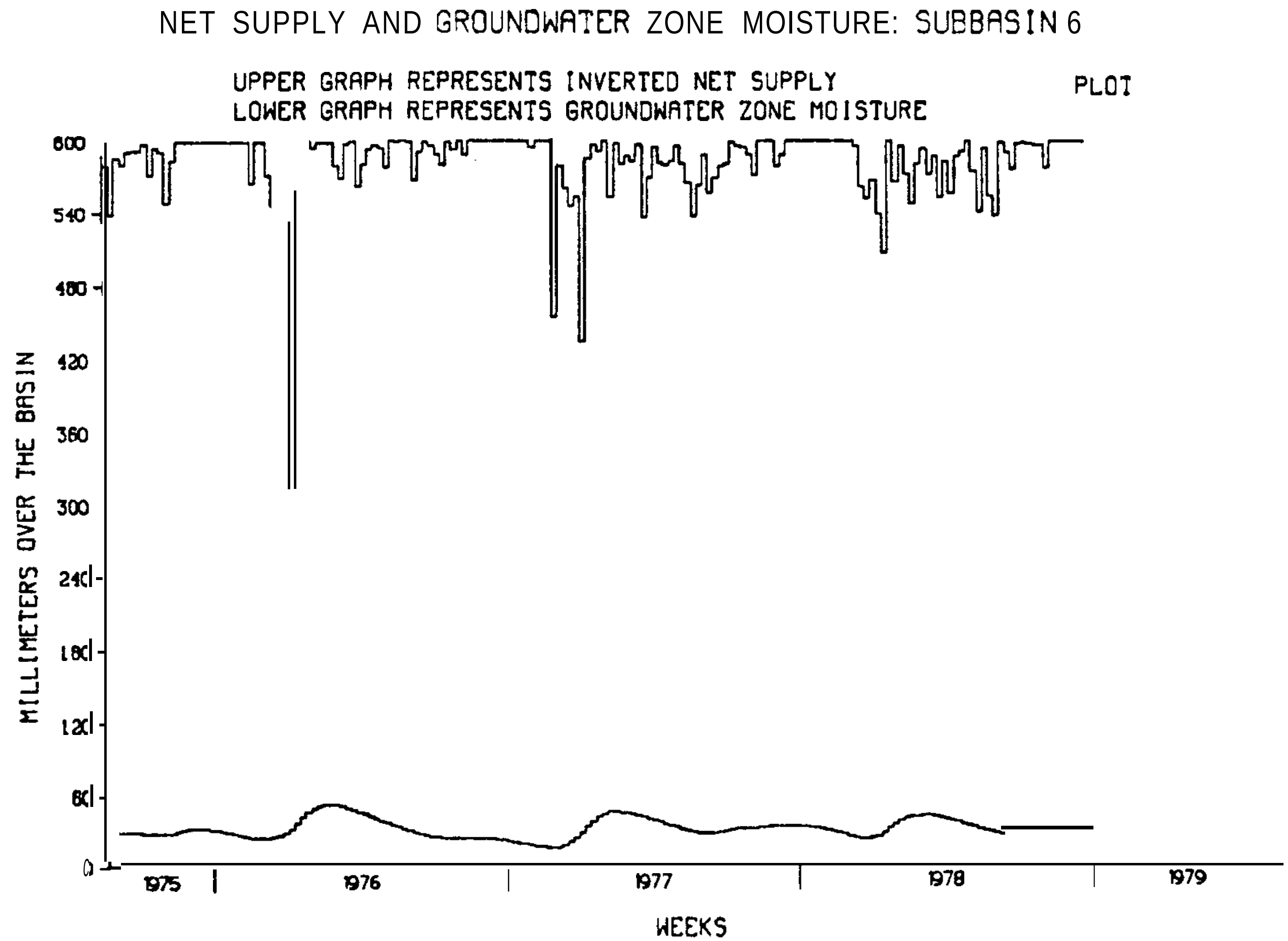
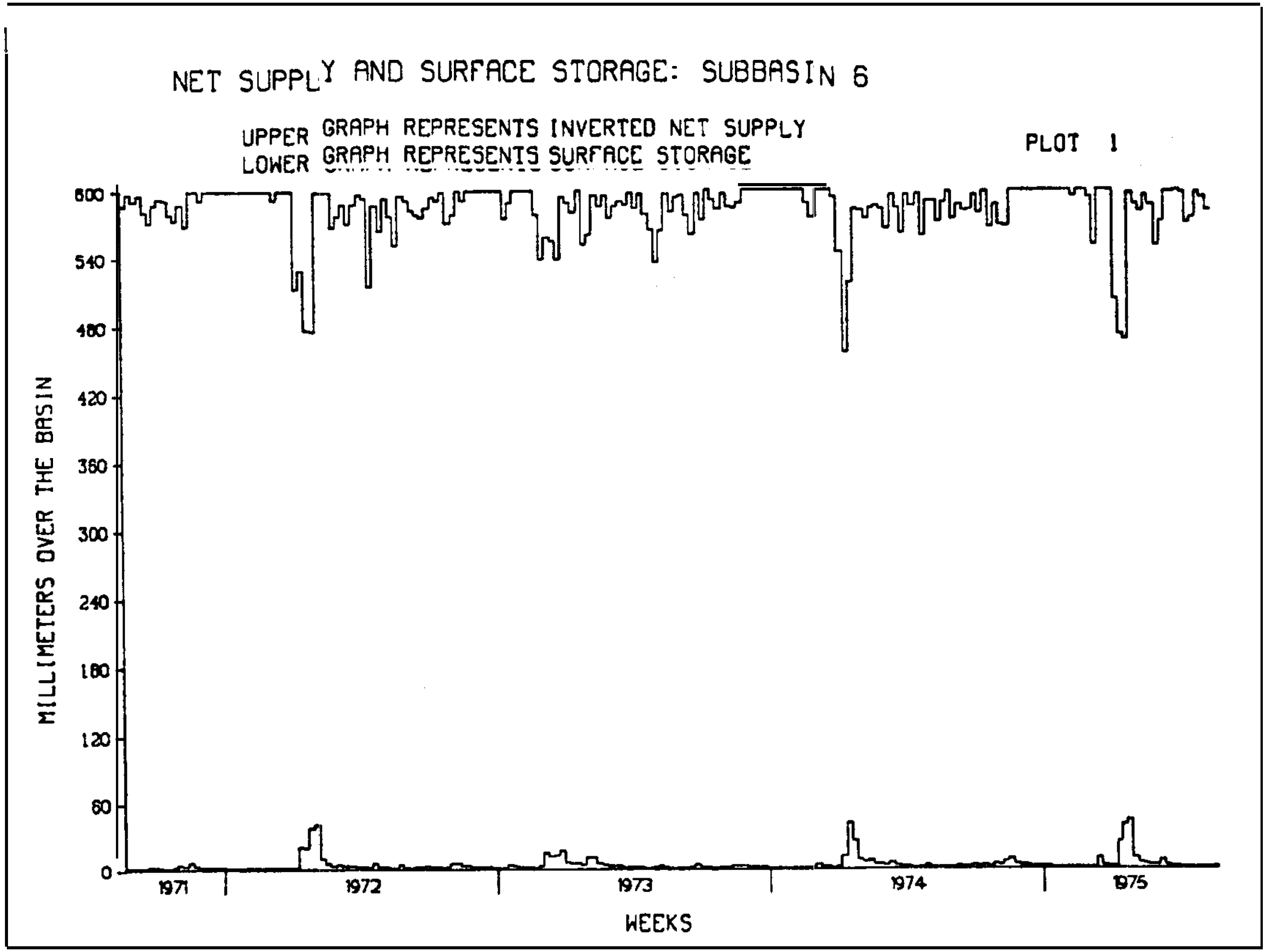


FIGURE 10.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6 (cont.).*



day rate to wa day snowpack,
oun surface ag 6 (cont.).

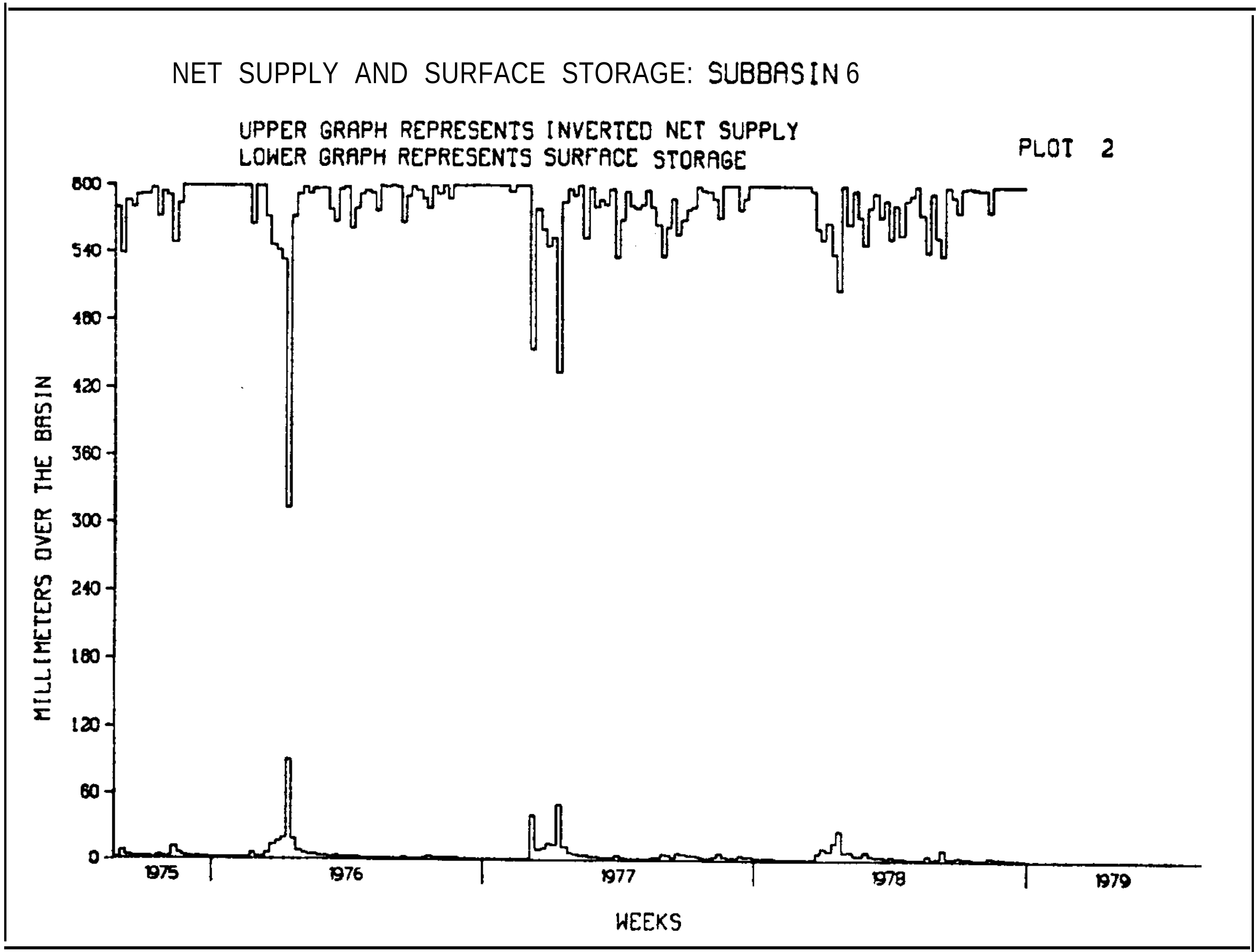


FIGURE 10.--*Seven-day net supply mte to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 6 (cont.).*

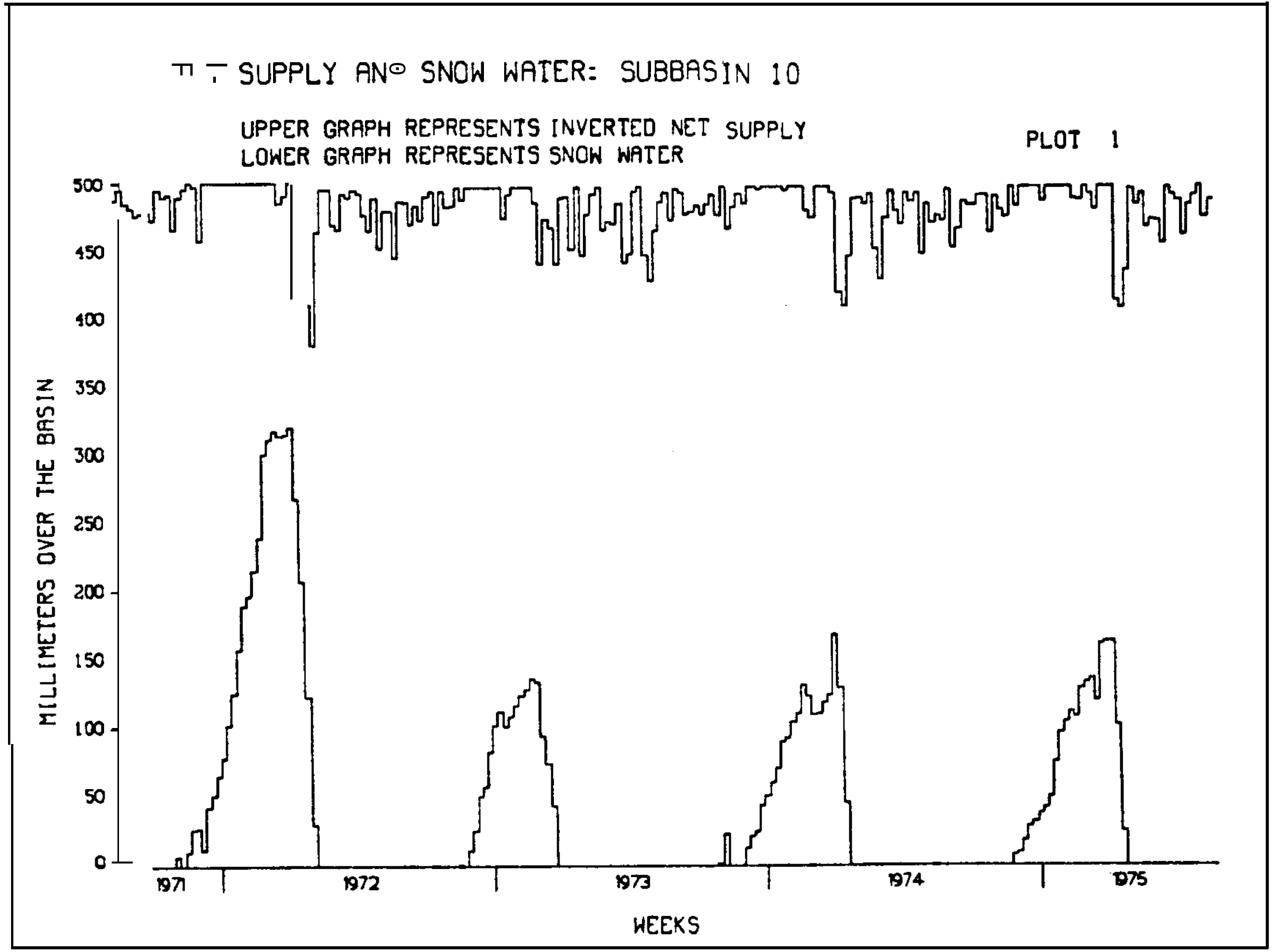


FIGURE 1.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10.*

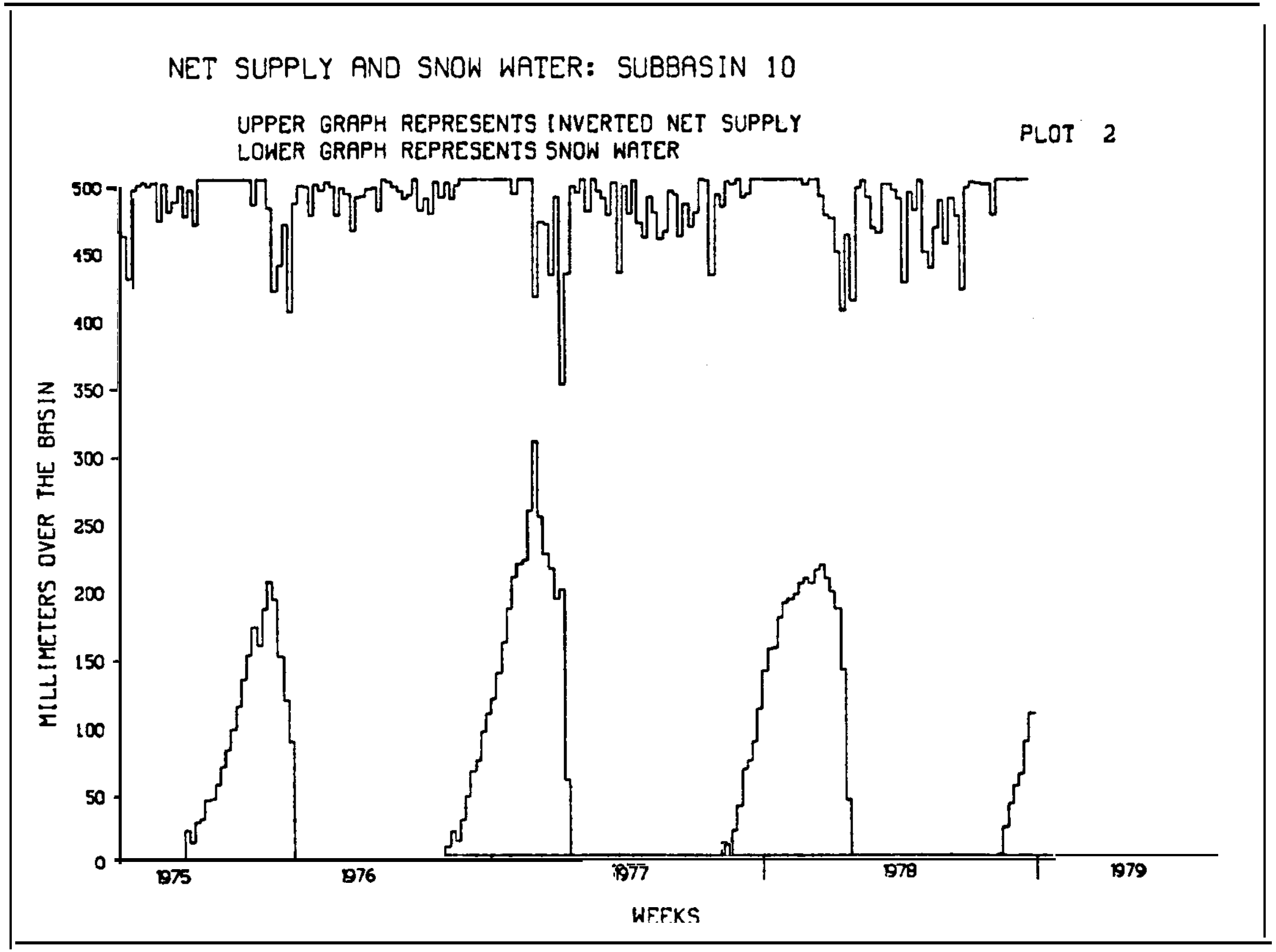


FIGURE 11.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones. groundwater, and surface storages for subbasin 10 (cont.).*

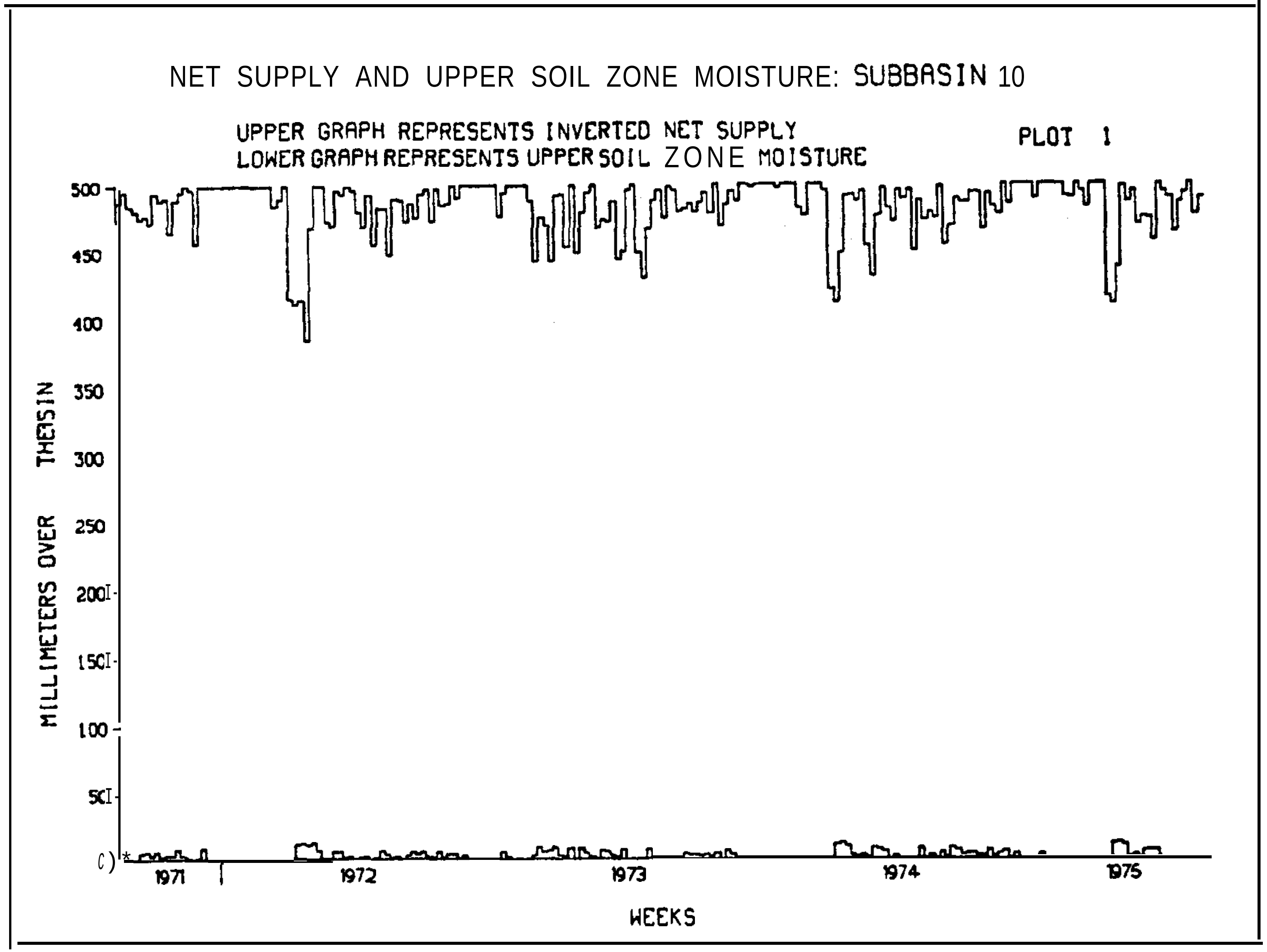


FIGURE 11.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

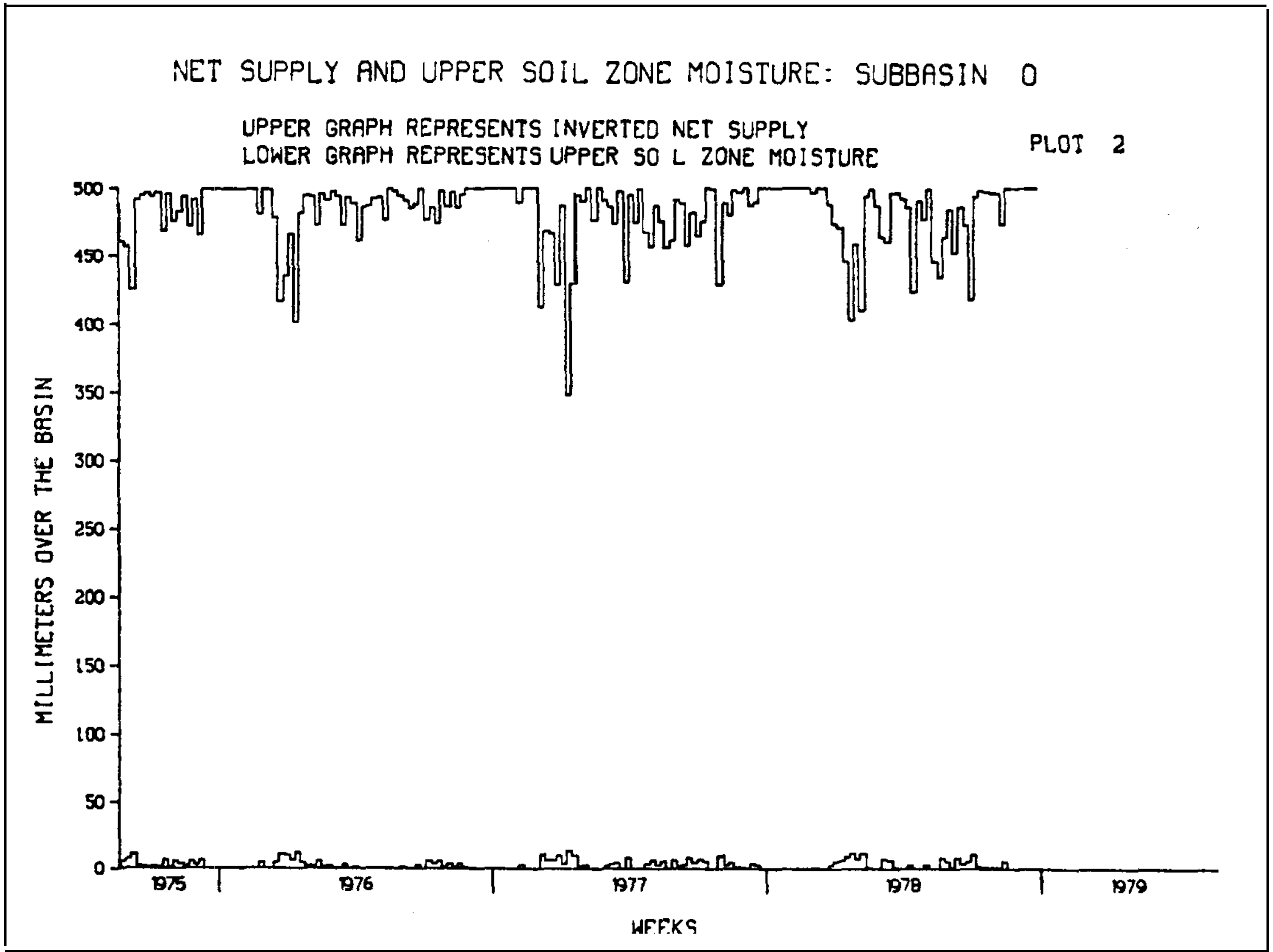


FIGURE 1.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

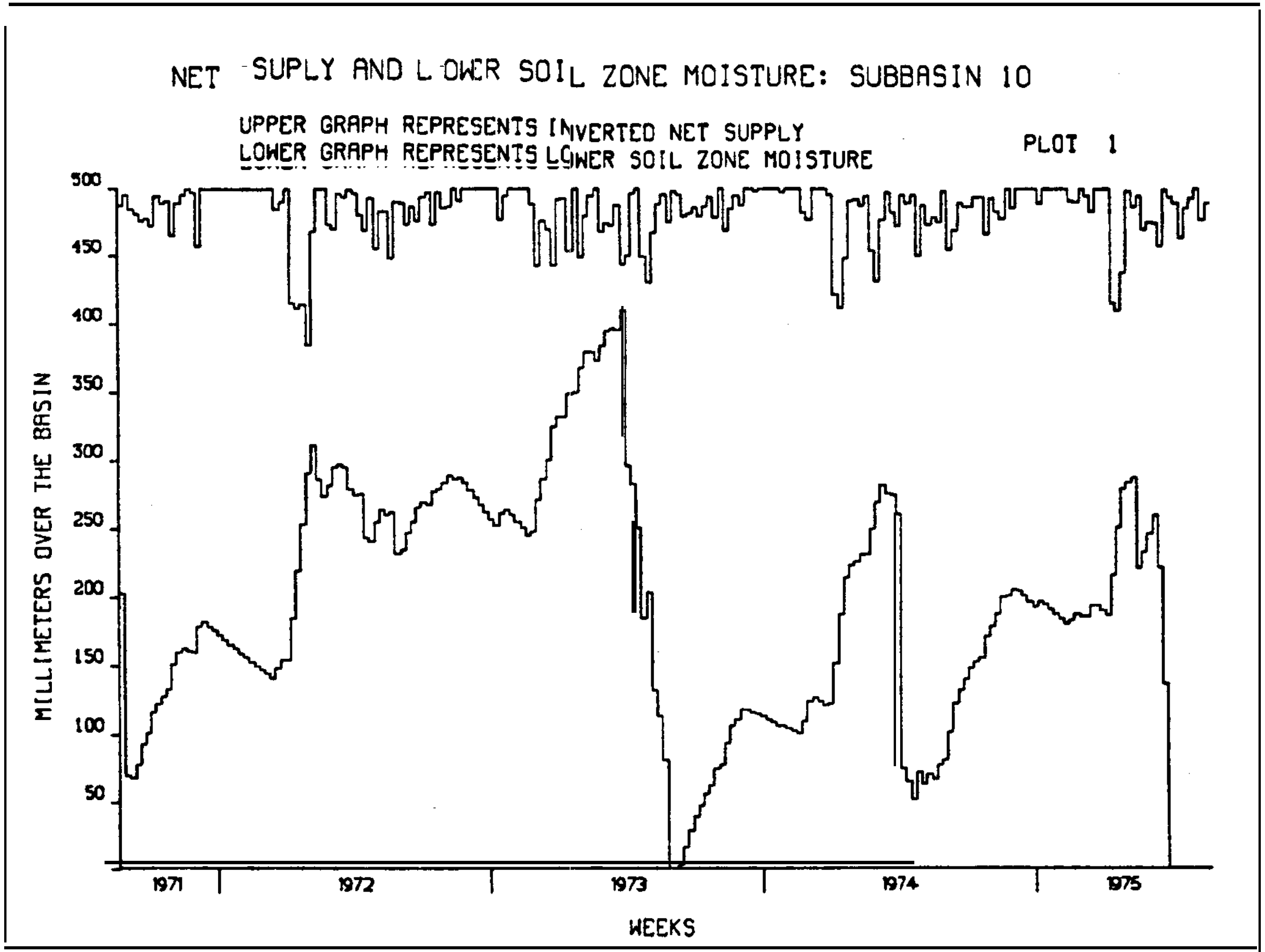


FIGURE 1.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

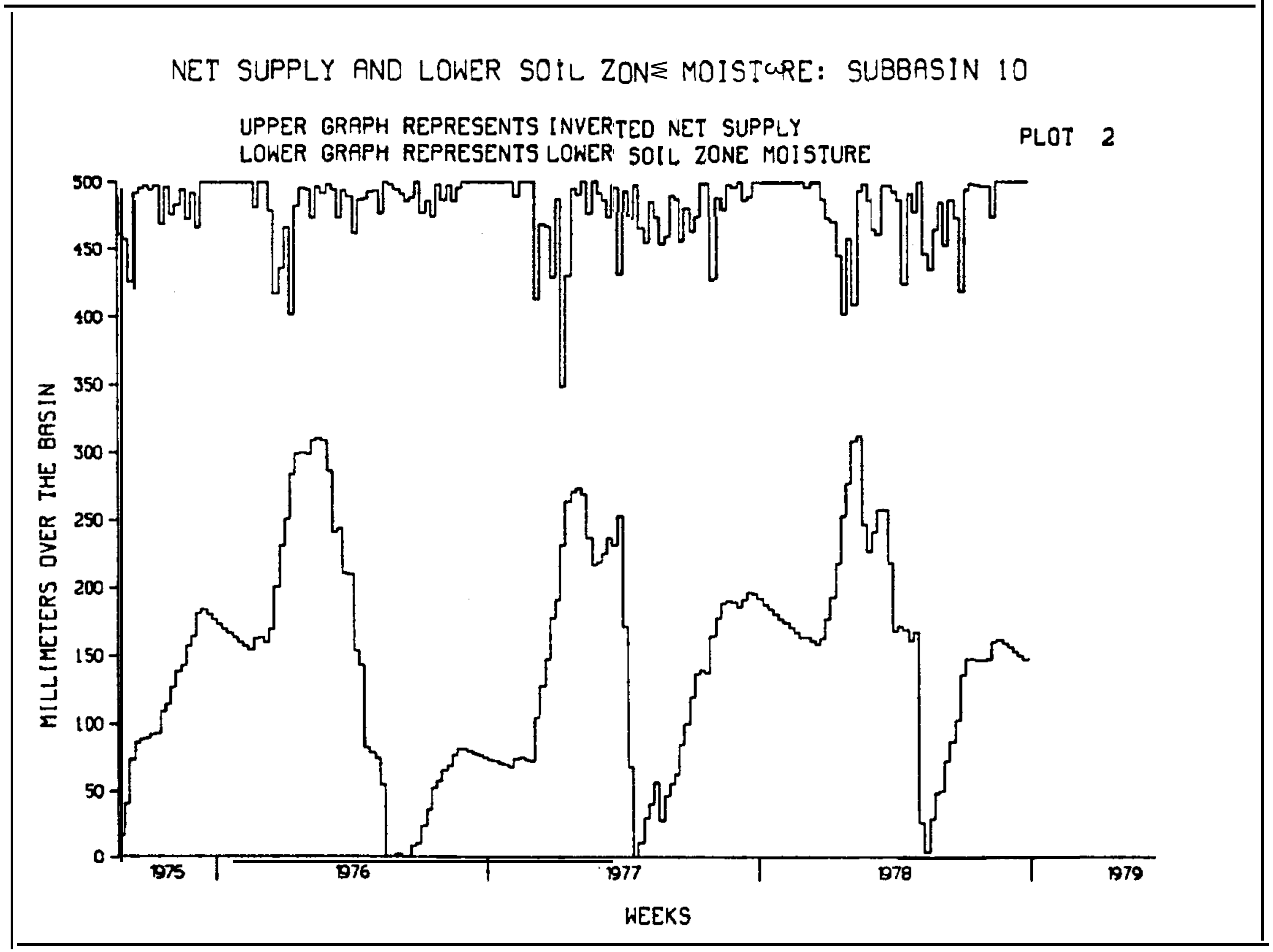


FIGURE 1.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

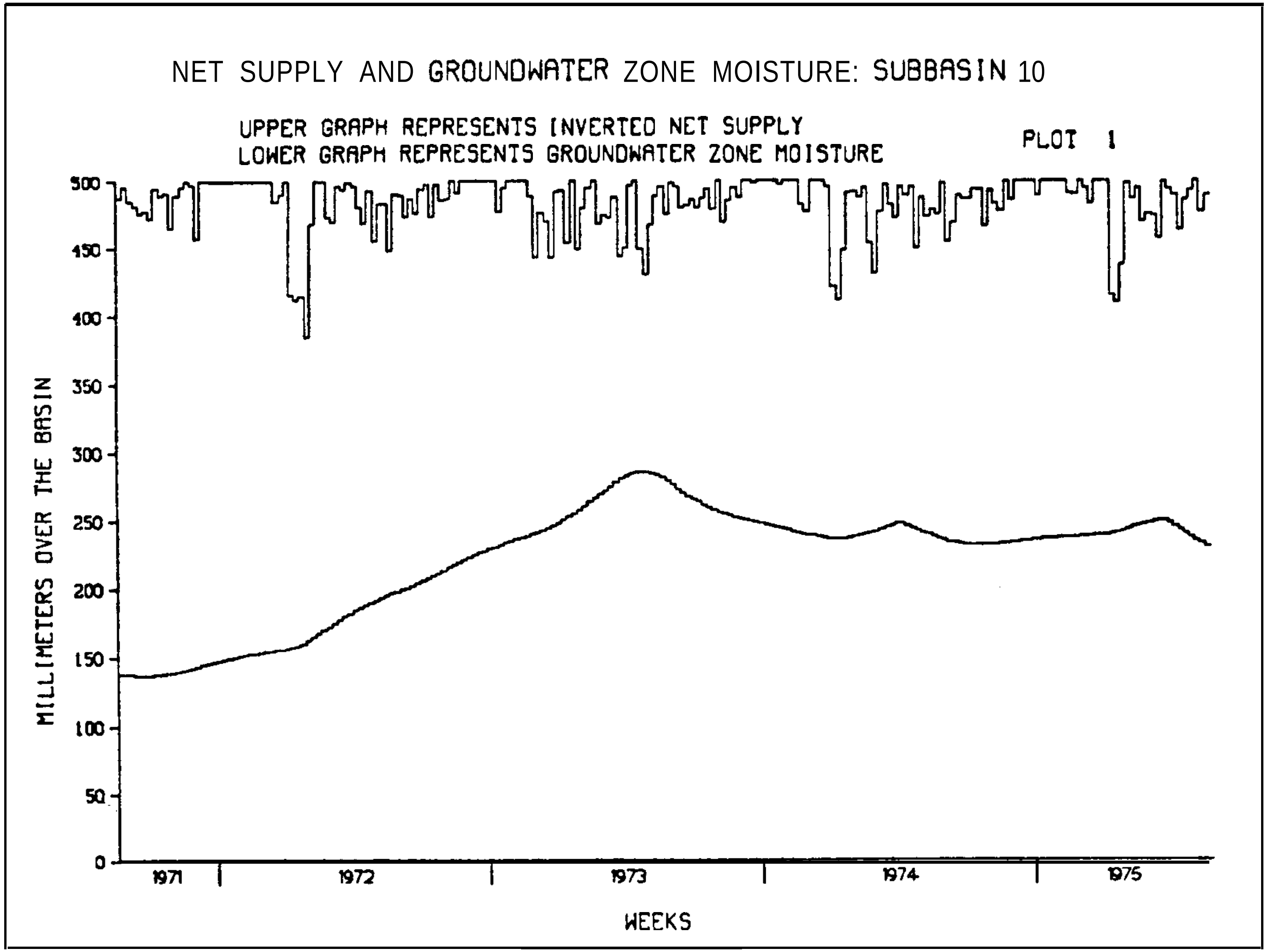


FIGURE 11.--*Seven-day net supply mte to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

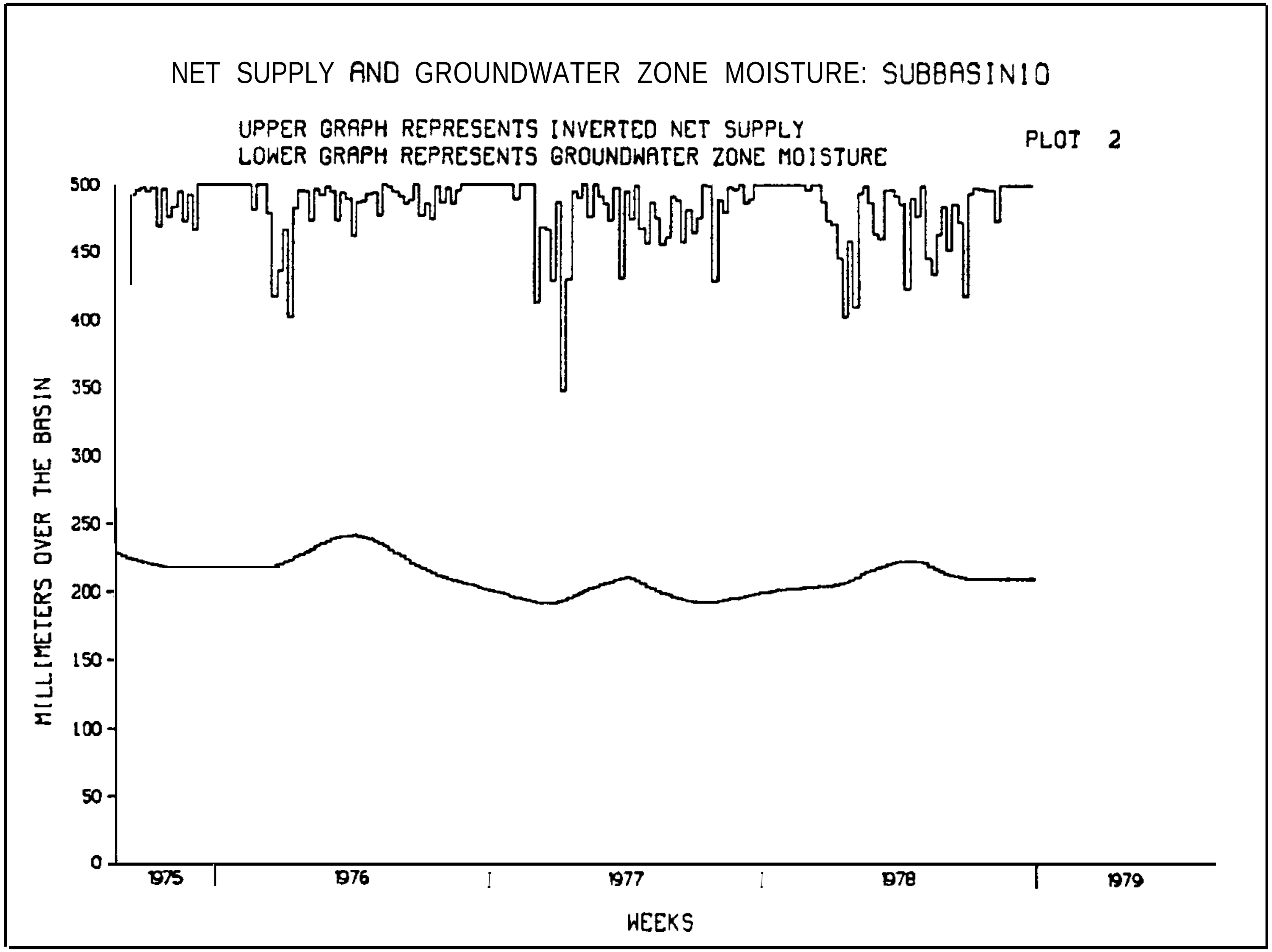


FIGURE 11.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

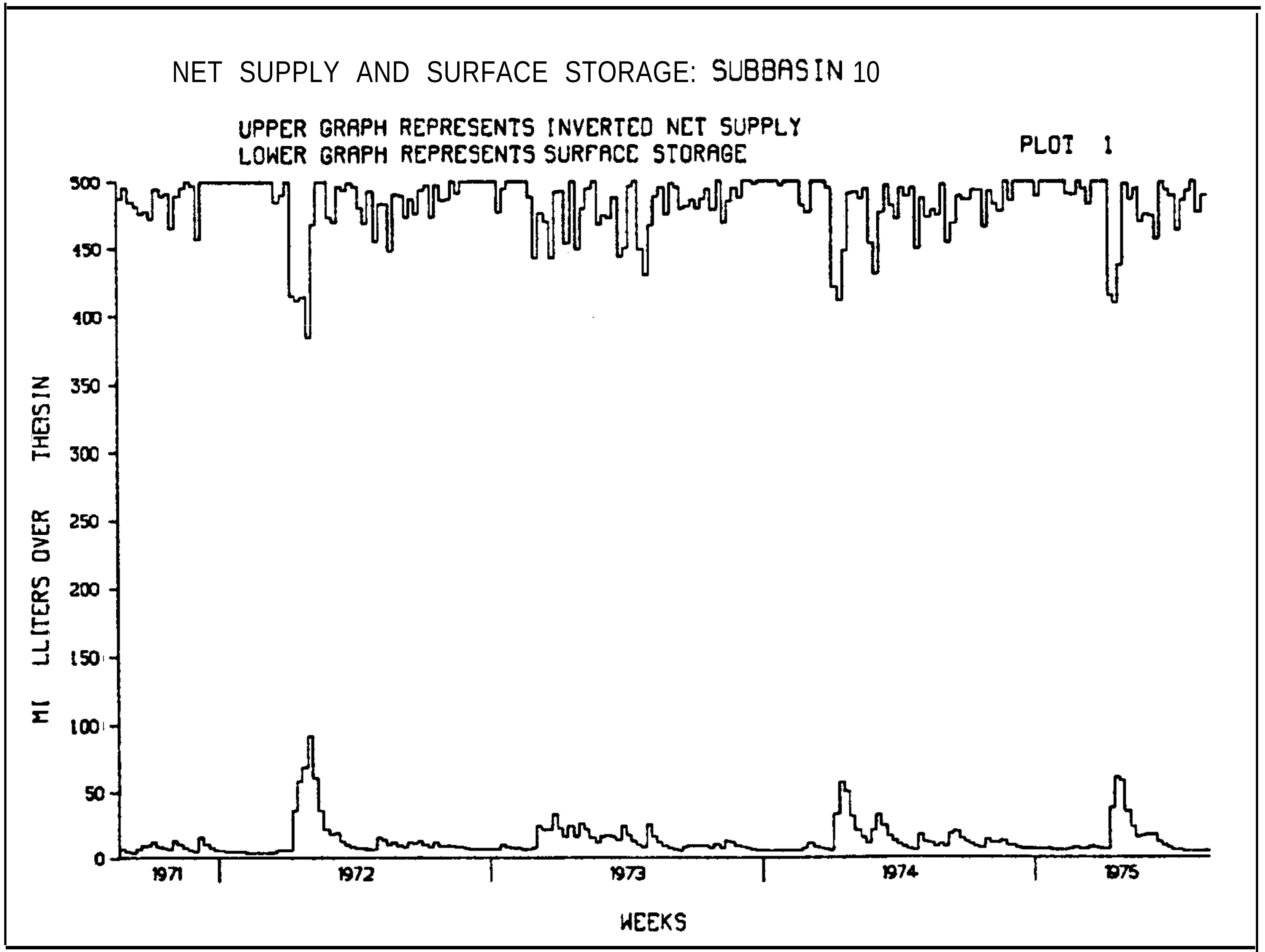


FIGURE 11.--*Seven-day net* supply *rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

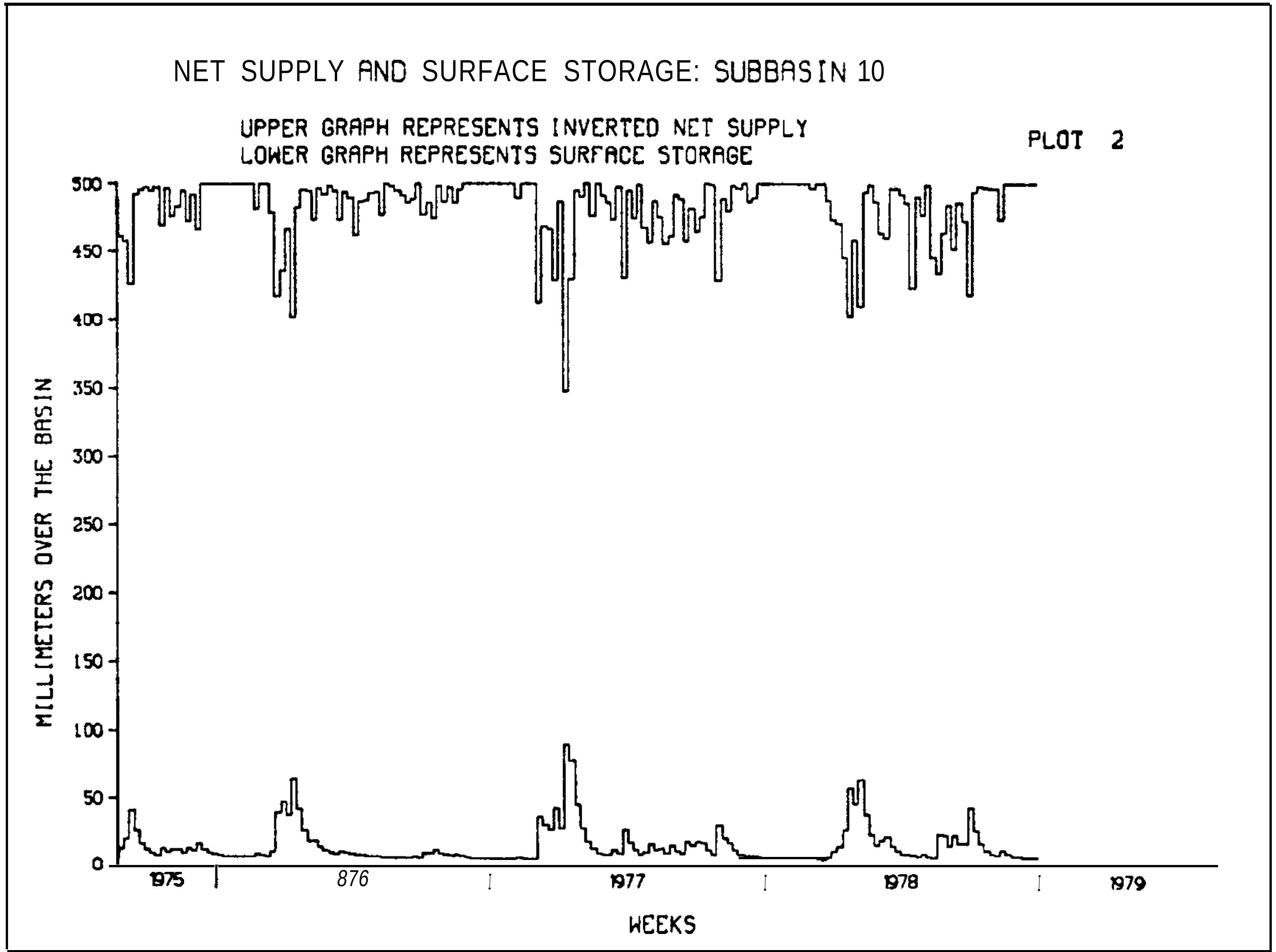


FIGURE 11.--*Seven-day net supply mte to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 10 (cont.).*

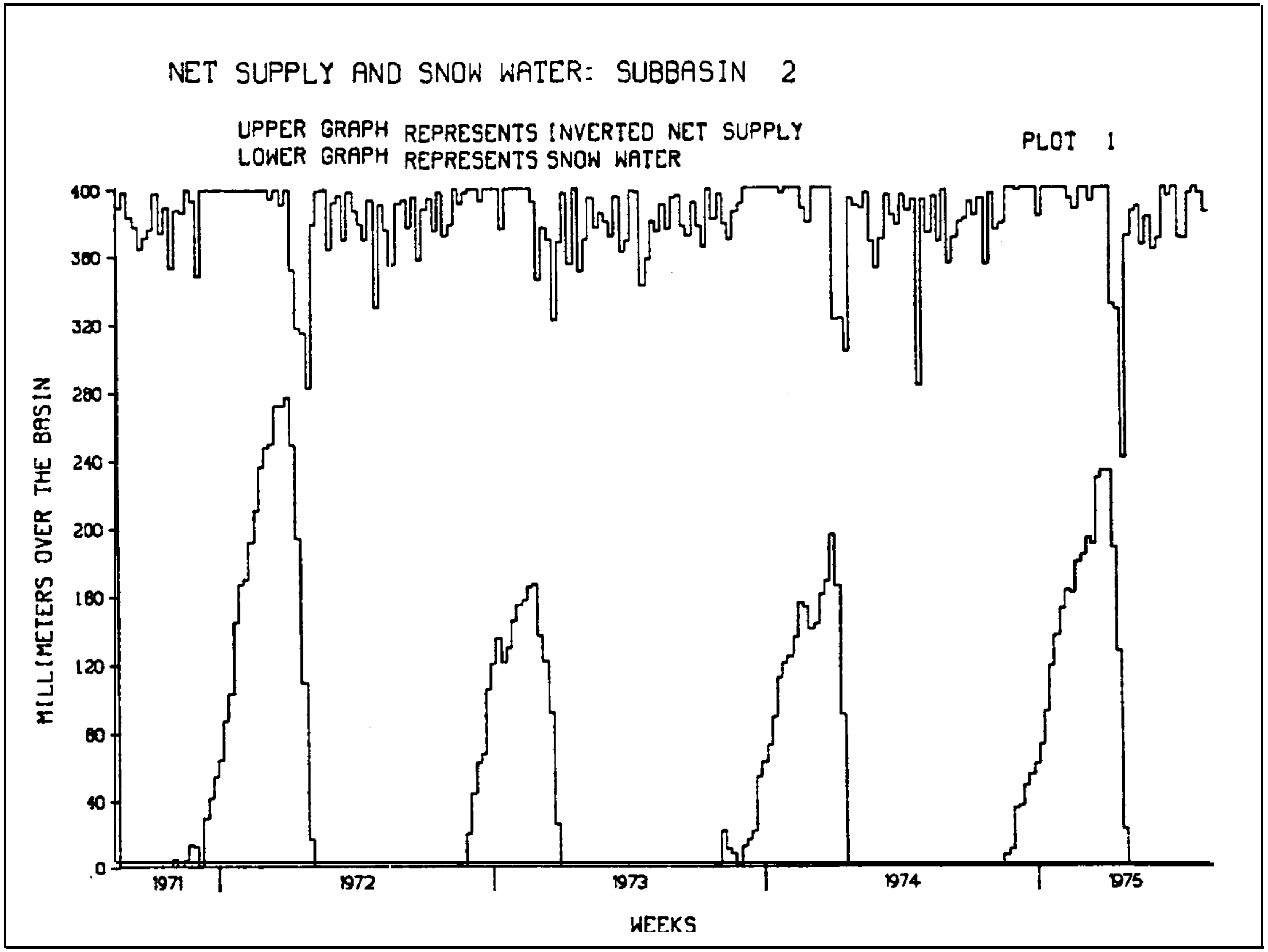


FIGURE 2.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 12.*

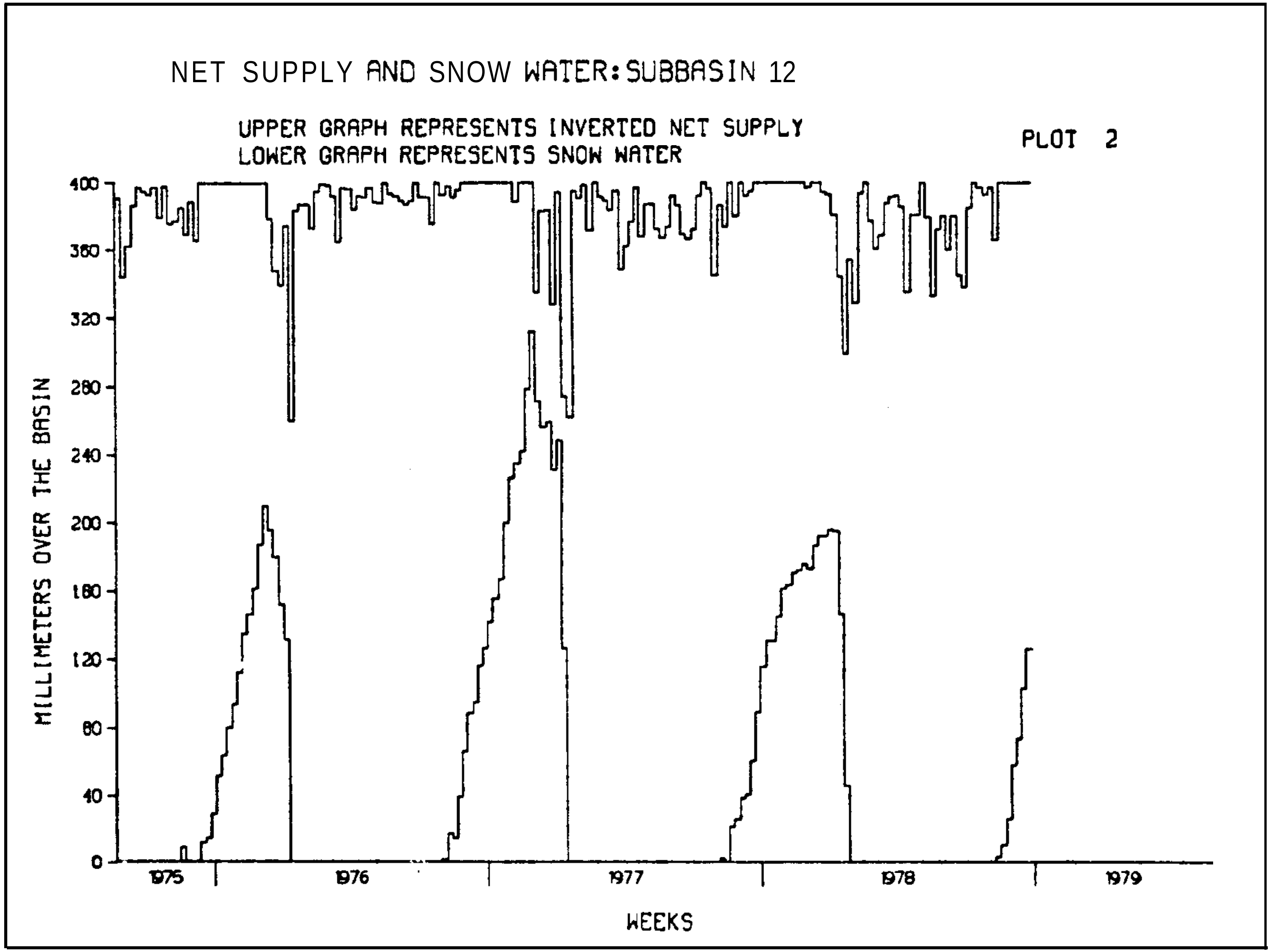


FIGURE 12.--Seven-day *net supply rate to the watershed and 7th day snowpack,* soil zones, *groundwater, and* surface *storages* for *subbasin 12 (cont.).*

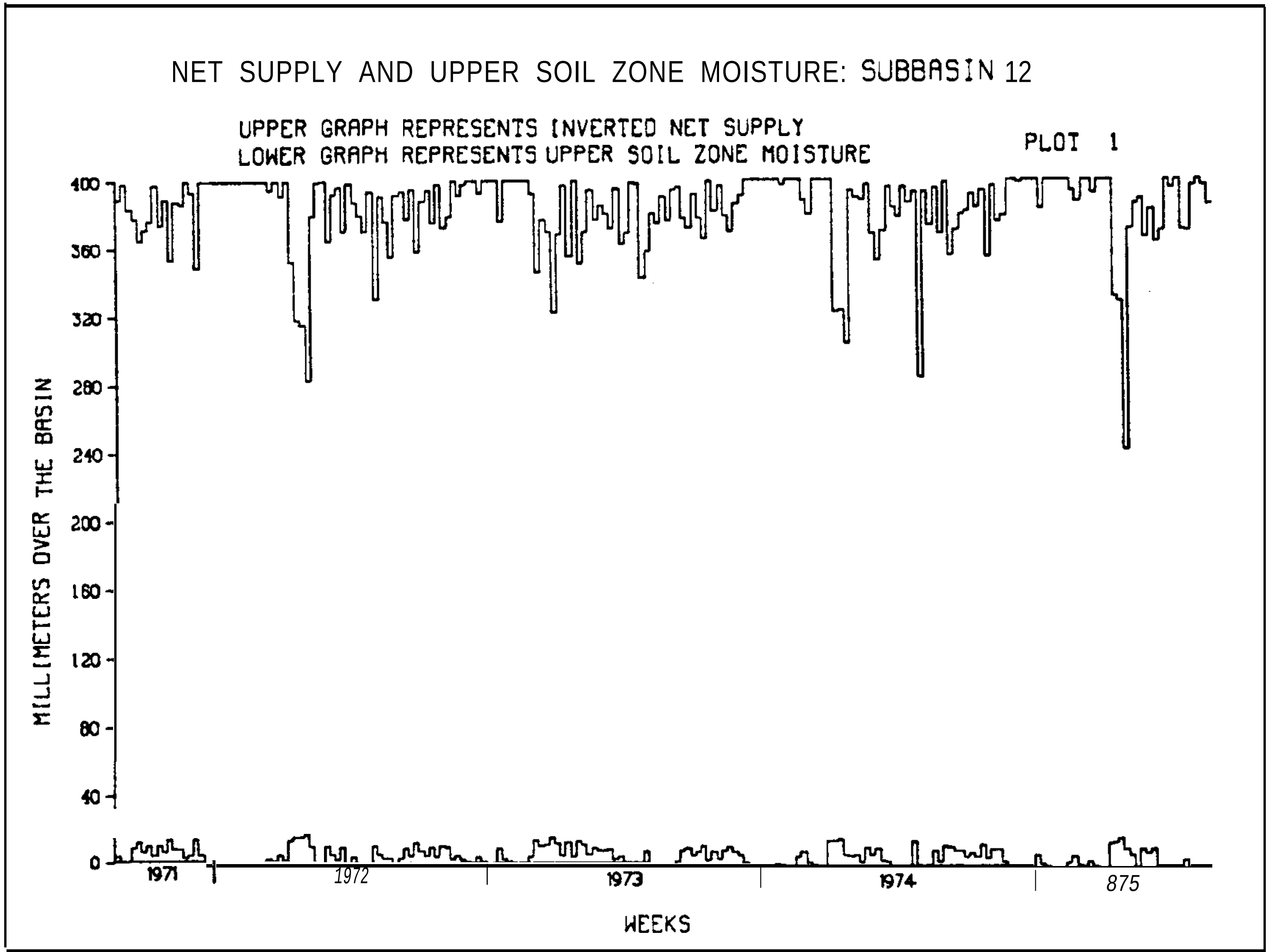


FIGURE 12.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 12 (cont.).*

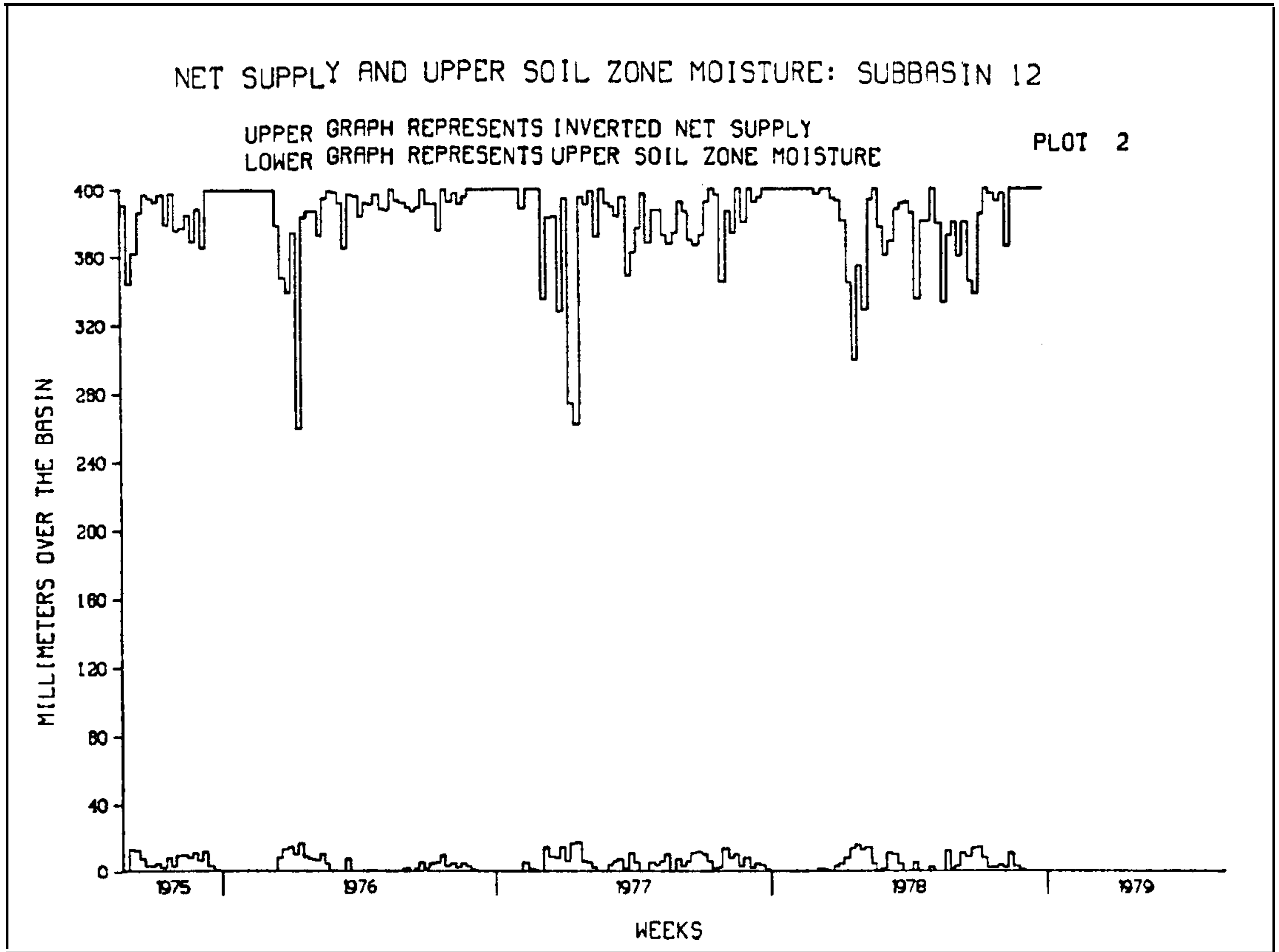
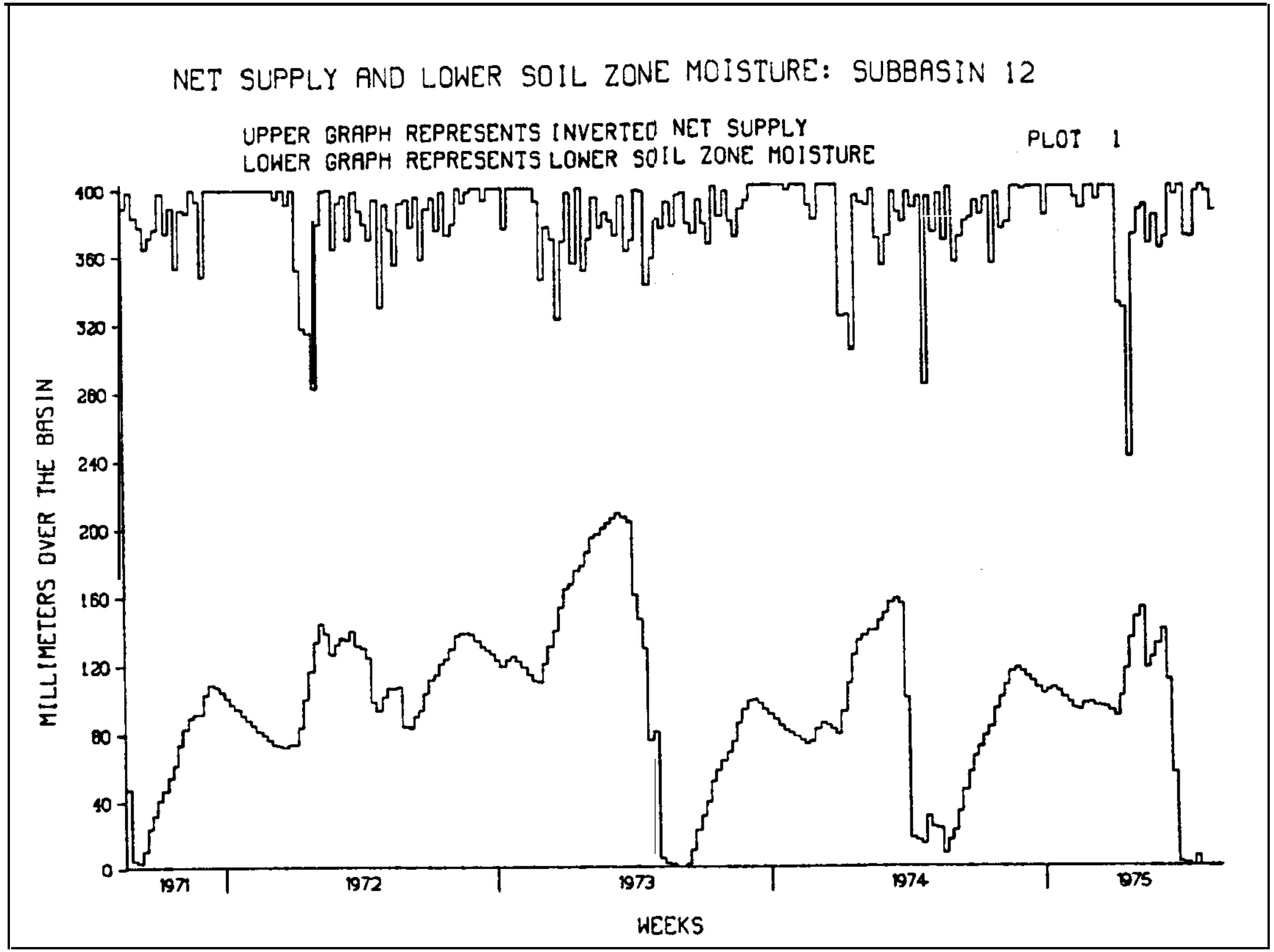


FIGURE 1 ... *day snowpack,*
soil ... *12 (cont.).*


NET SUPPLY AND LOWER SOIL ZONE MOISTURE: SUBBASIN 12
UPPER GRAPH REPRESENTS INVERTED NET SUPPLY
LOWER GRAPH REPRESENTS LOWER SOIL ZONE MOISTURE
PLOT 1
MILLIMETERS OVER THE BASIN
400
360
320
280
240
200
160
120
80
40
0
1971
1972
1973
1974
1975
WEEKS

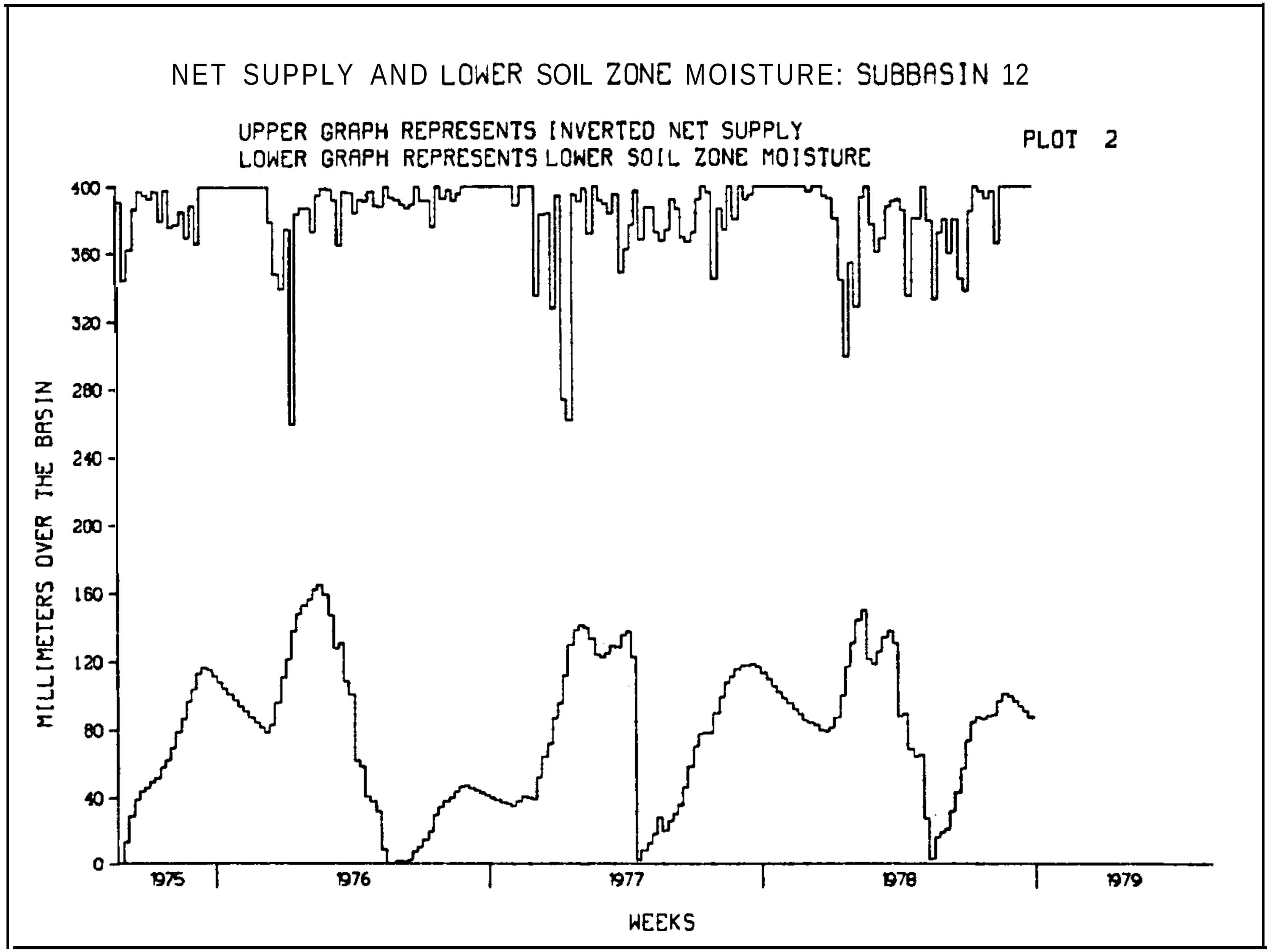


FIGURE 12.--Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 12 (cont.).

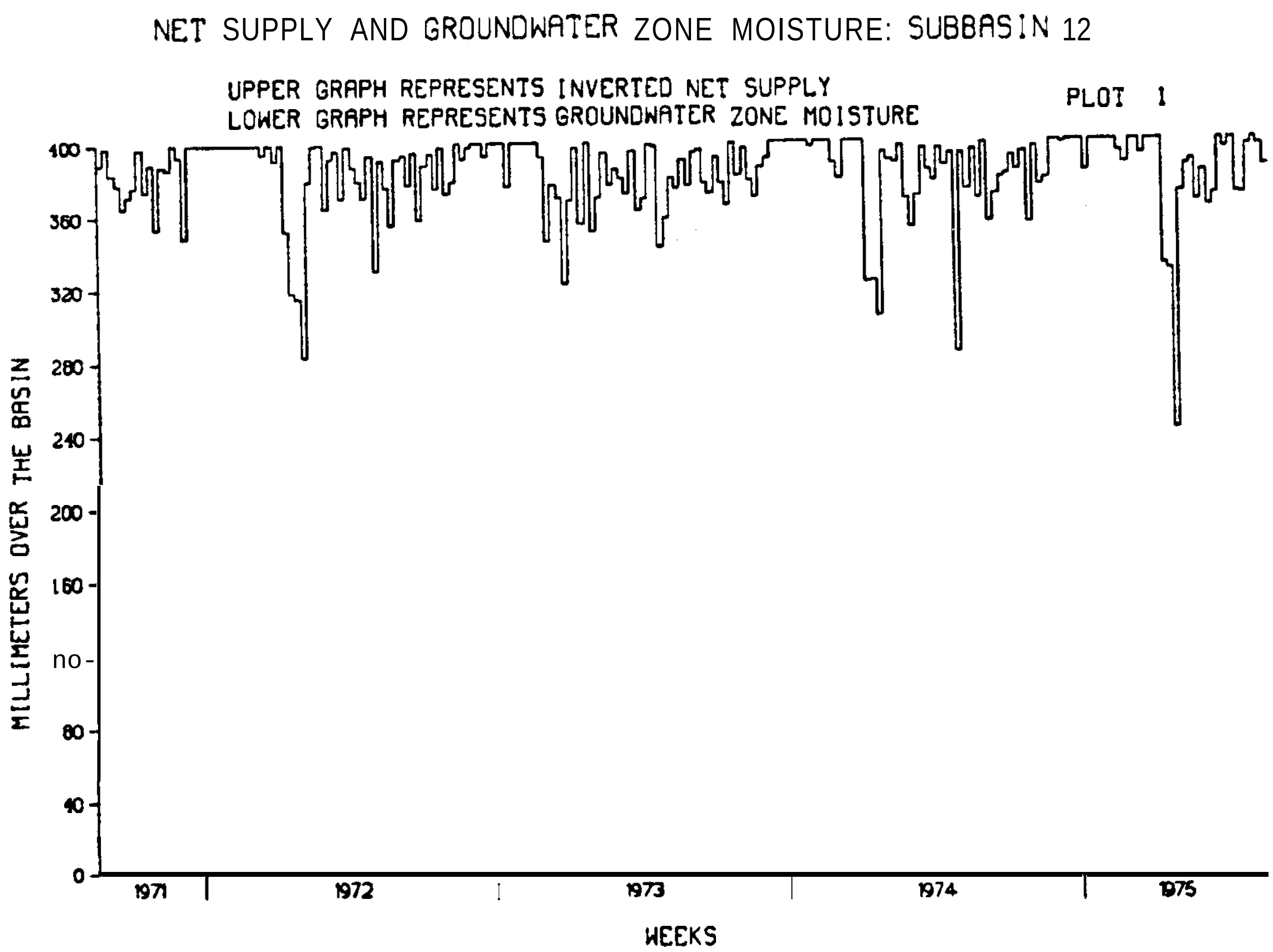


FIGURE 12.--Seven-day *net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 12 (cont.).*

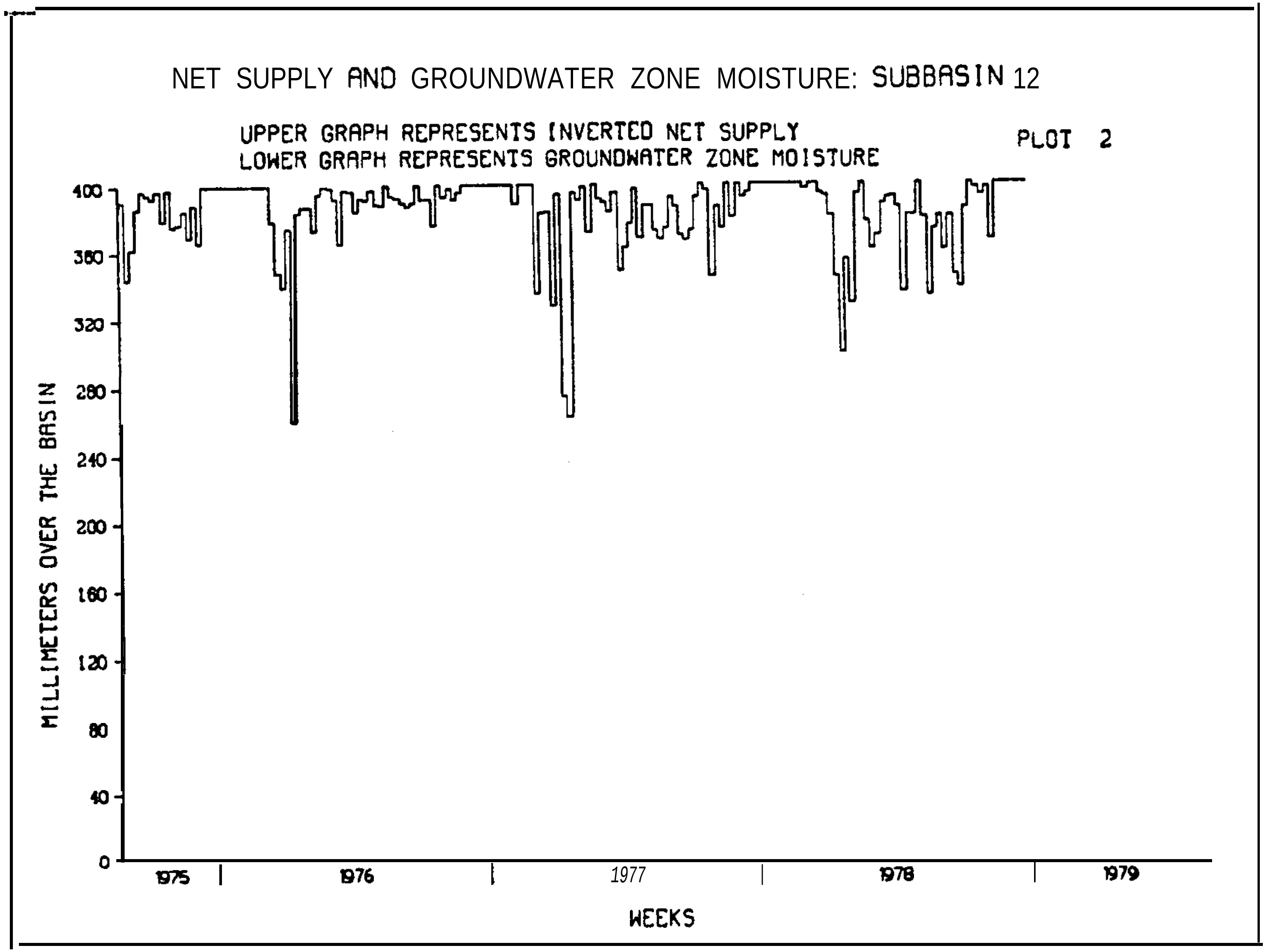


FIGURE 12.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 12 (cont.).*

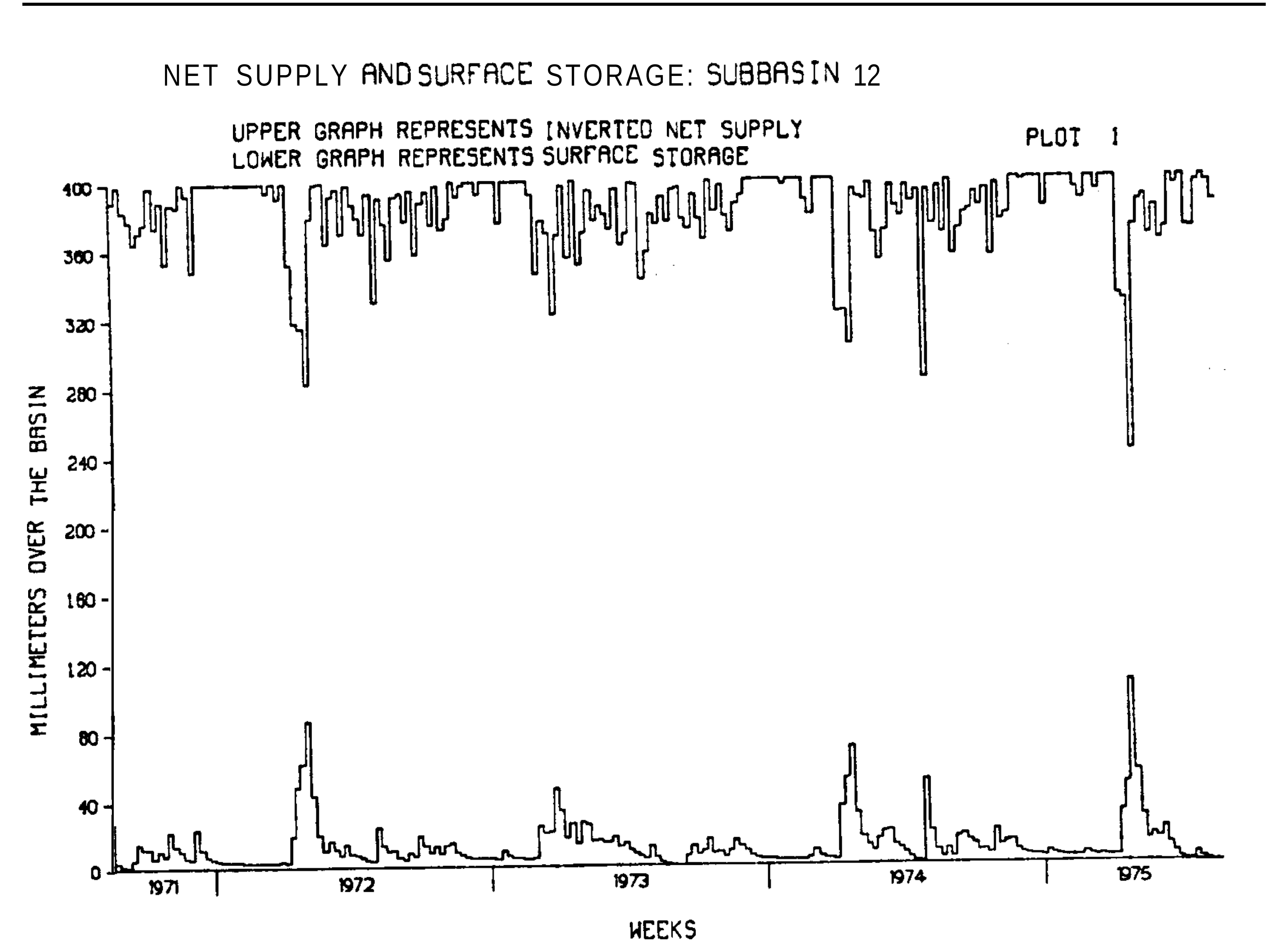


FIGURE 12.--Seven-day *net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 12 (cont.).*

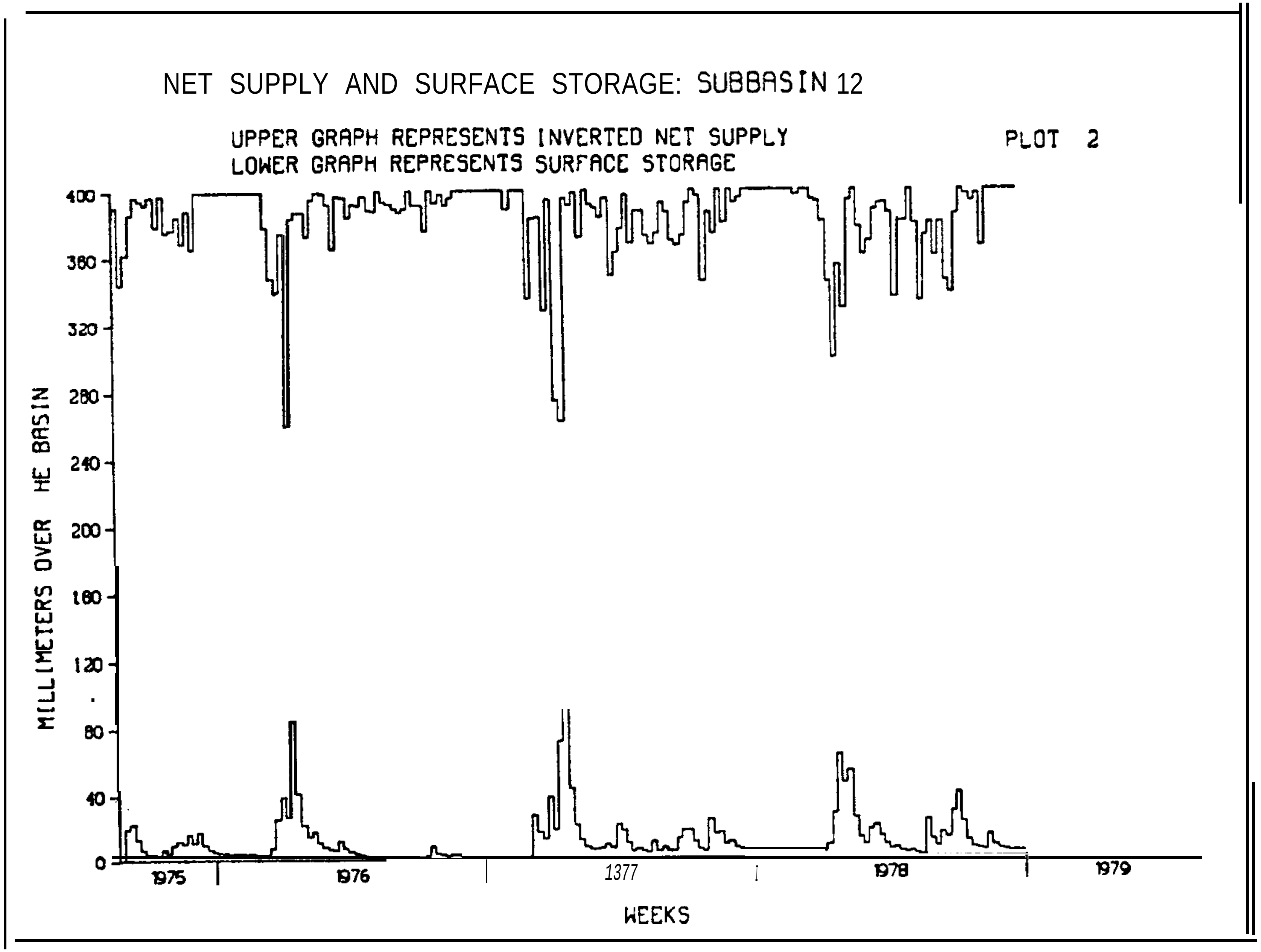


FIGURE 12.--*Seven-day net supply mte to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 12 (cont.).*

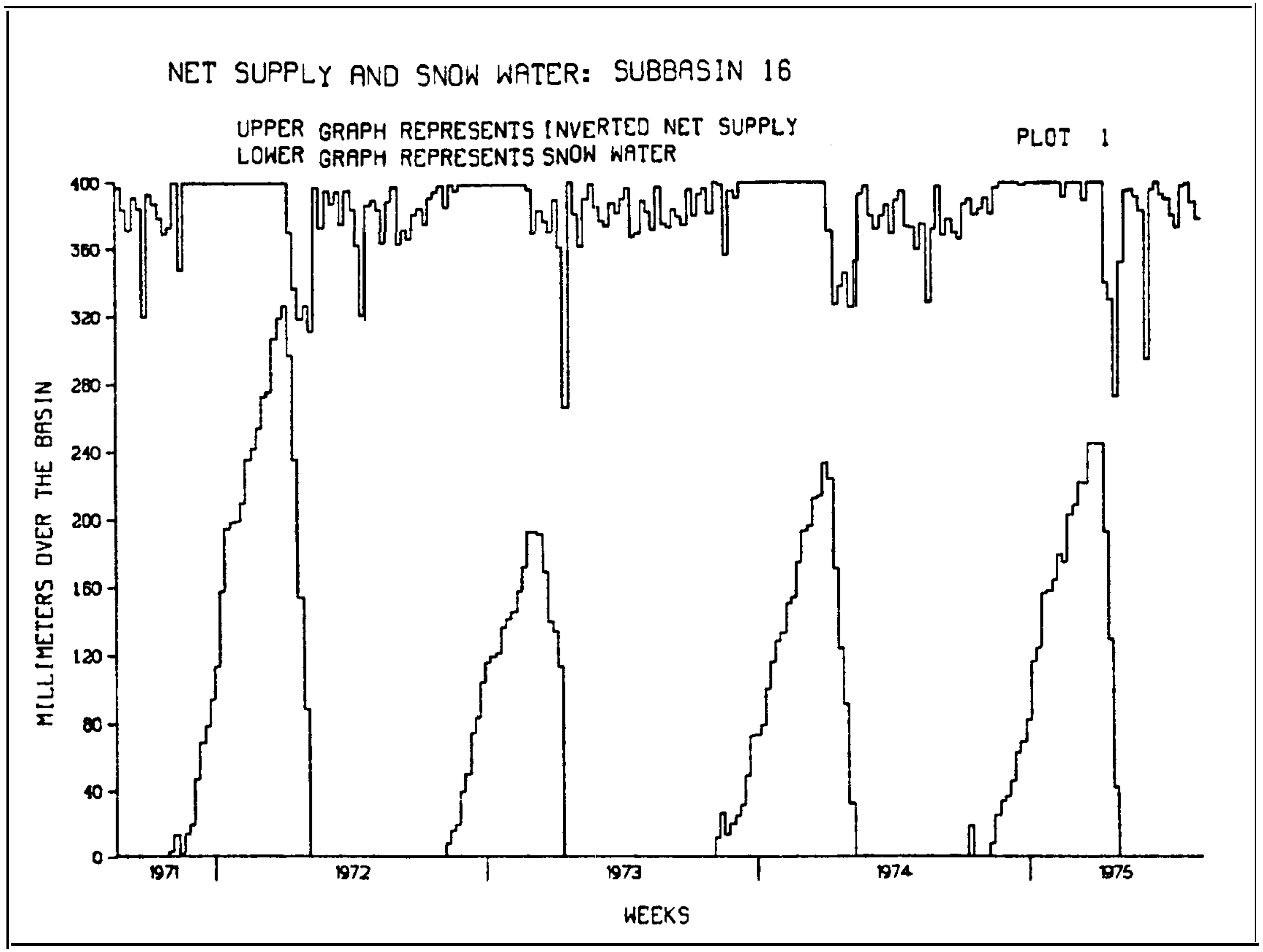


FIGURE 13.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16.*

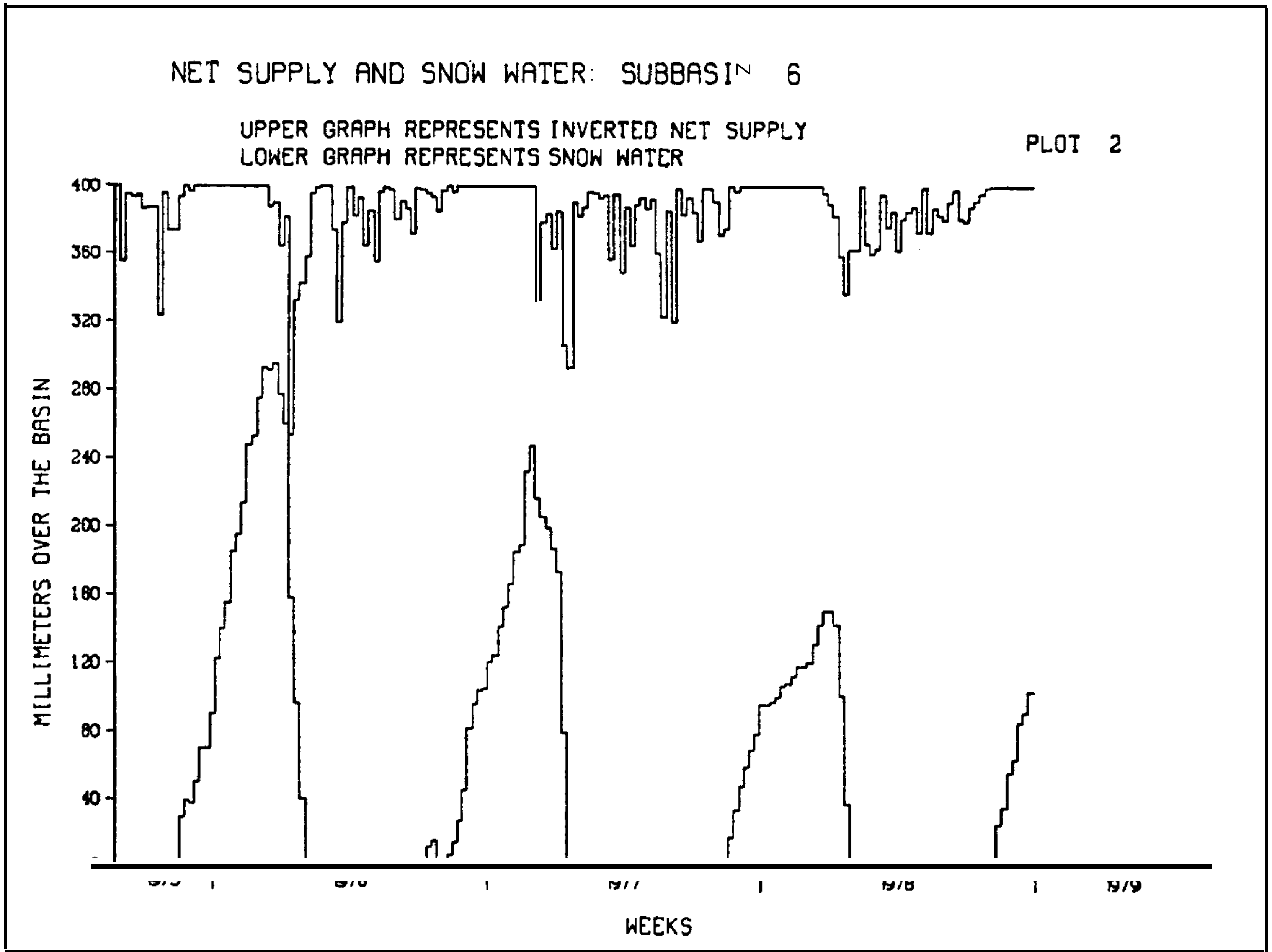


FIGURE 3.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).*

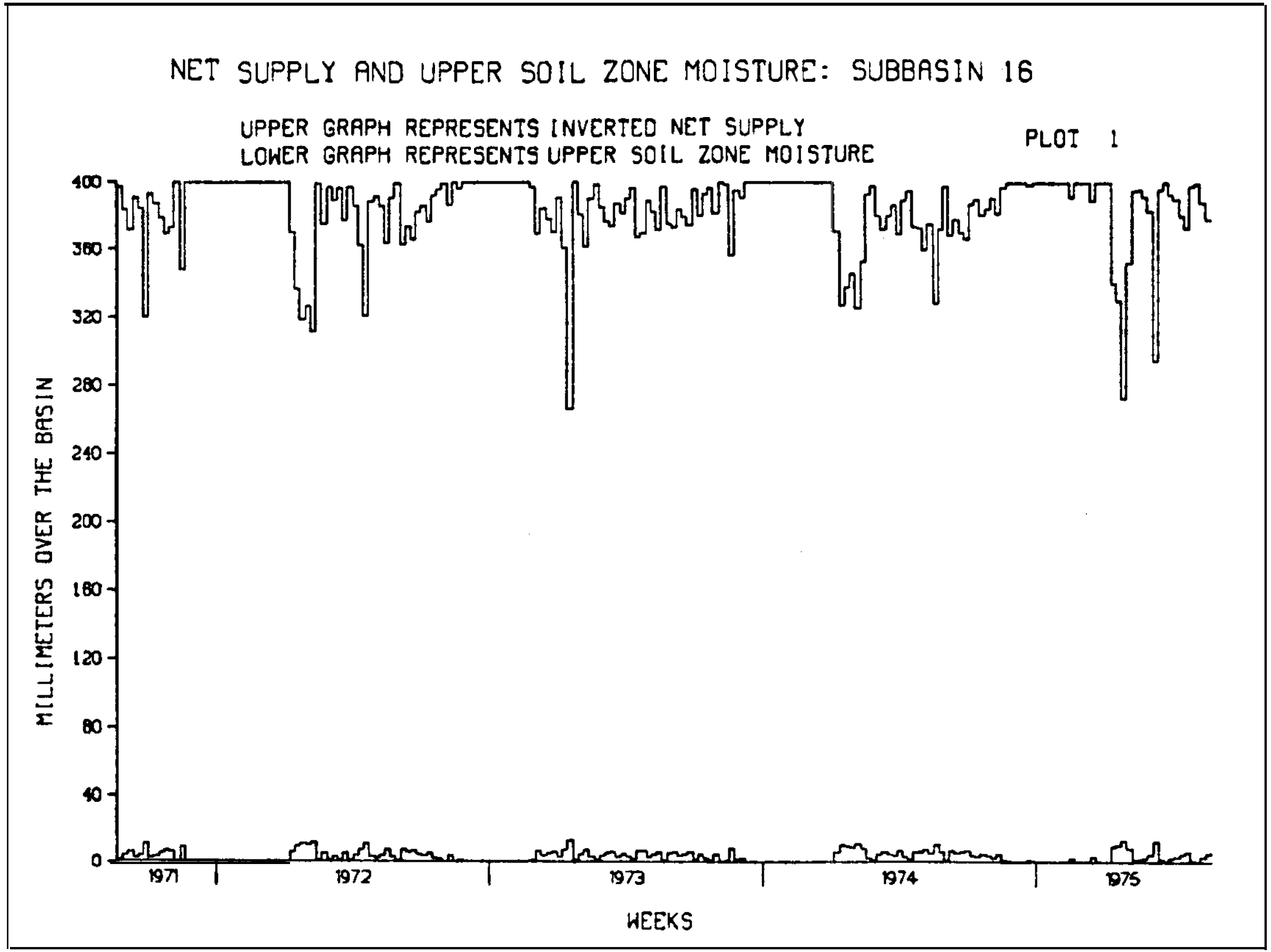


FIGURE 3.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).*

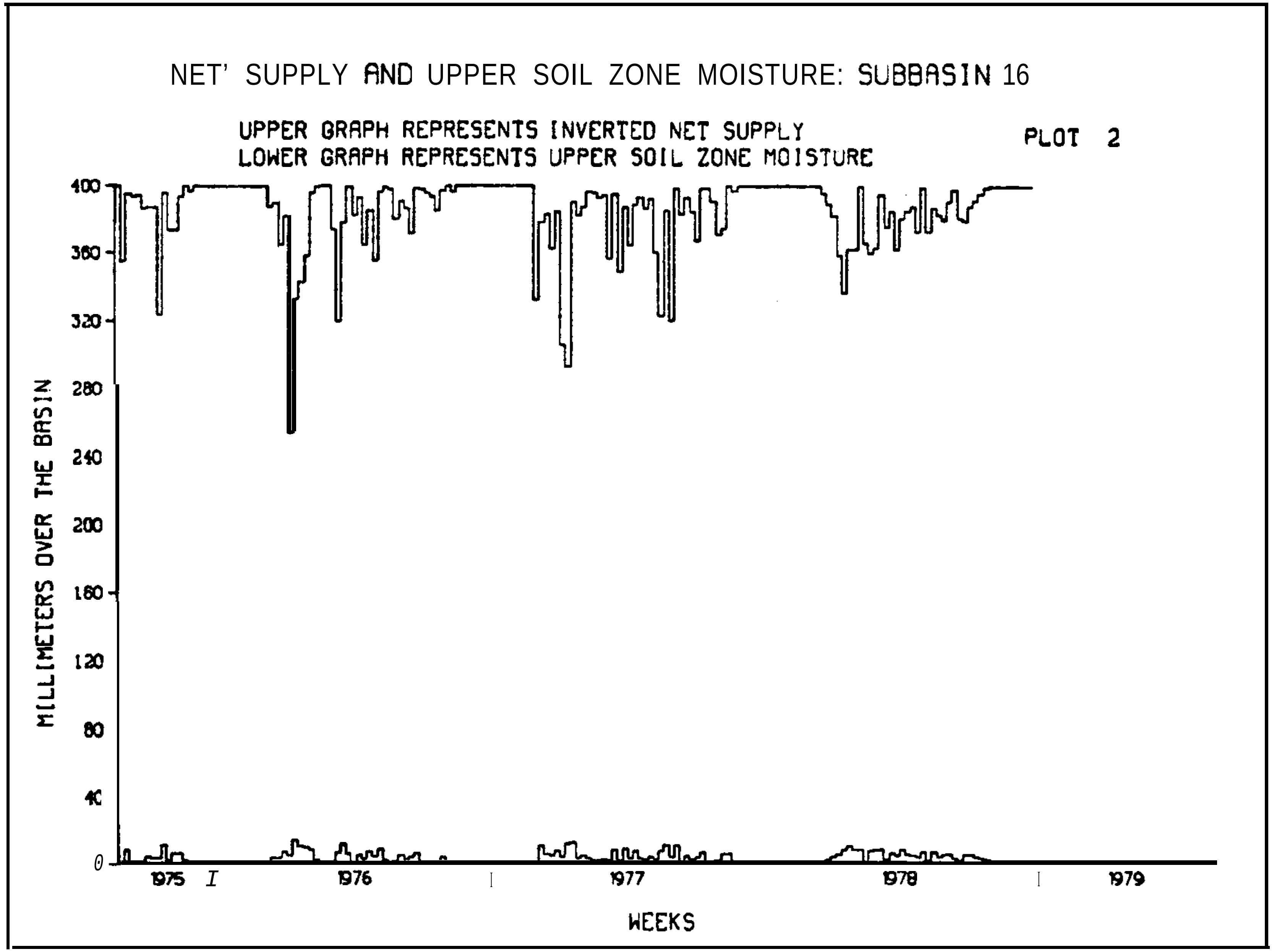


FIGURE 13.--Seven-day *net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).*

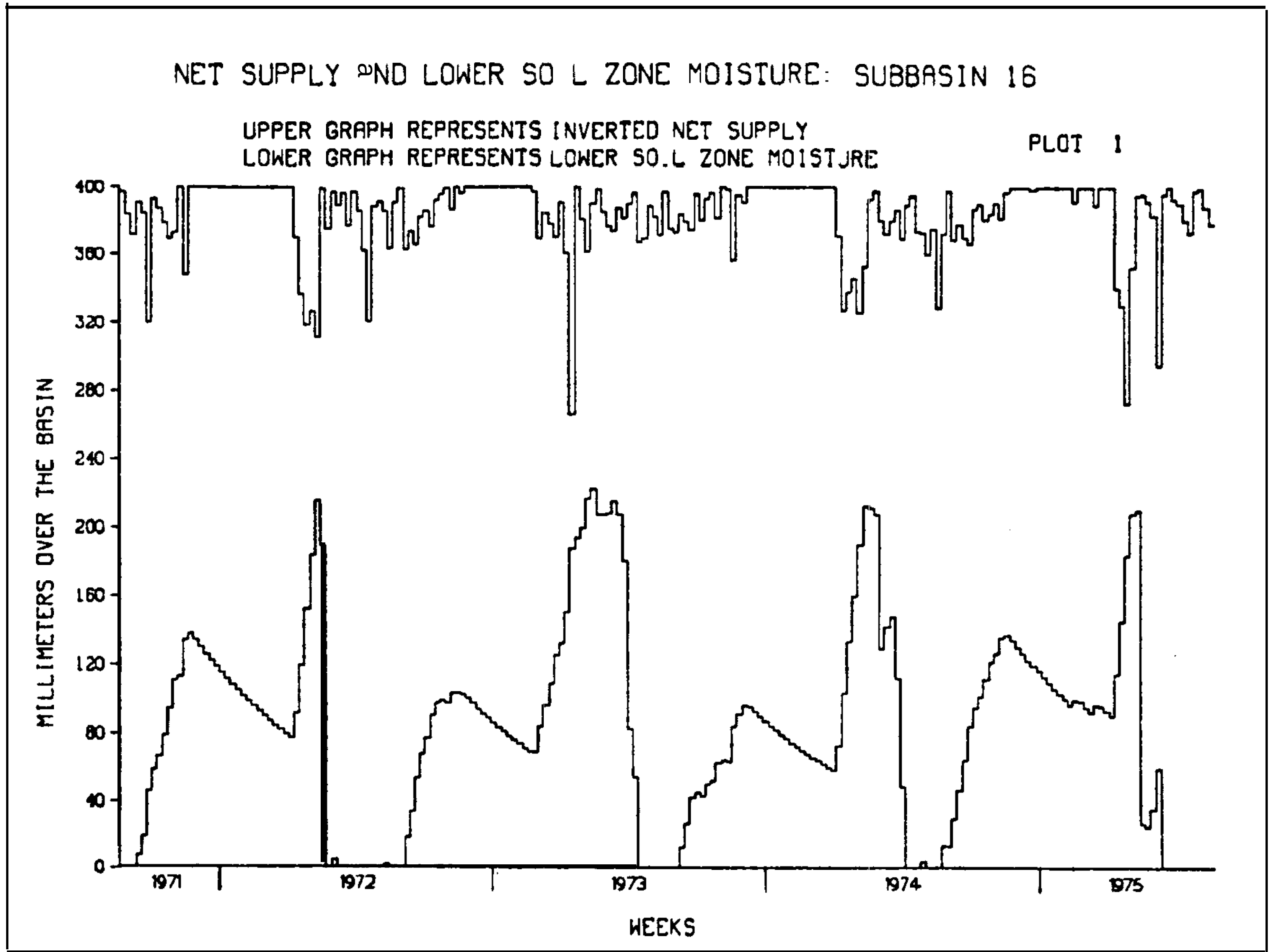


FIGURE 3.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).*

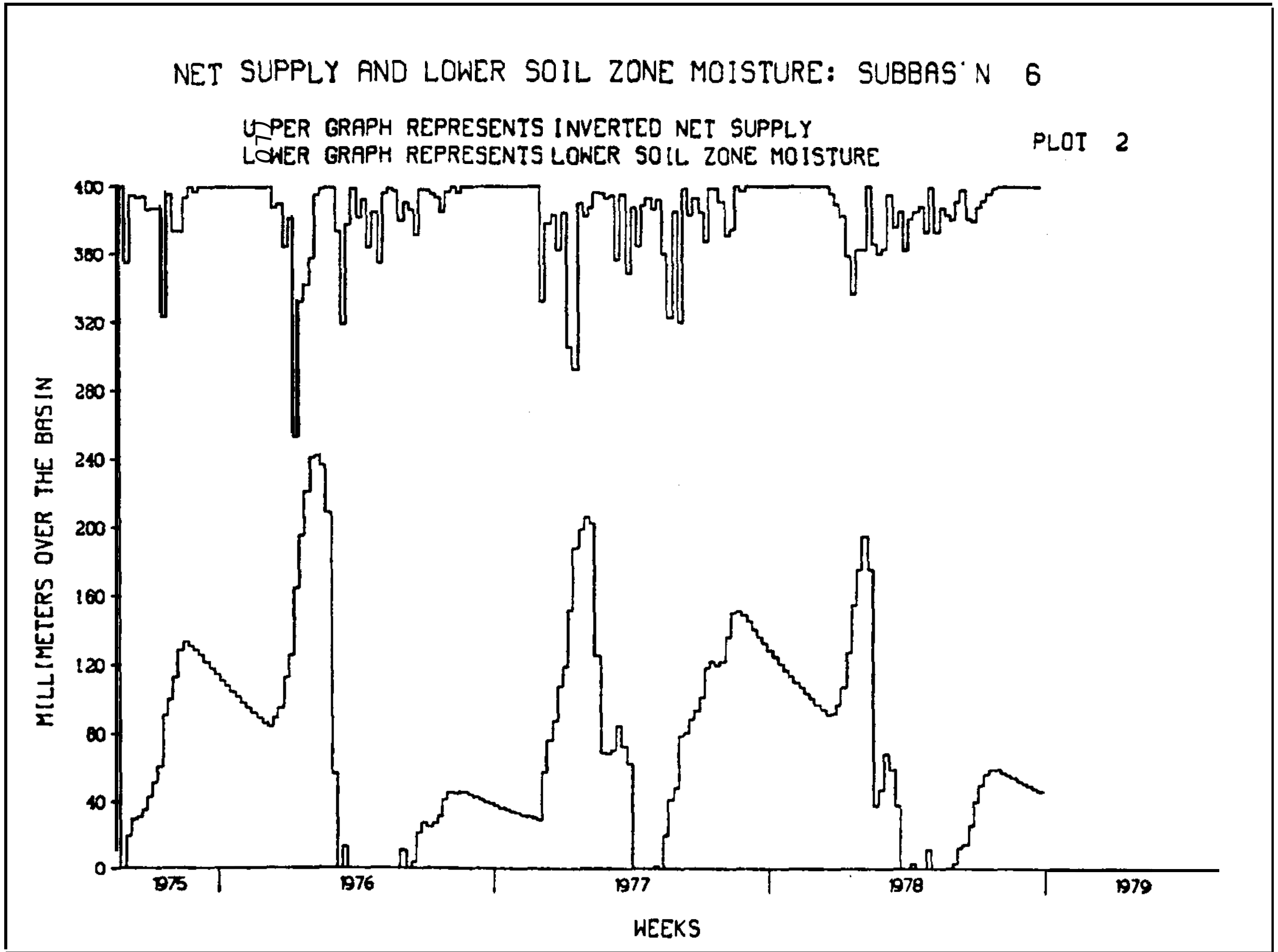


FIGURE 3.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).*

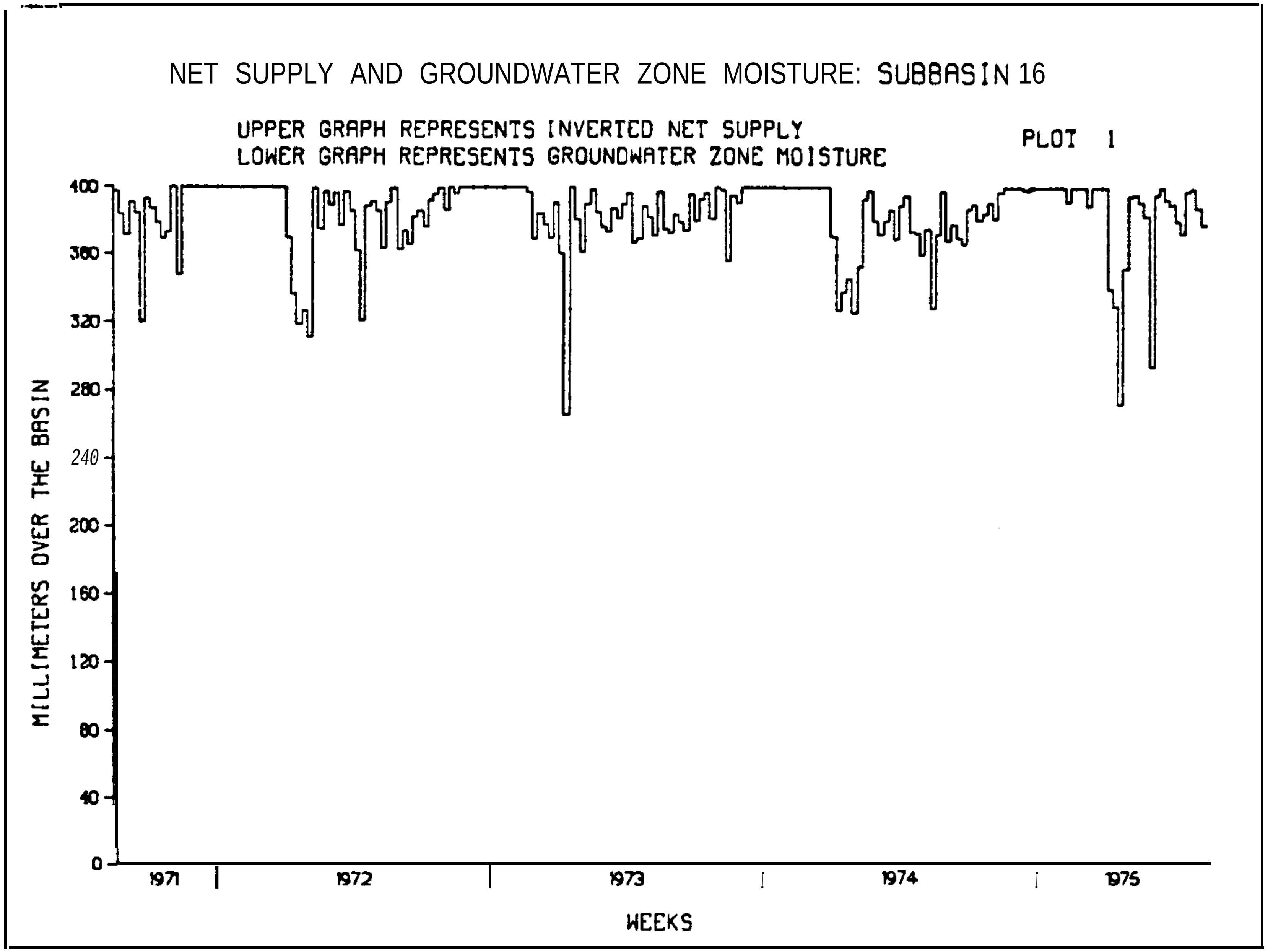


FIGURE 13.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).*

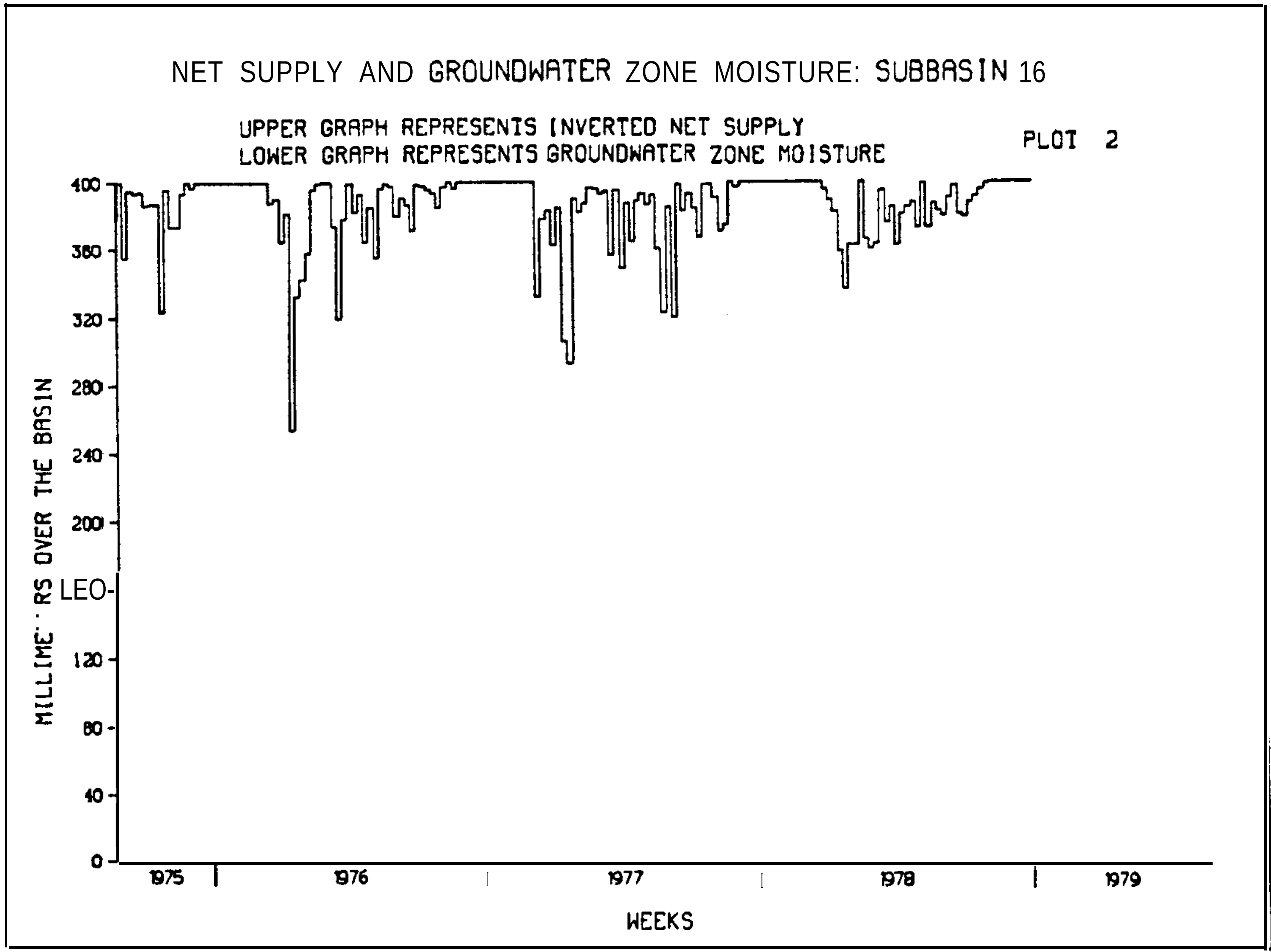


FIGURE 13.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).*

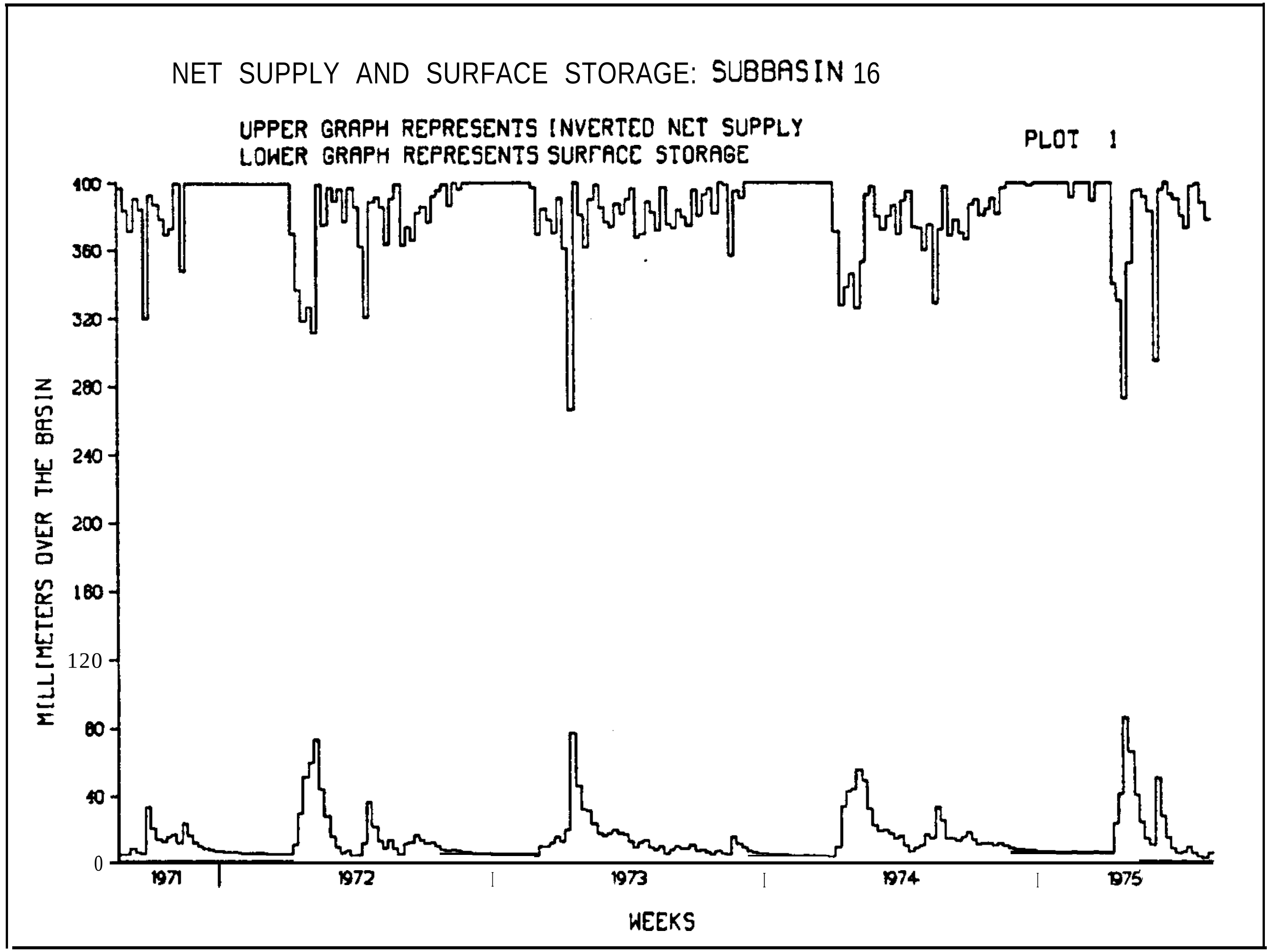


FIGURE 13.--Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 16 (cont.).

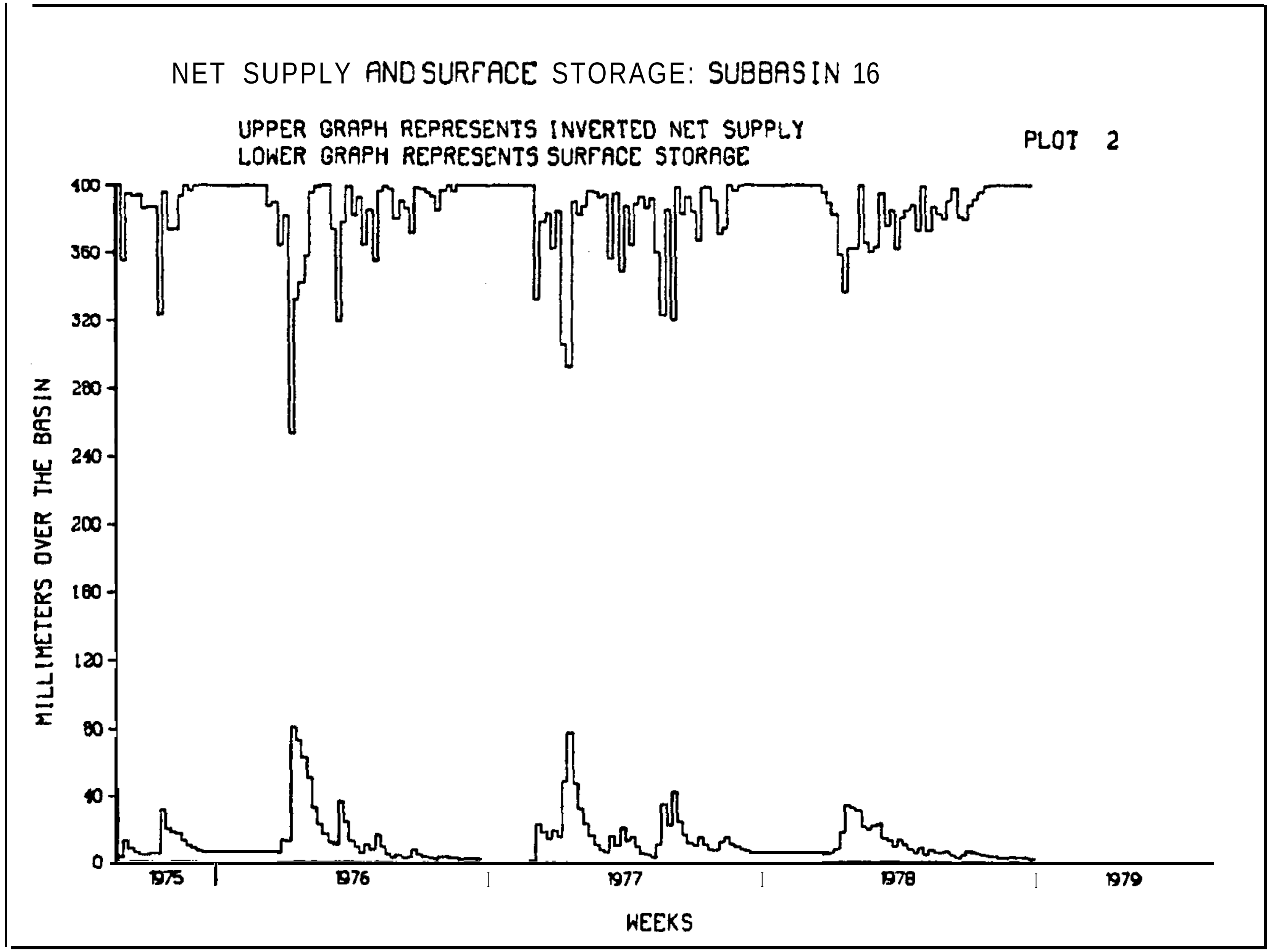


FIGURE 13.--Seven-day *net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages* for *subbasin 16 (cont.).*

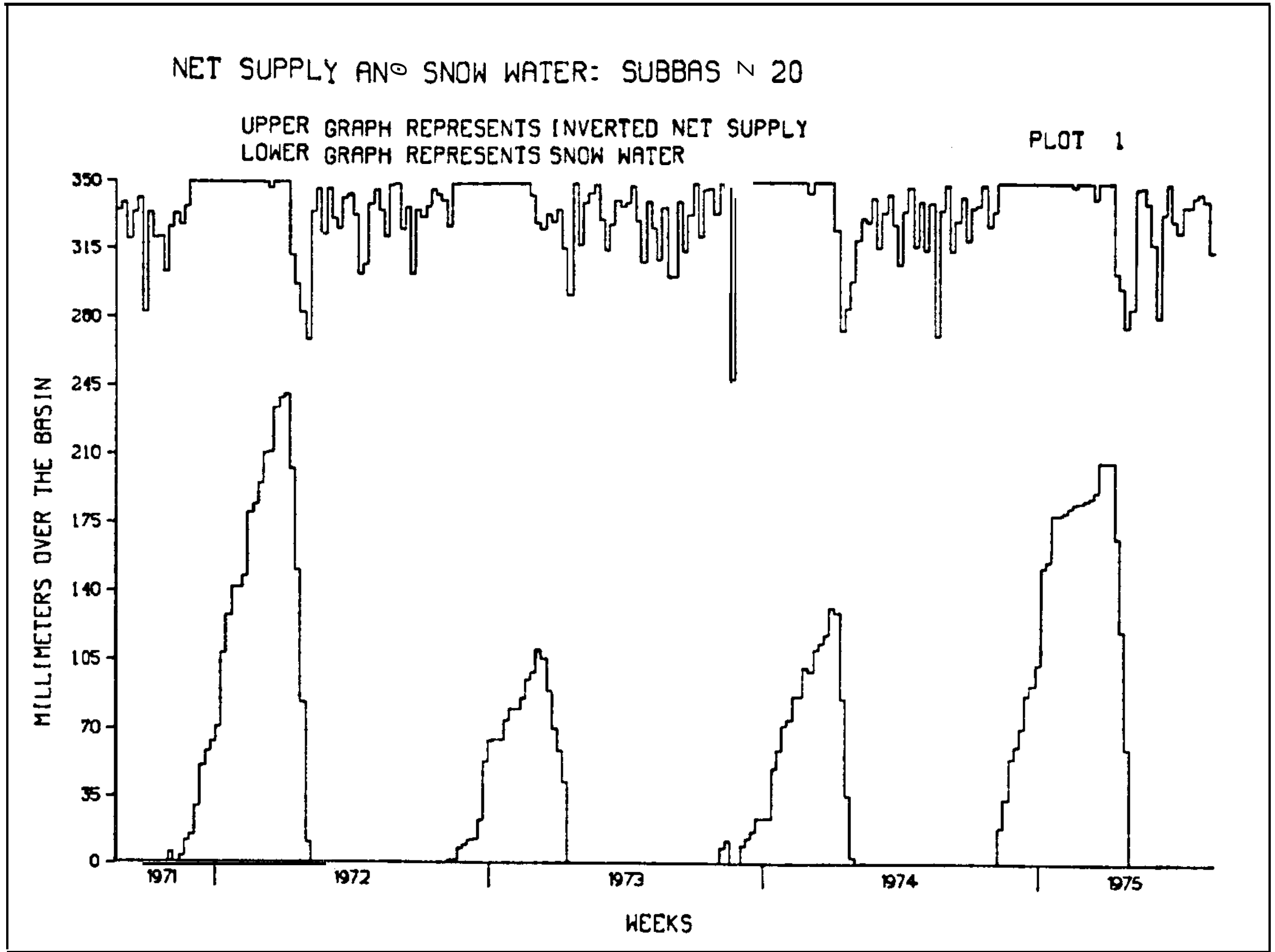


FIGURE 4.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*

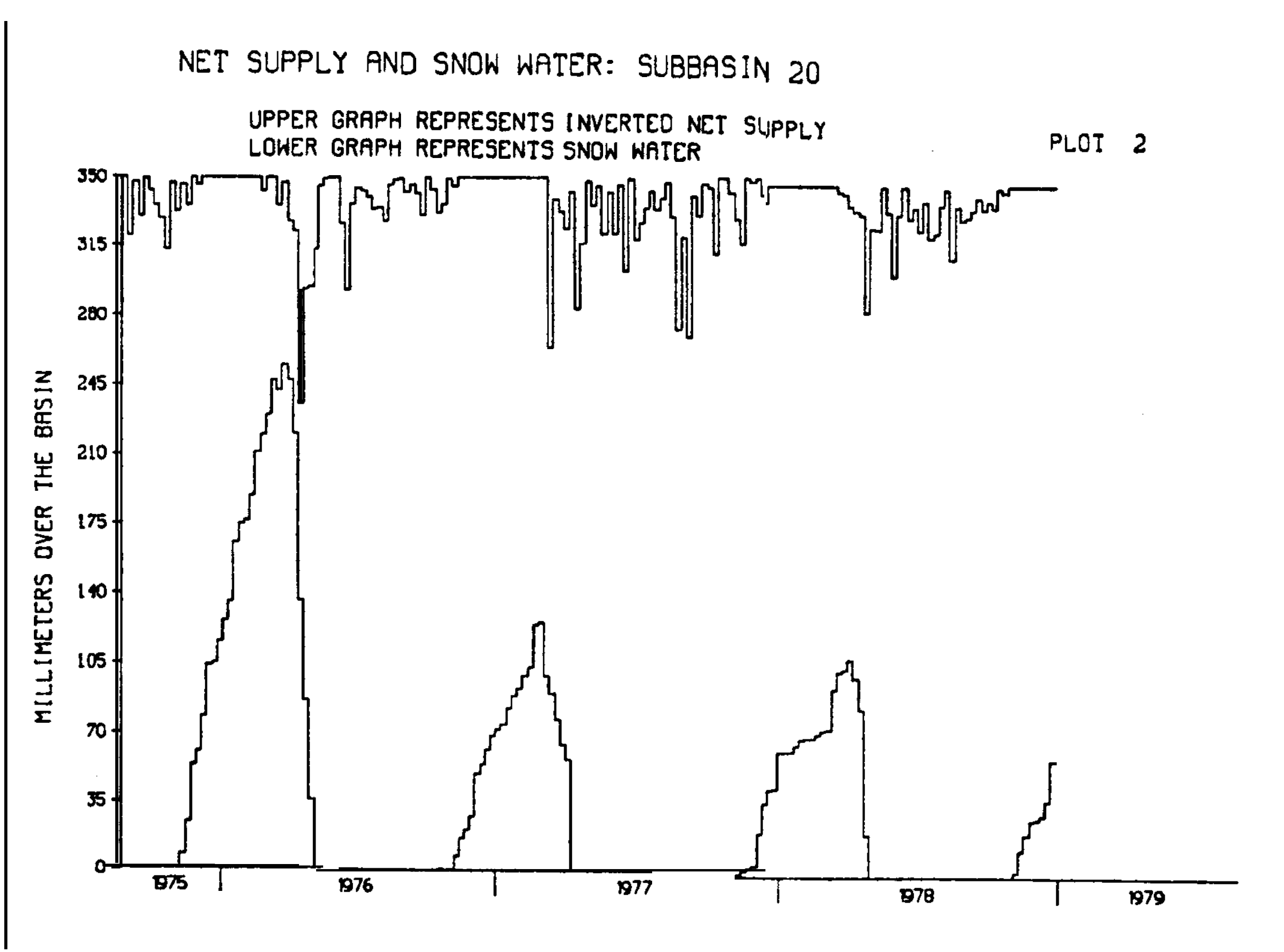


FIGURE 14.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*

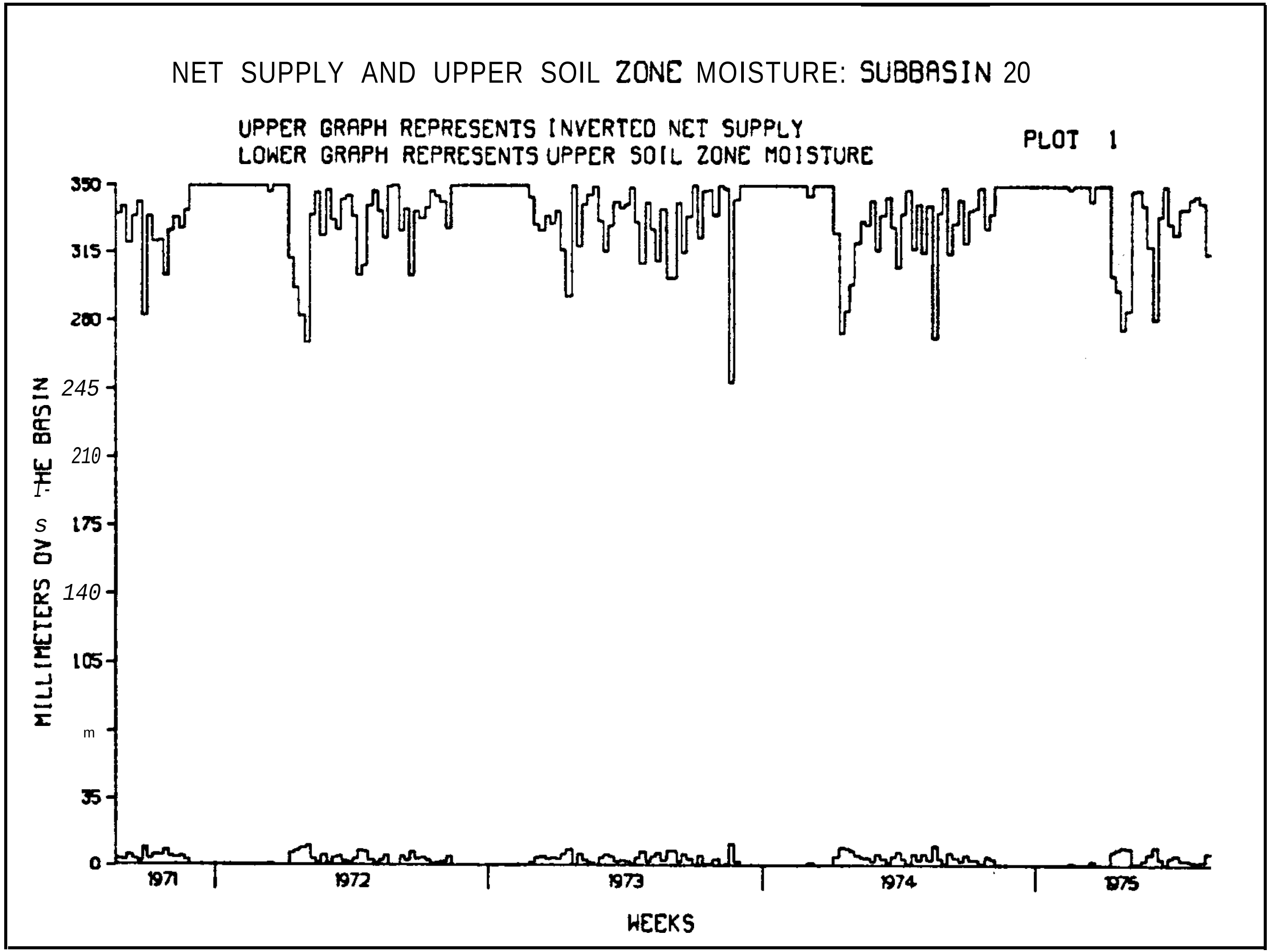


FIGURE 14.--Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).

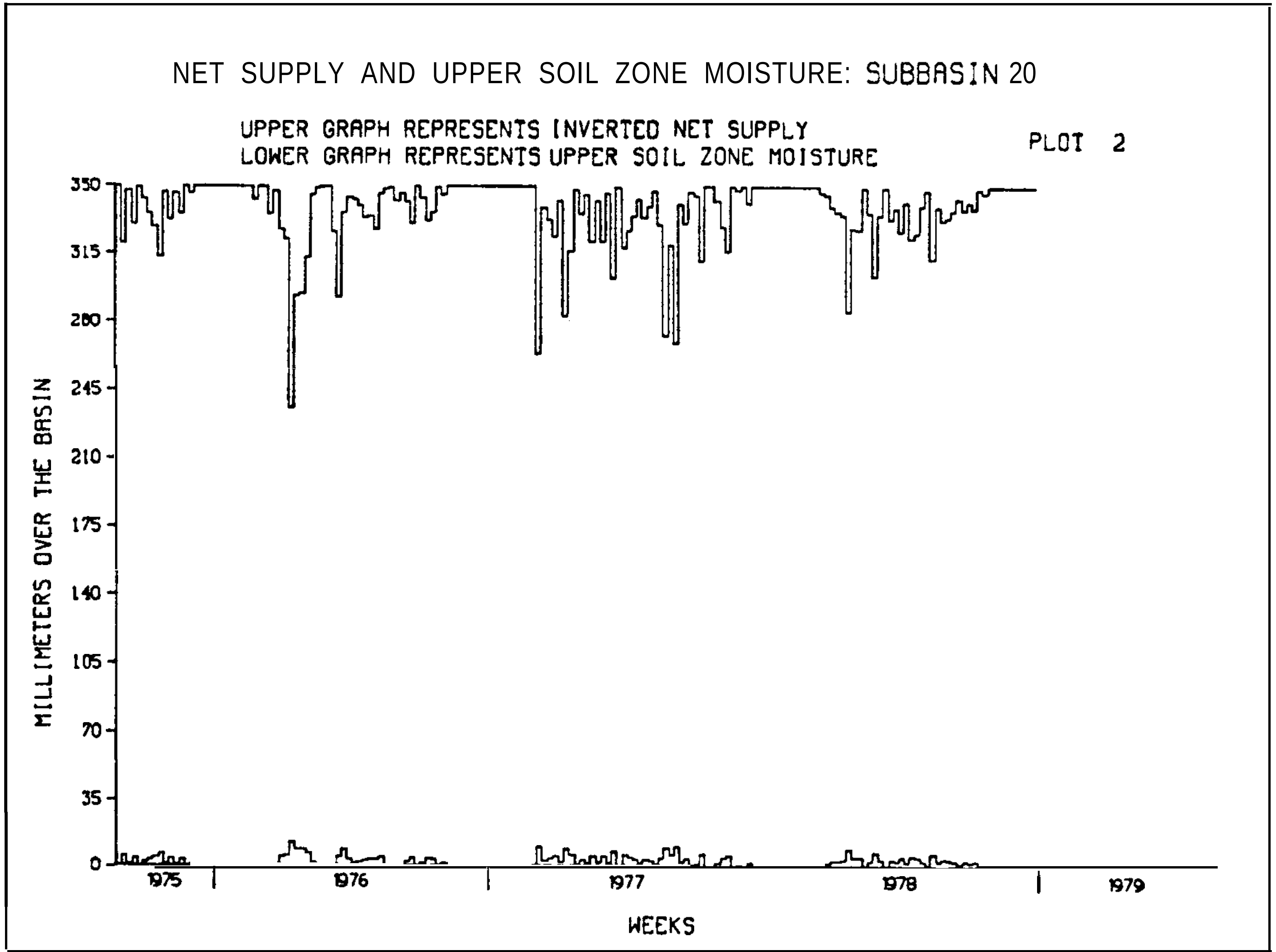


FIGURE 14.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*

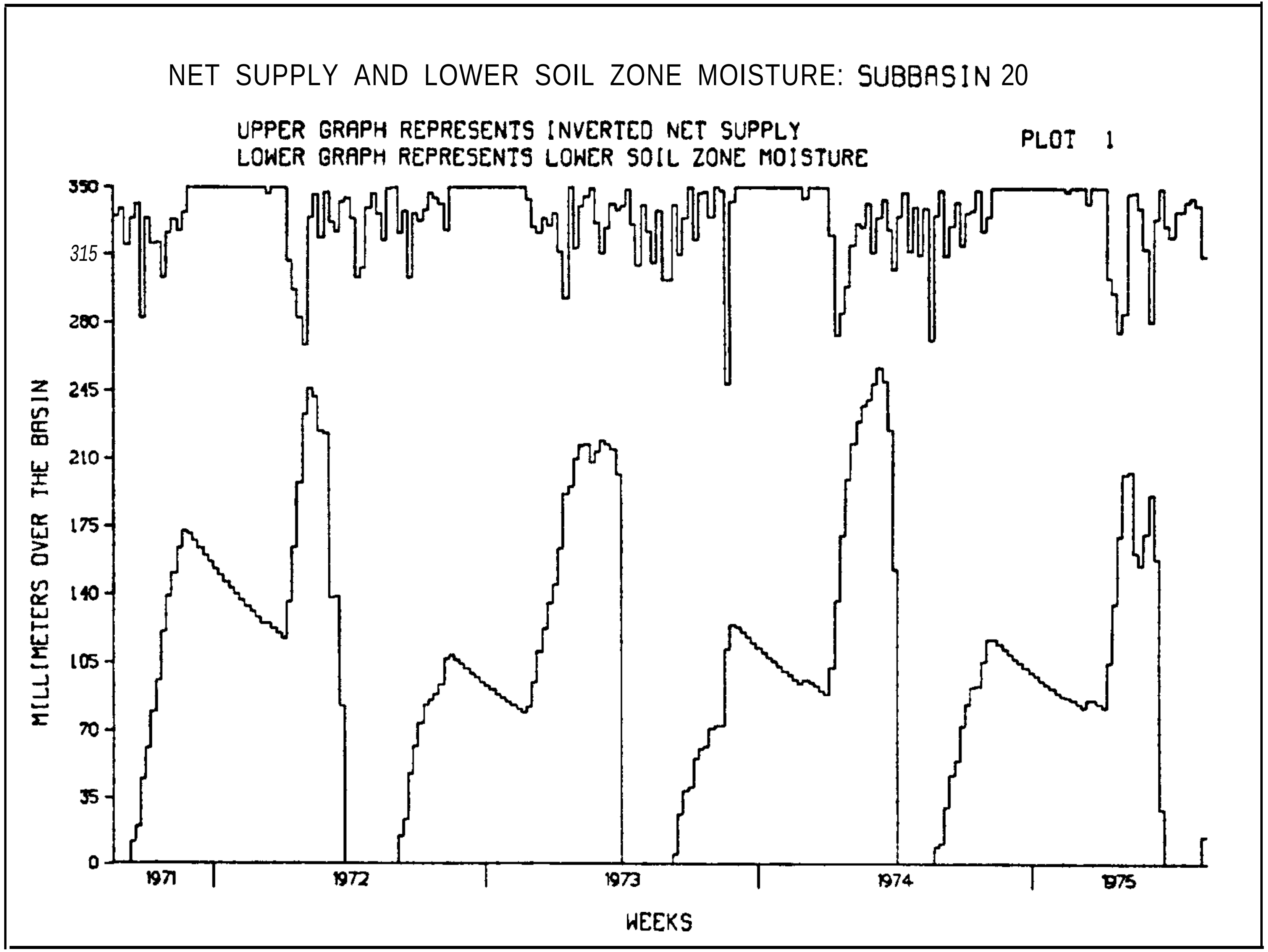


FIGURE 14.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*

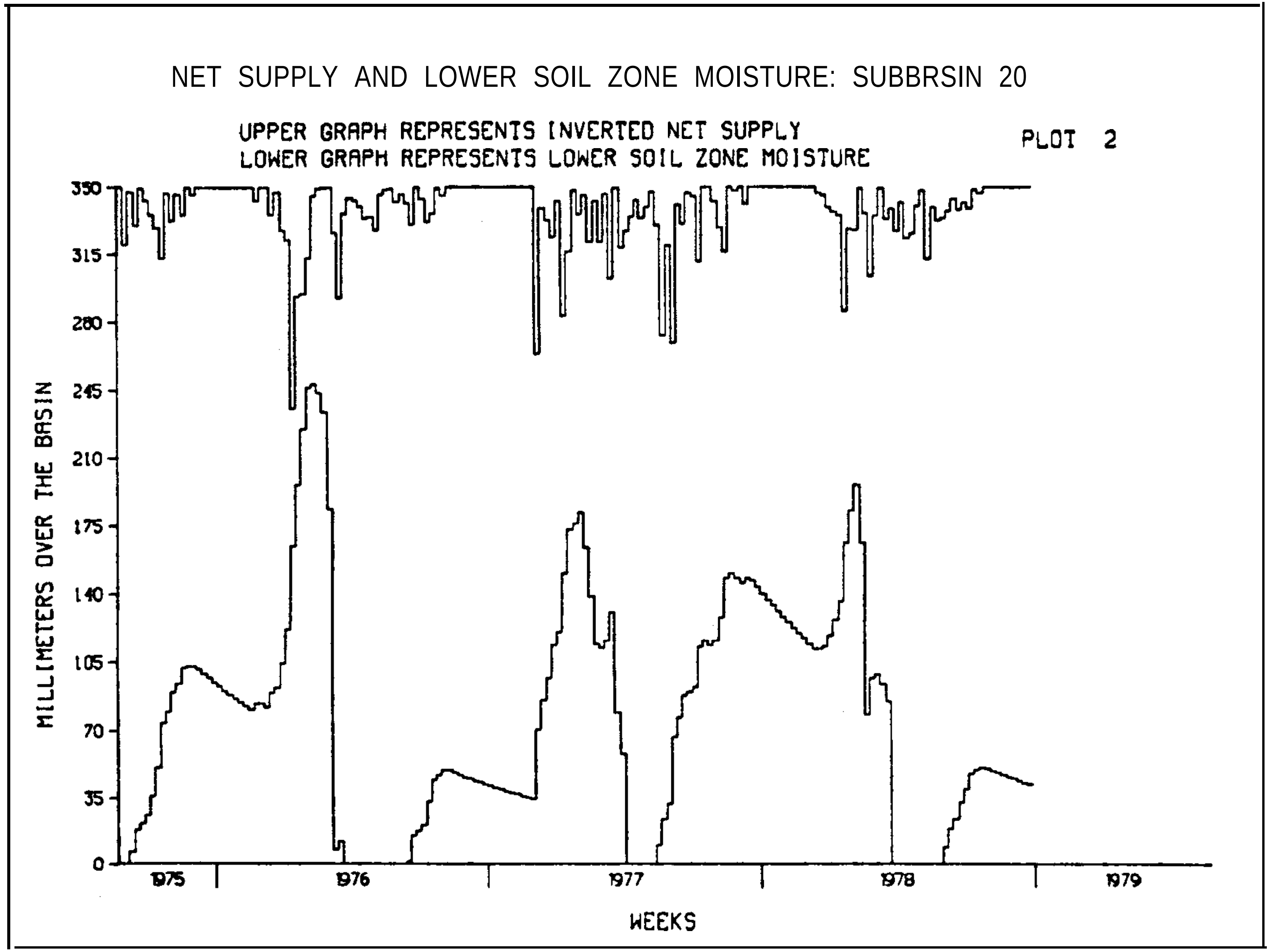


FIGURE 14.--Seven-day *net supply rate to the watershed and 7th day snowpack, soil zones, groundwater,* and surface *storages for subbasin 20 (cont.).*

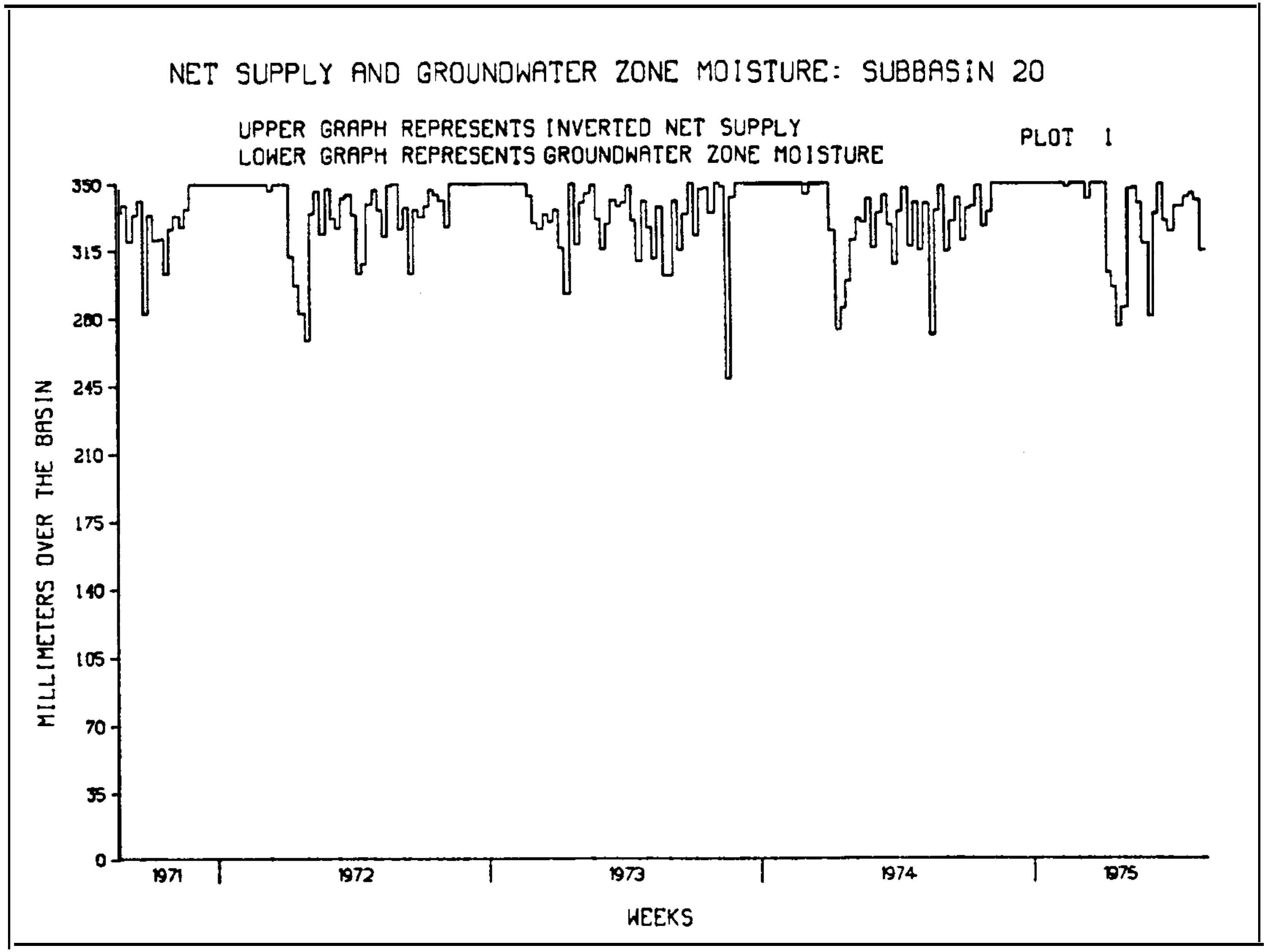


FIGURE 4.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*

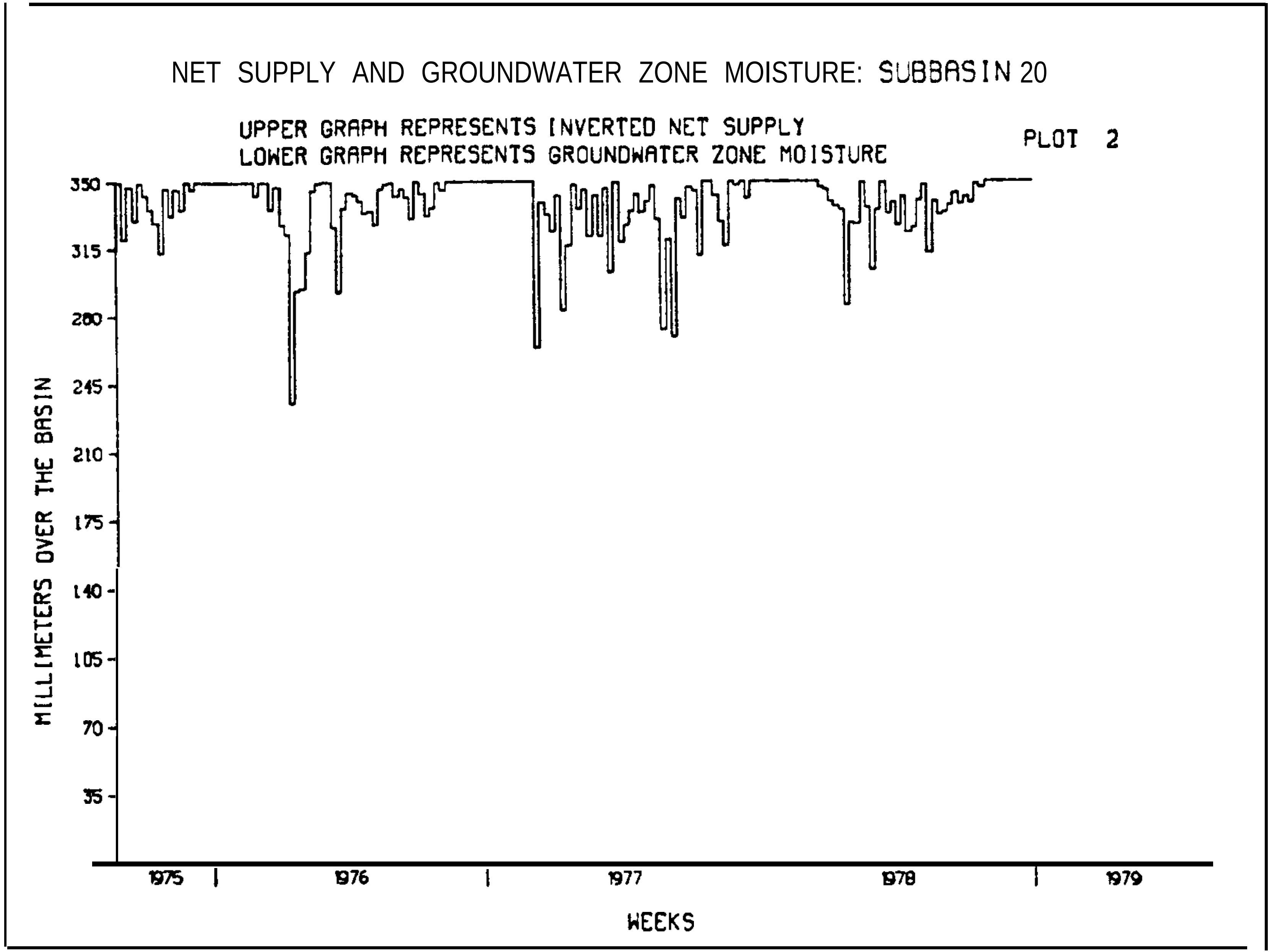


FIGURE 14.--Seven-day *net supply mte to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*

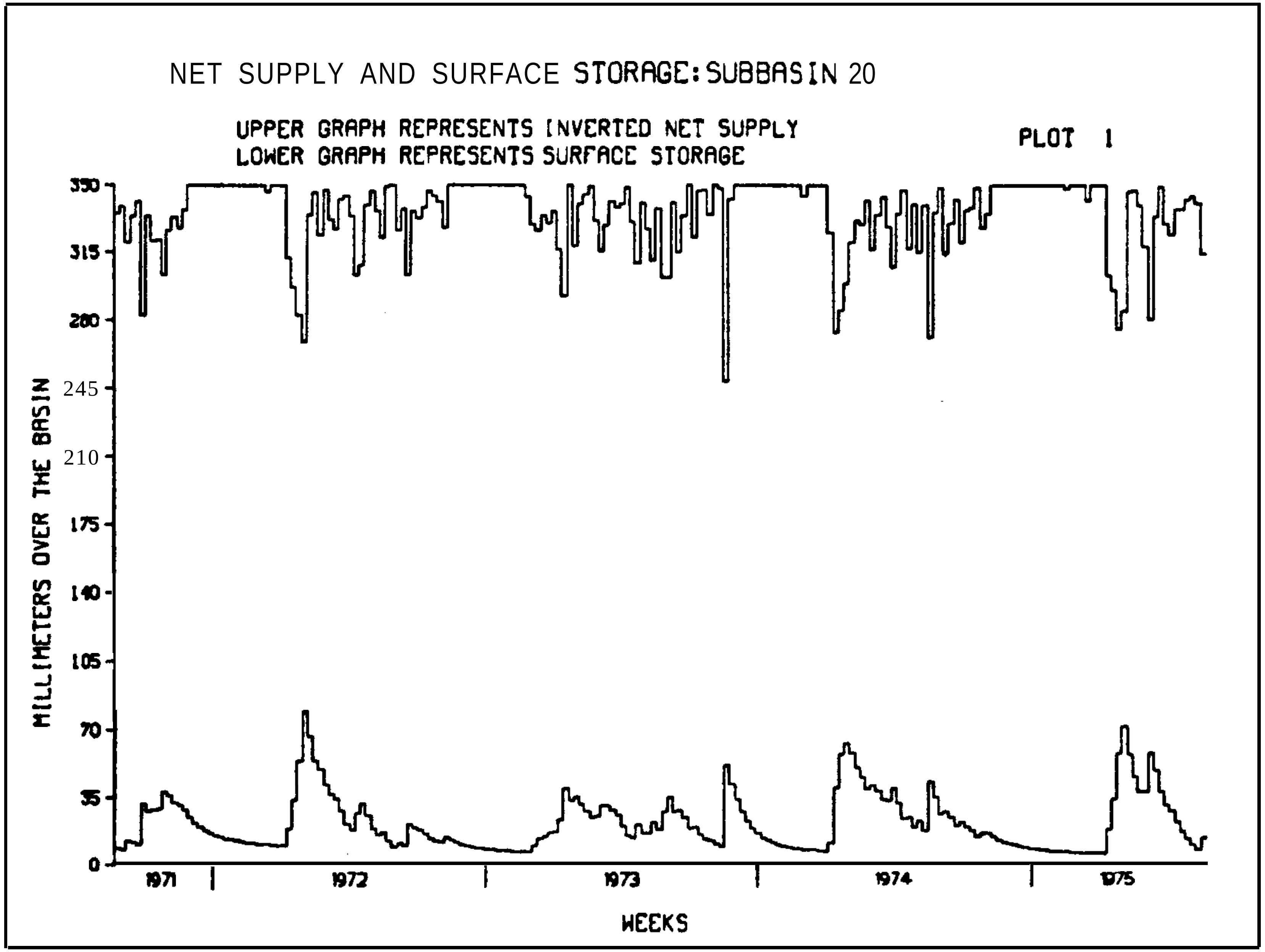
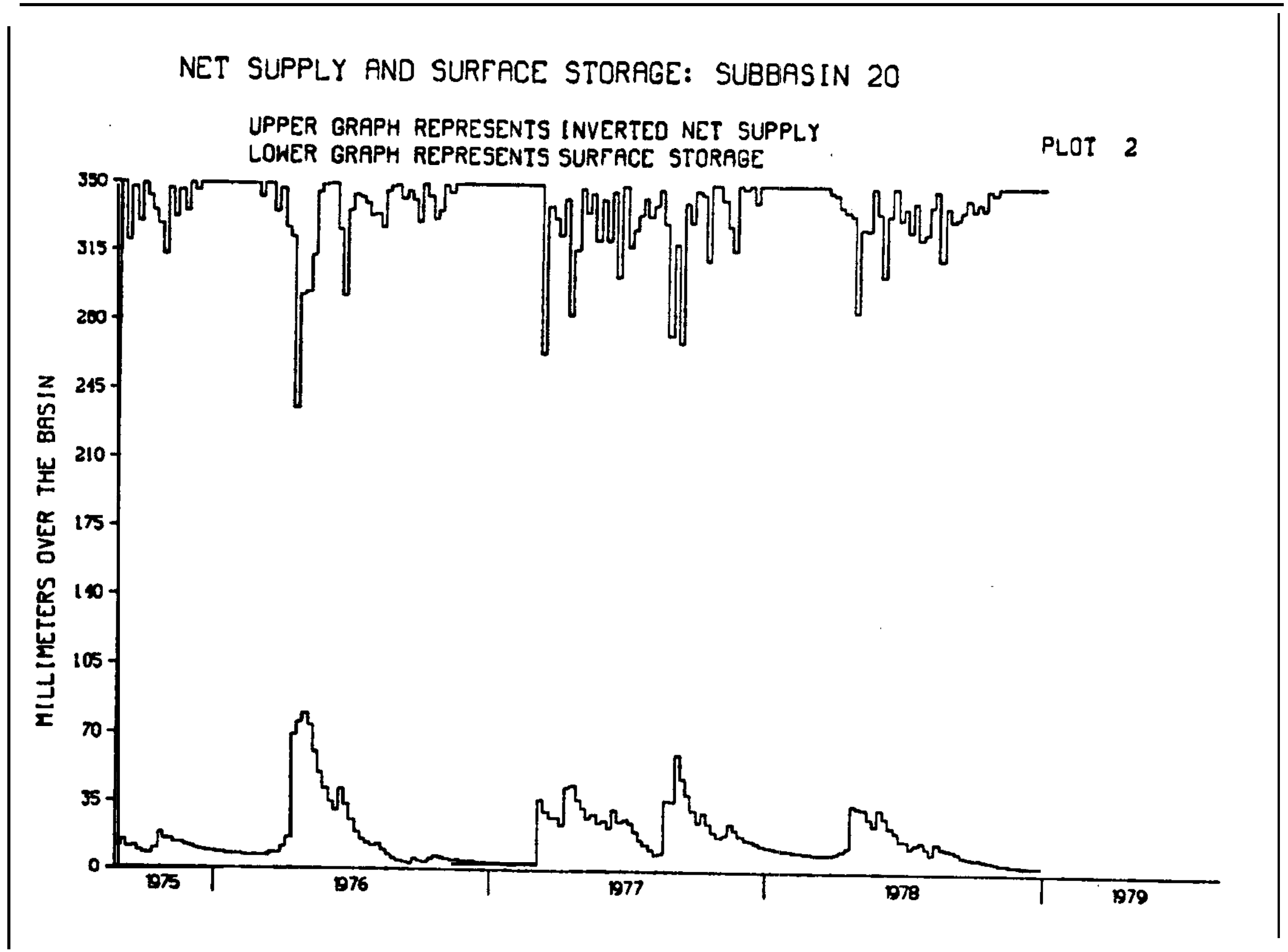


FIGURE 14.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*



IGURE 14.--*Seven-day net supply rate to the watershed and 7th day snowpack, soil zones, groundwater, and surface storages for subbasin 20 (cont.).*

Appendix J.--HYDROGRAPHS FOR 7-d OUTFLOW VOLUMES

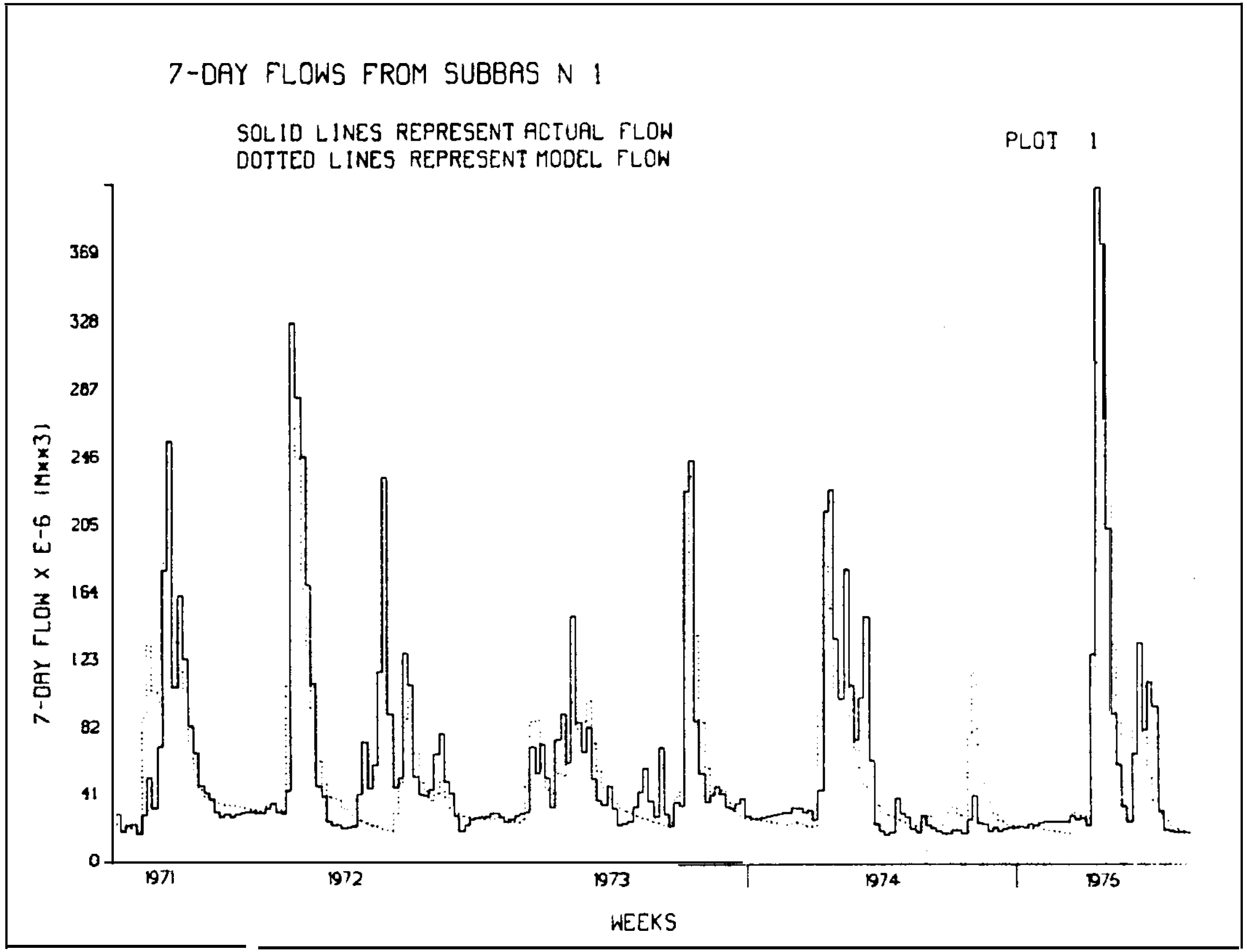


FIGURE 15. *-Hydrograph of 7-d outflow volumes for subbasin 1*

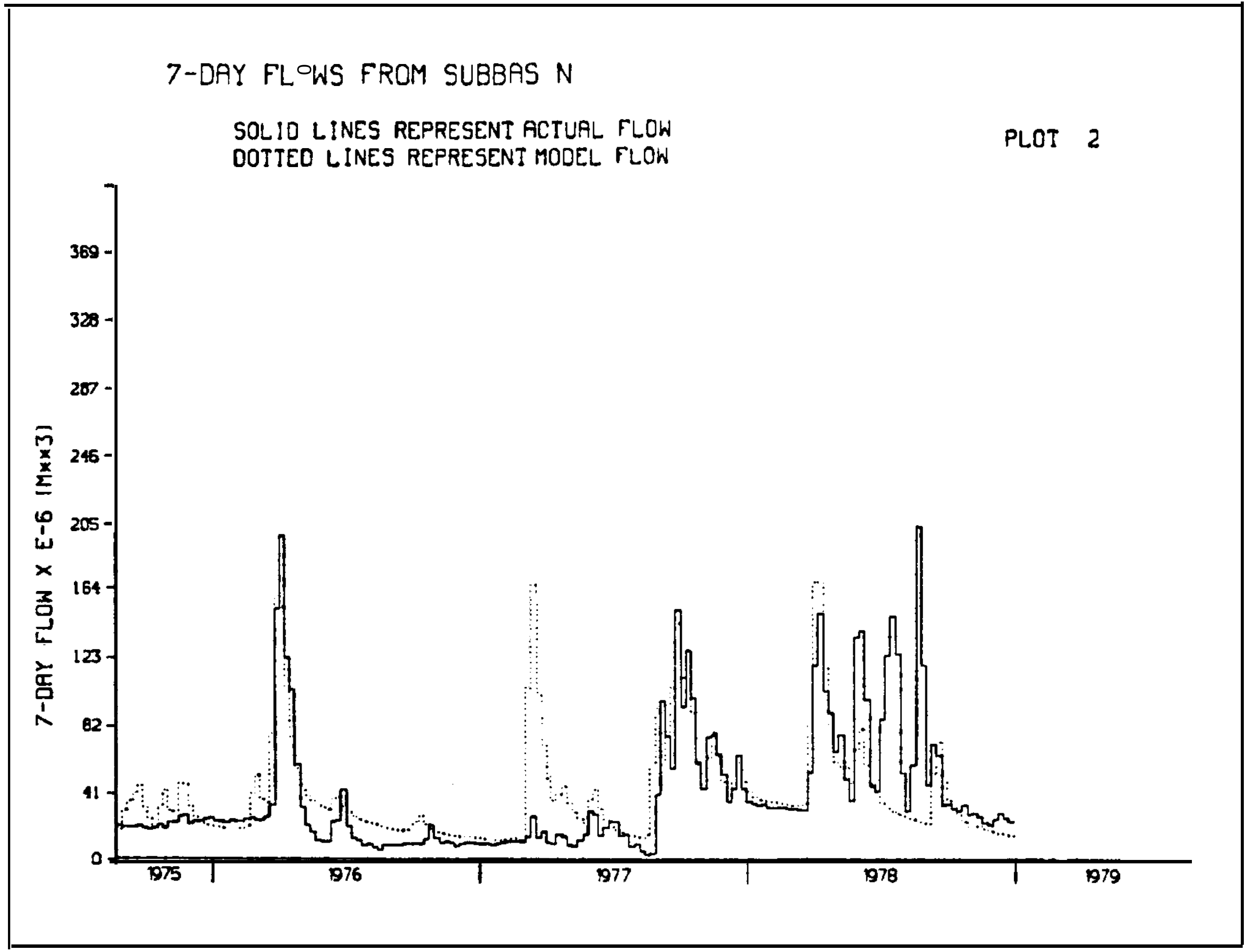


FIGURE 15. -Hydrograph of 7-d outflow volumes for subbasin I (cont.).

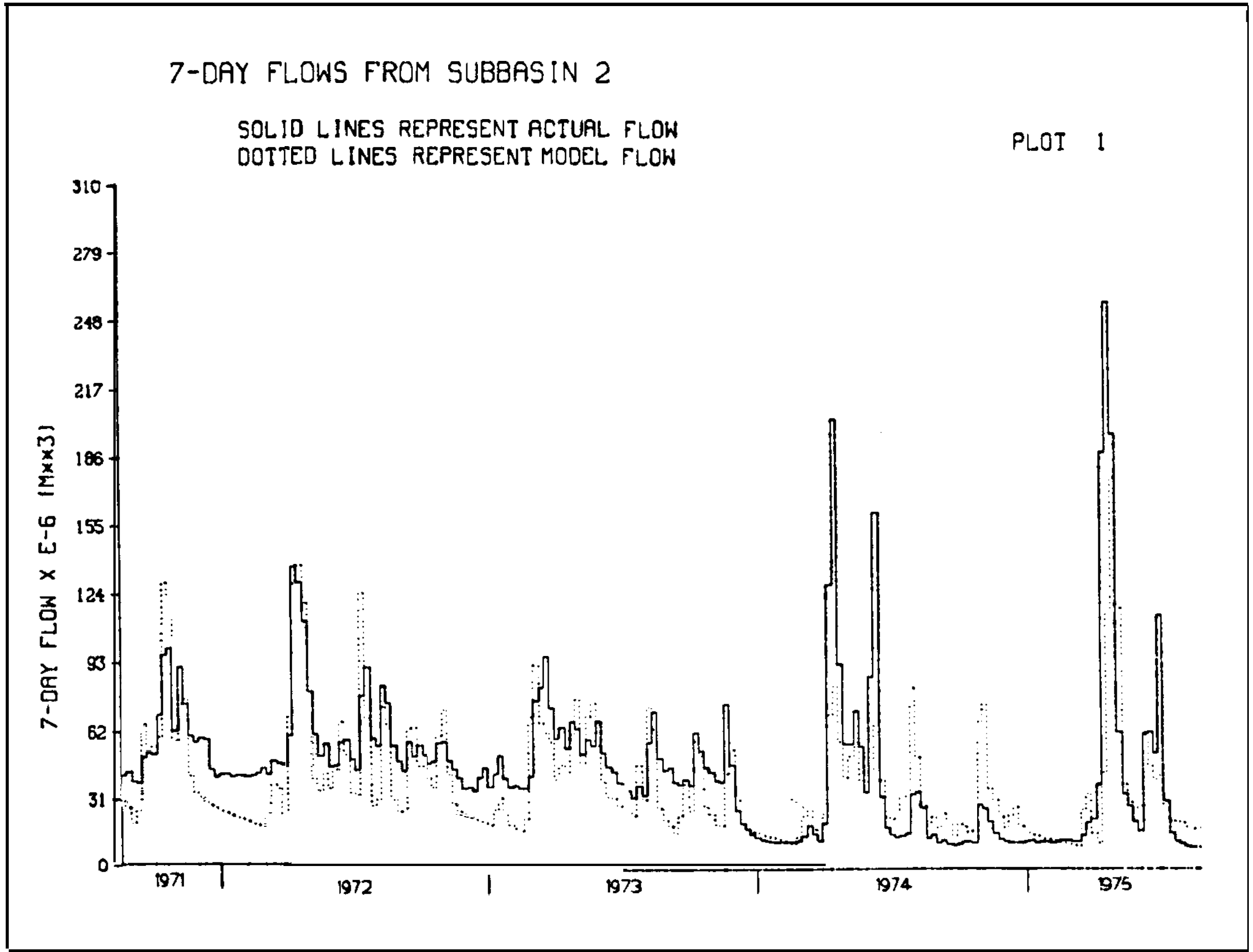


FIGURE 6.- *Hydrograph of 7-d outflow volumes for subbasin 2.*

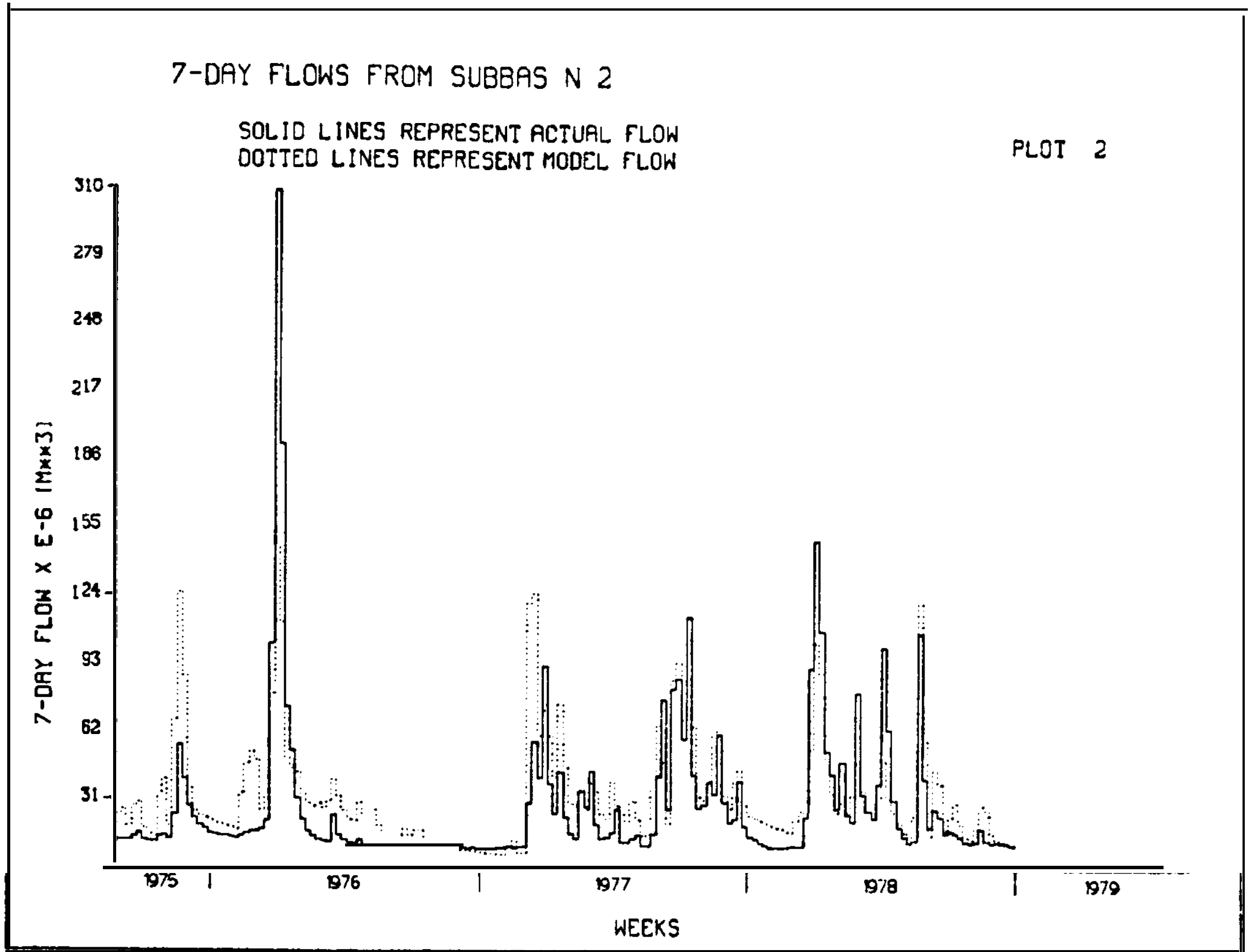
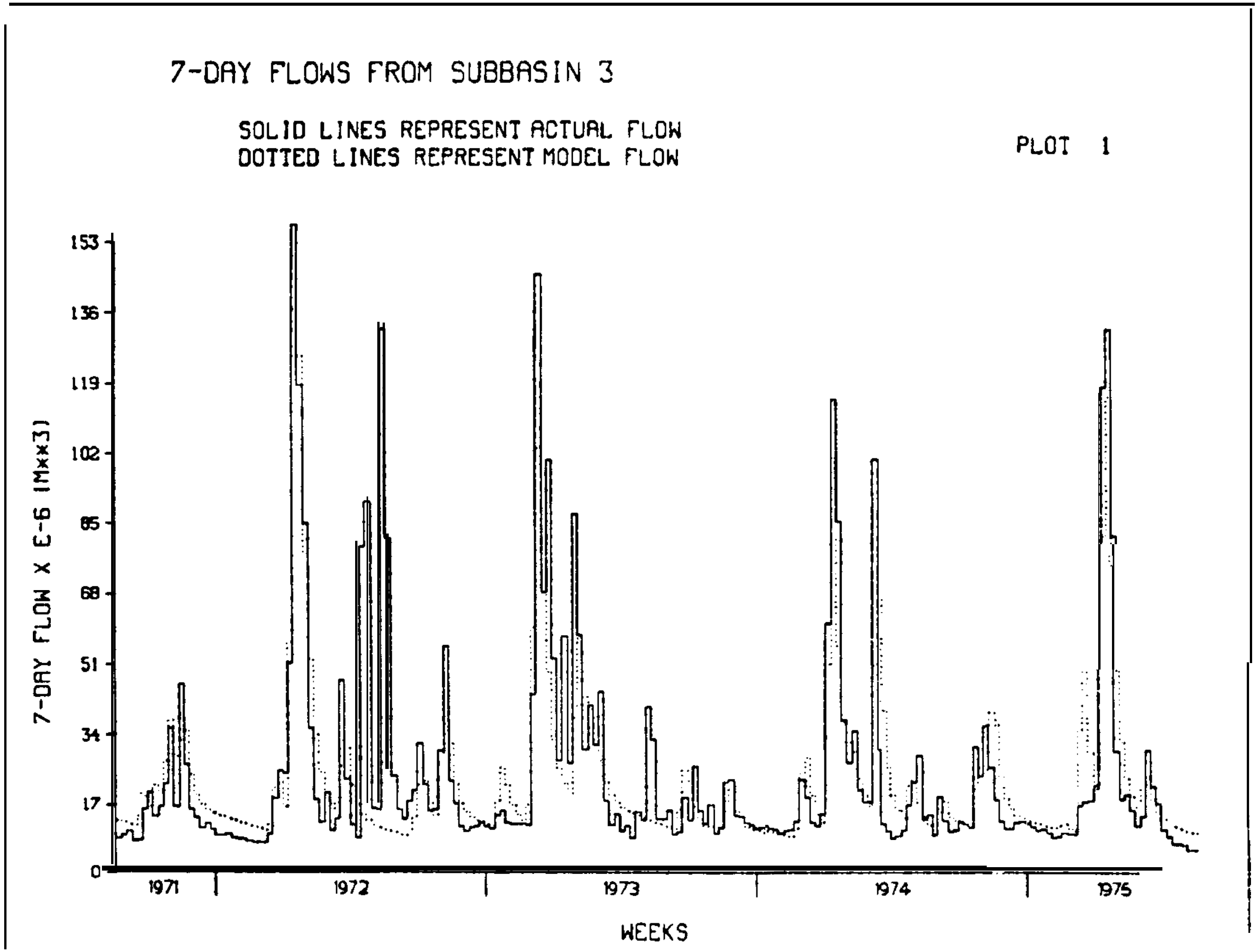


FIGURE 16.--*Hydrograph of 7-d outflow volumes for subbasin 2 (cont. .*



17. -Hydrograph of 7-d outflow volumes for subbasin 3.

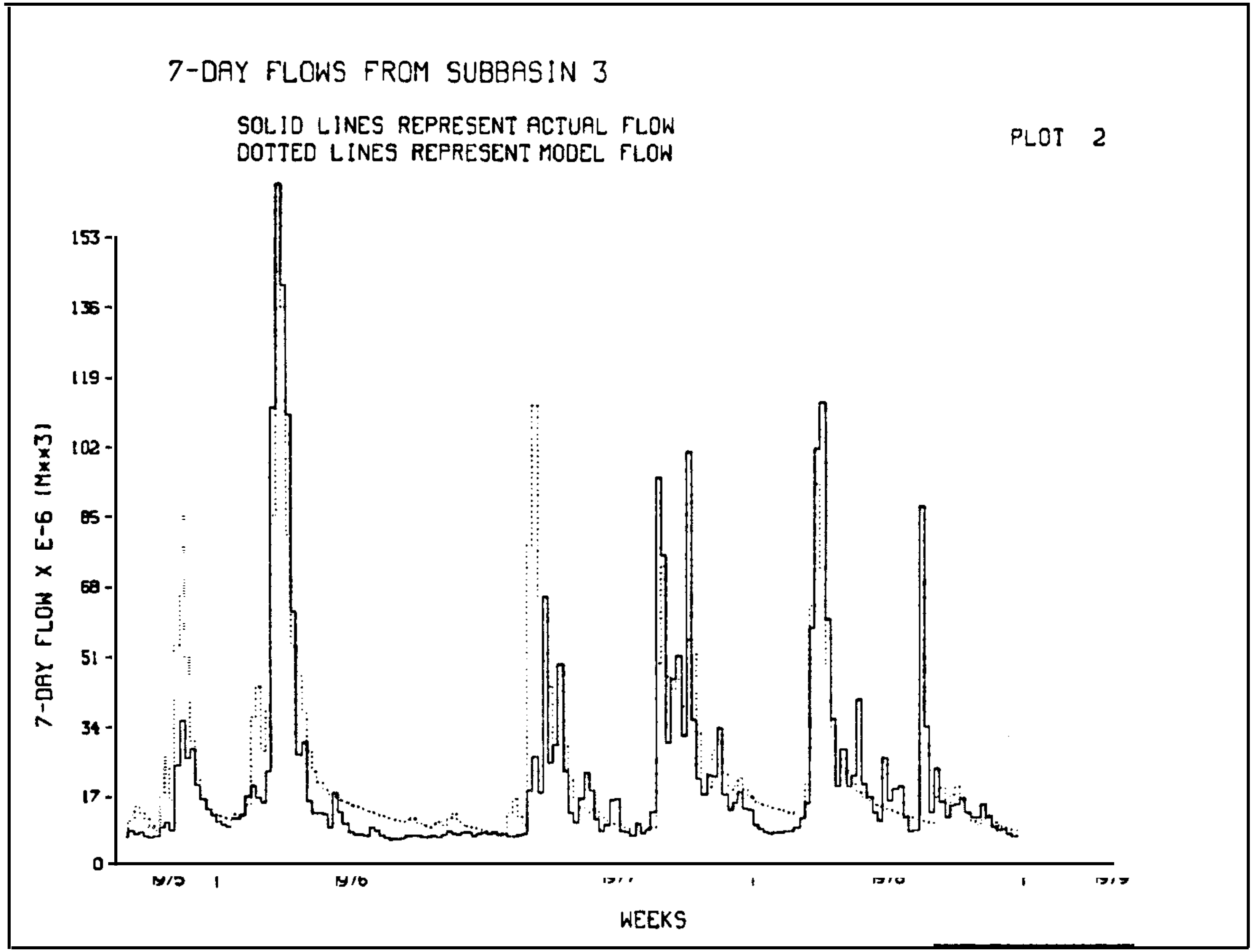


FIGURE 7. -*Hydrograph of 7-d outflow volumes for subbasin 3 (cont.).*

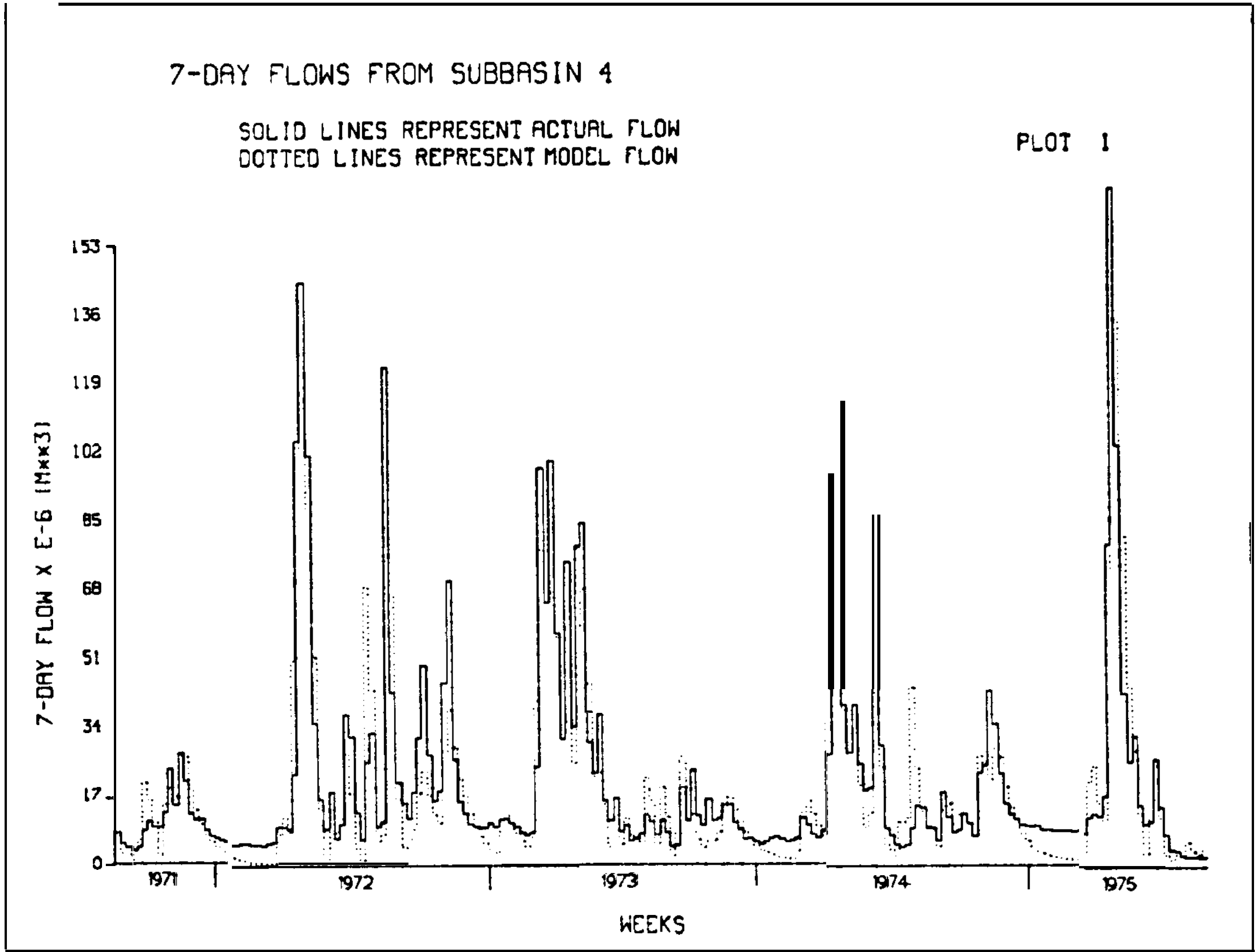


FIGURE 18. -*Hydrograph of 7-d outflow volumes for subbasin 4.*

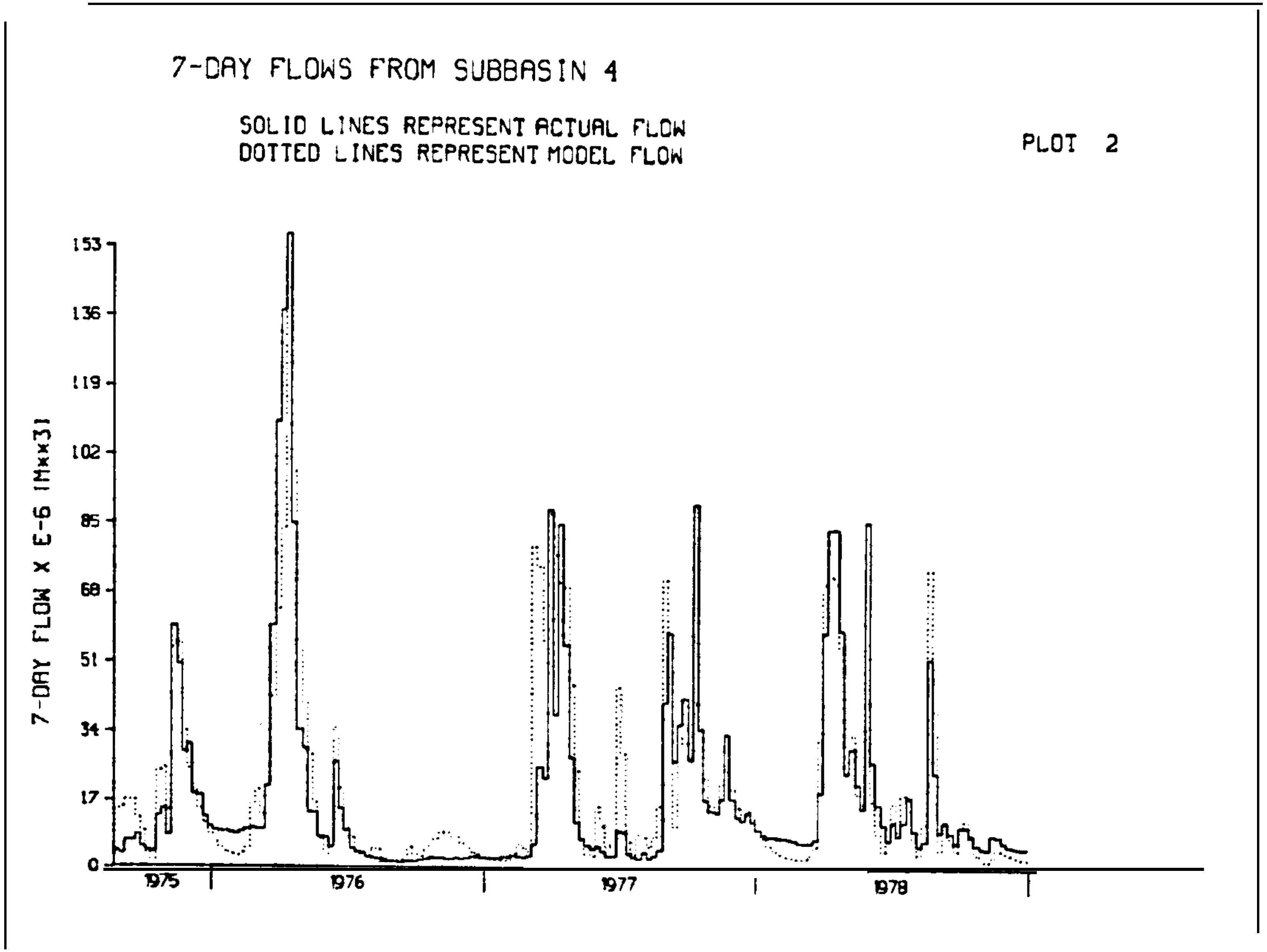


FIGURE 18.- *Hydrograph of 7-d outflow volumes for subbasin 4 (cont.*

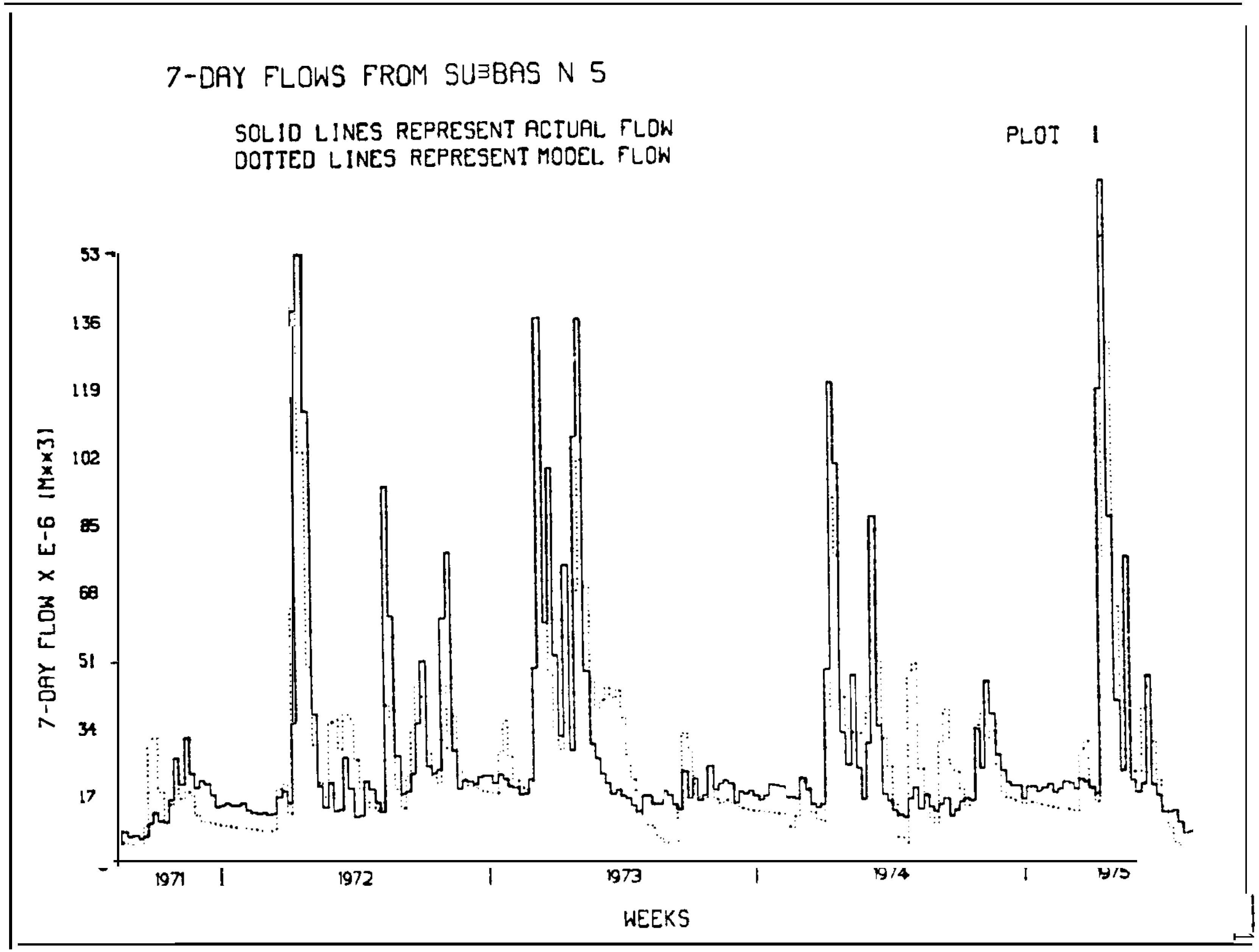
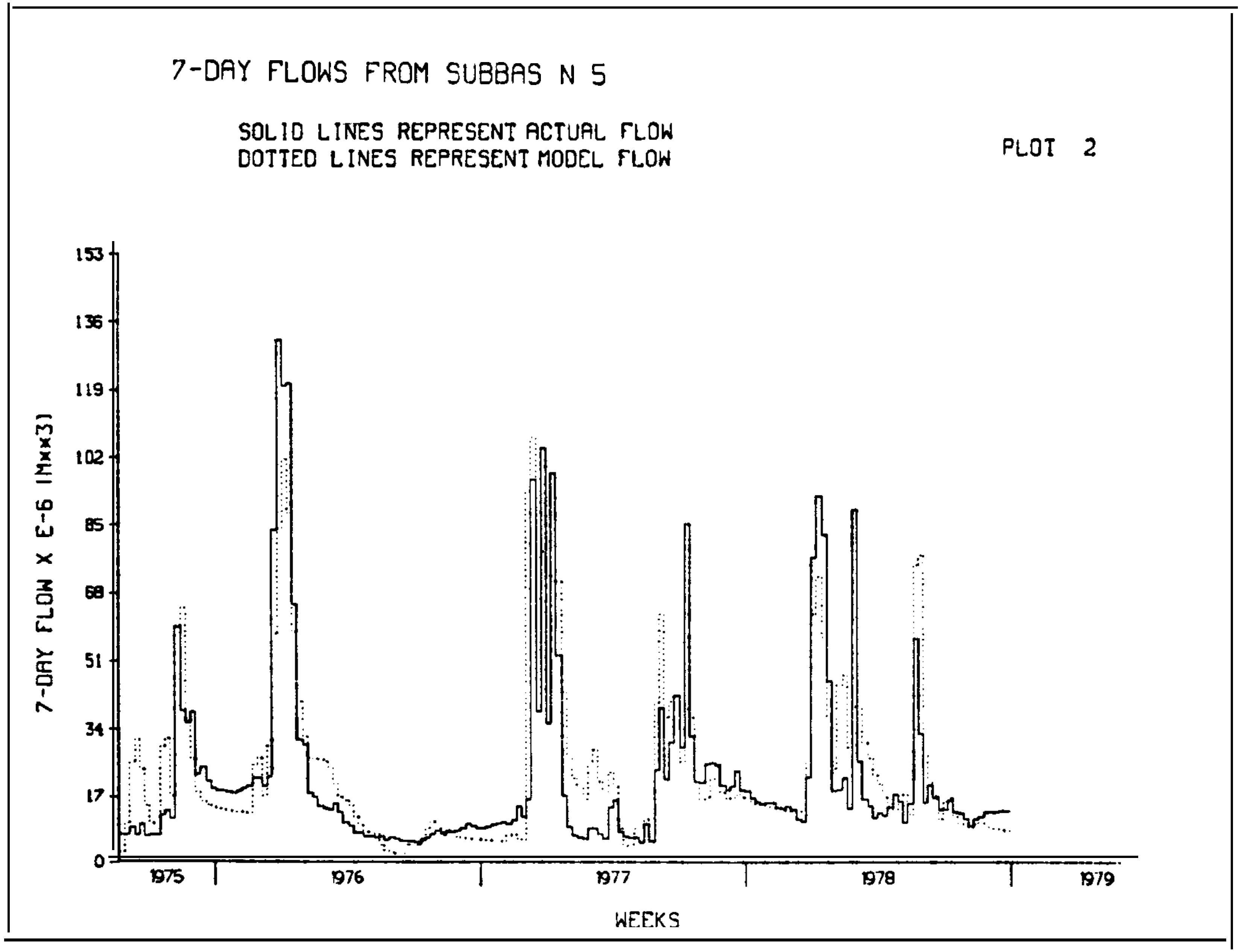


FIGURE 19. —*Hydrograph of 7-d outflow volumes for subbasin 5.*



— 9.--Hydrograph of 7-d outflow volumes for subbasin 5 (cont. .

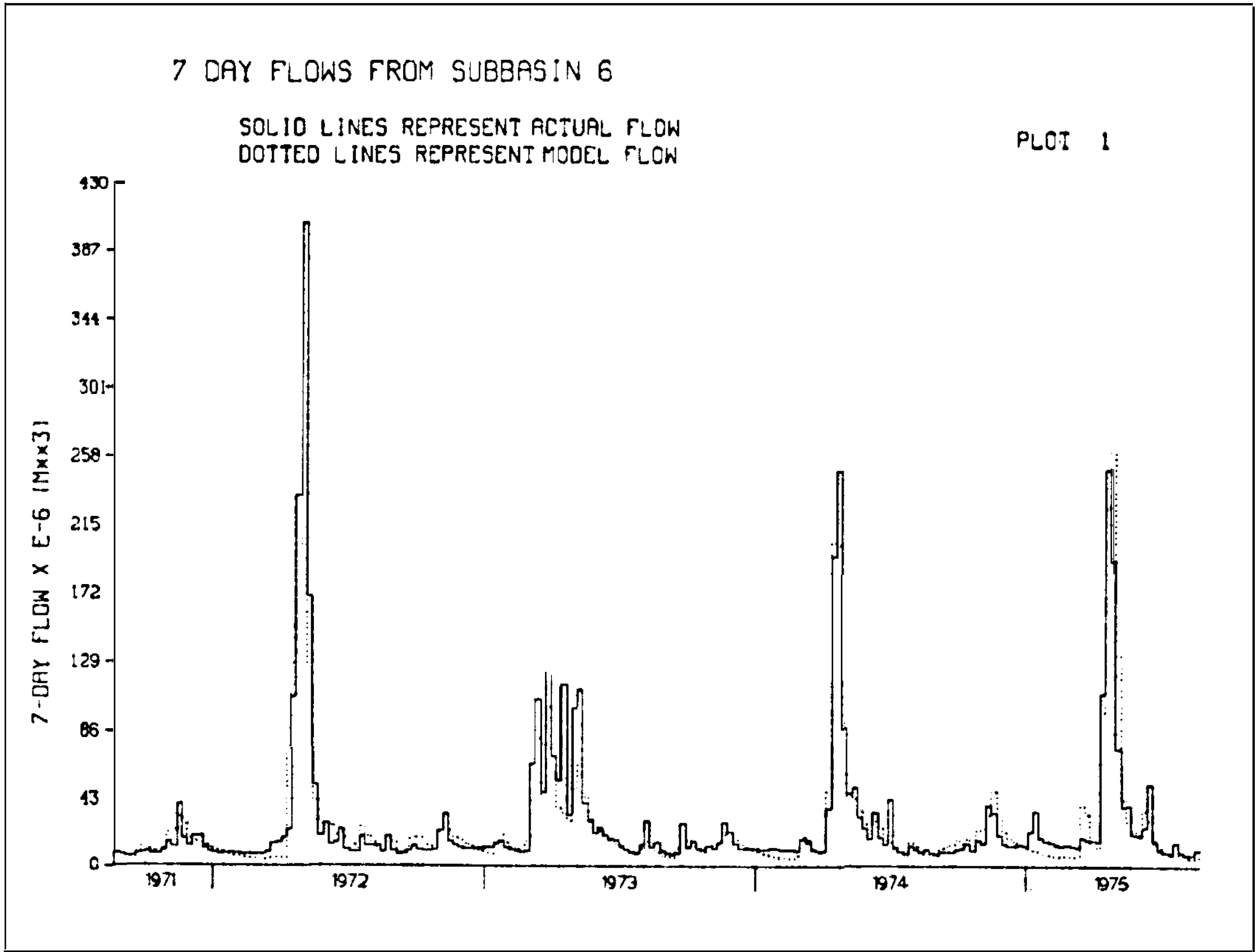


FIGURE 20 — *Hydrograph of 7-d outflow volumes for subbasin 6.*

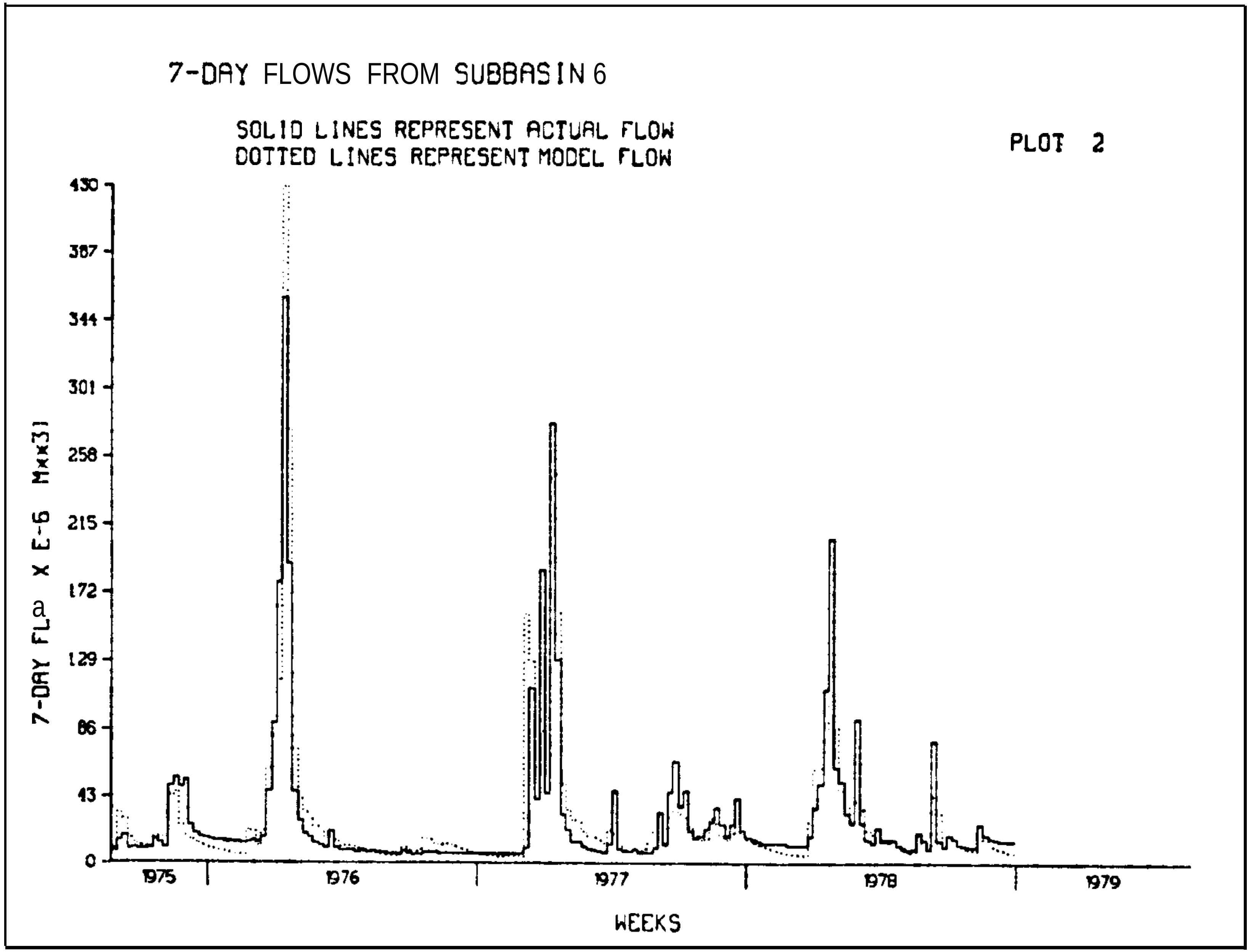


FIGURE 20.--*Hydrograph of 7-d outflow volumes for subbasin 6 (cont.).*

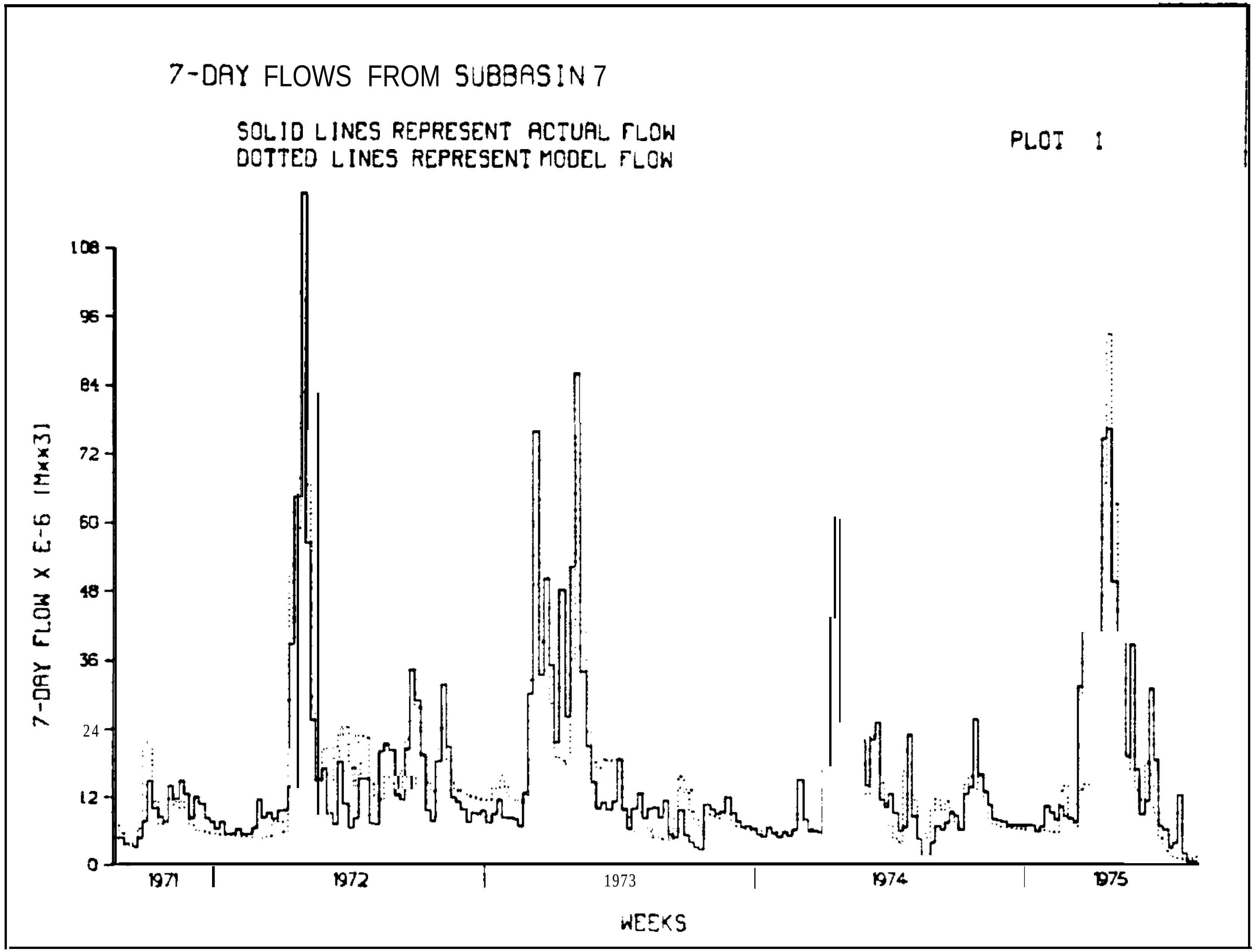


FIGURE 21.--*Hydrograph of 7-d outflow volumes for subbasin 7.*

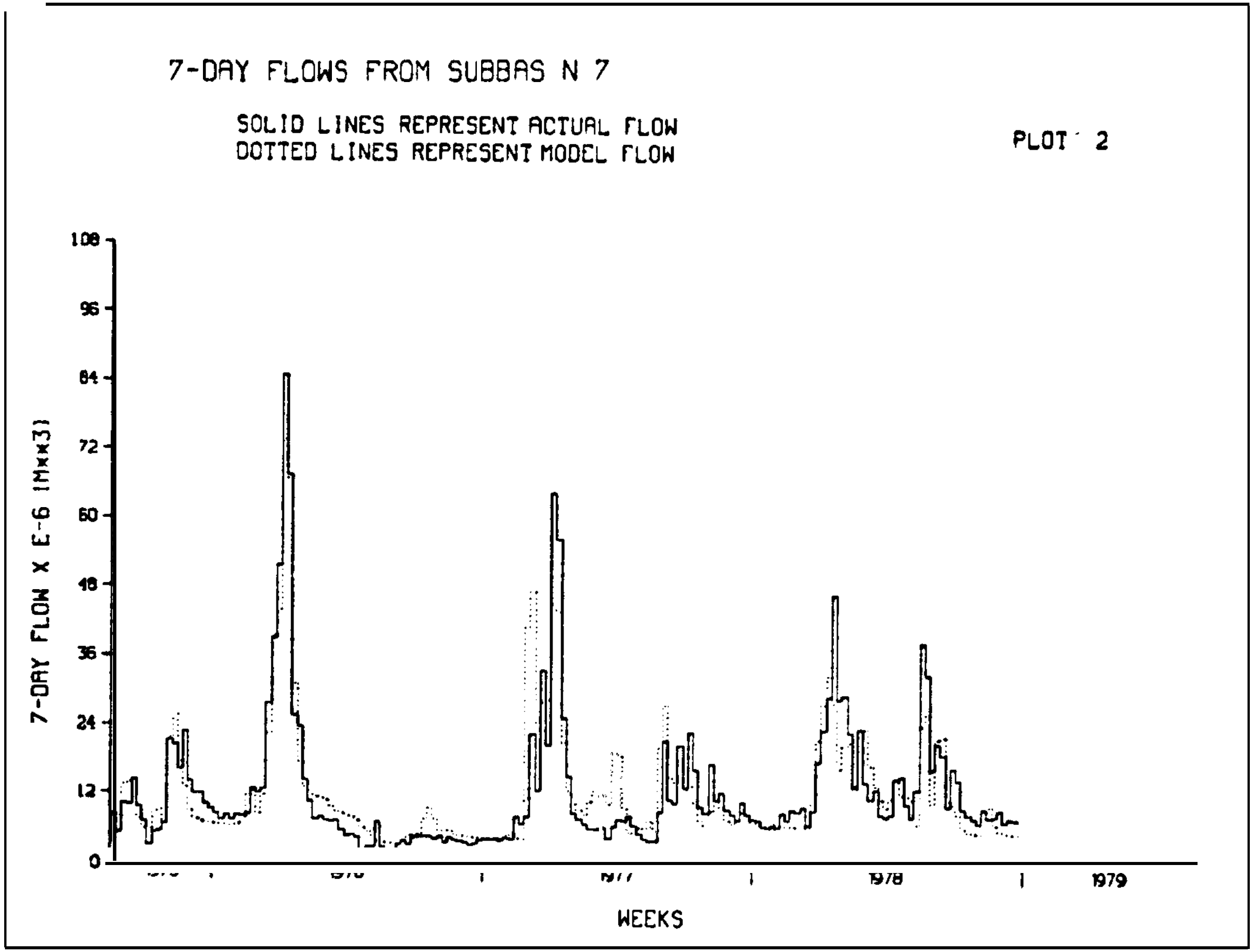


FIGURE 2 .- *Hydrograph of 7-d outflow volumes for subbasin 7 (cont. .*

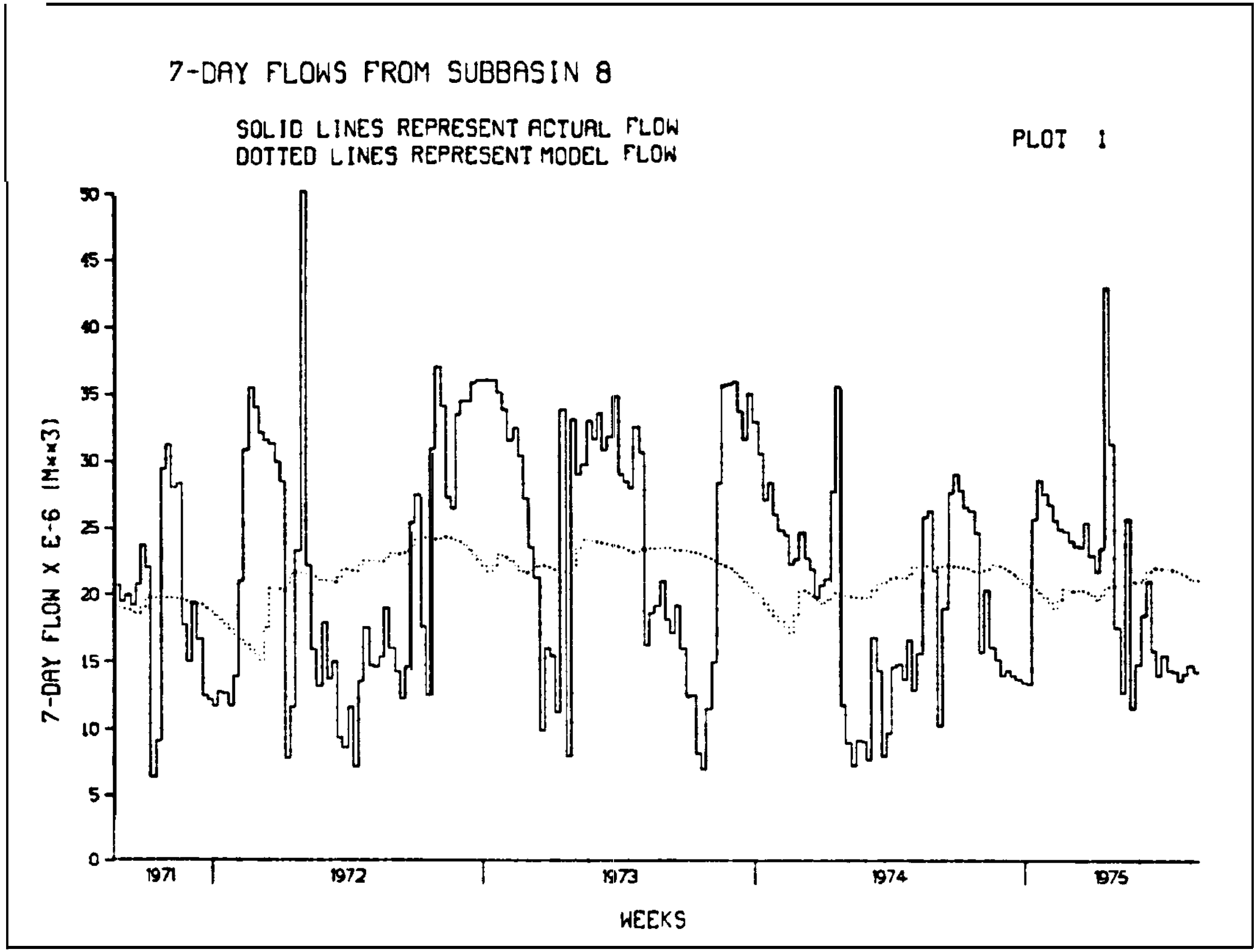


FIGURE 22.- *Hydrograph of 7-d outflow volumes for subbasin 8.*

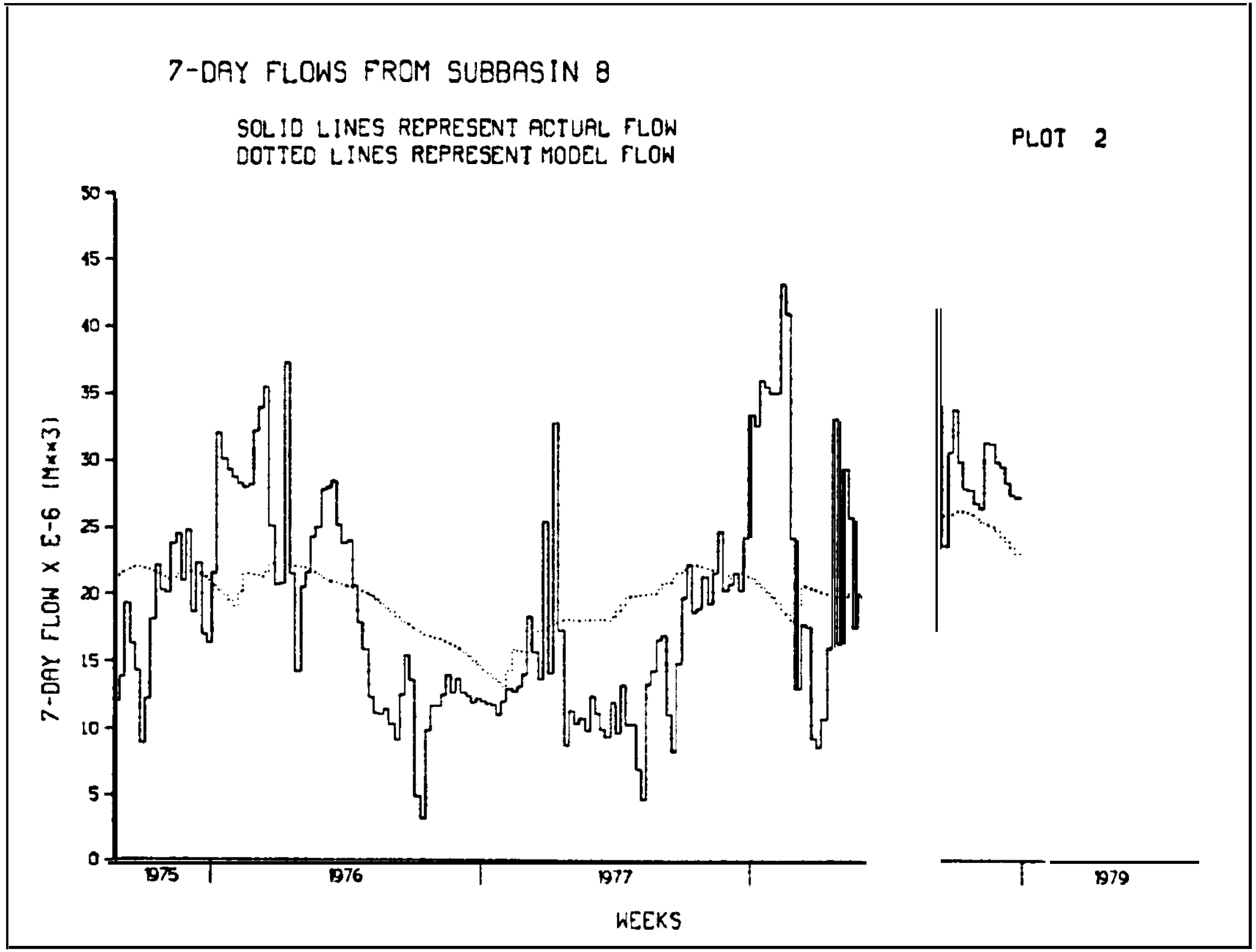


FIGURE 22.— *Hydrograph of 7-d outflow volumes for subbasin 8 (cont.* .

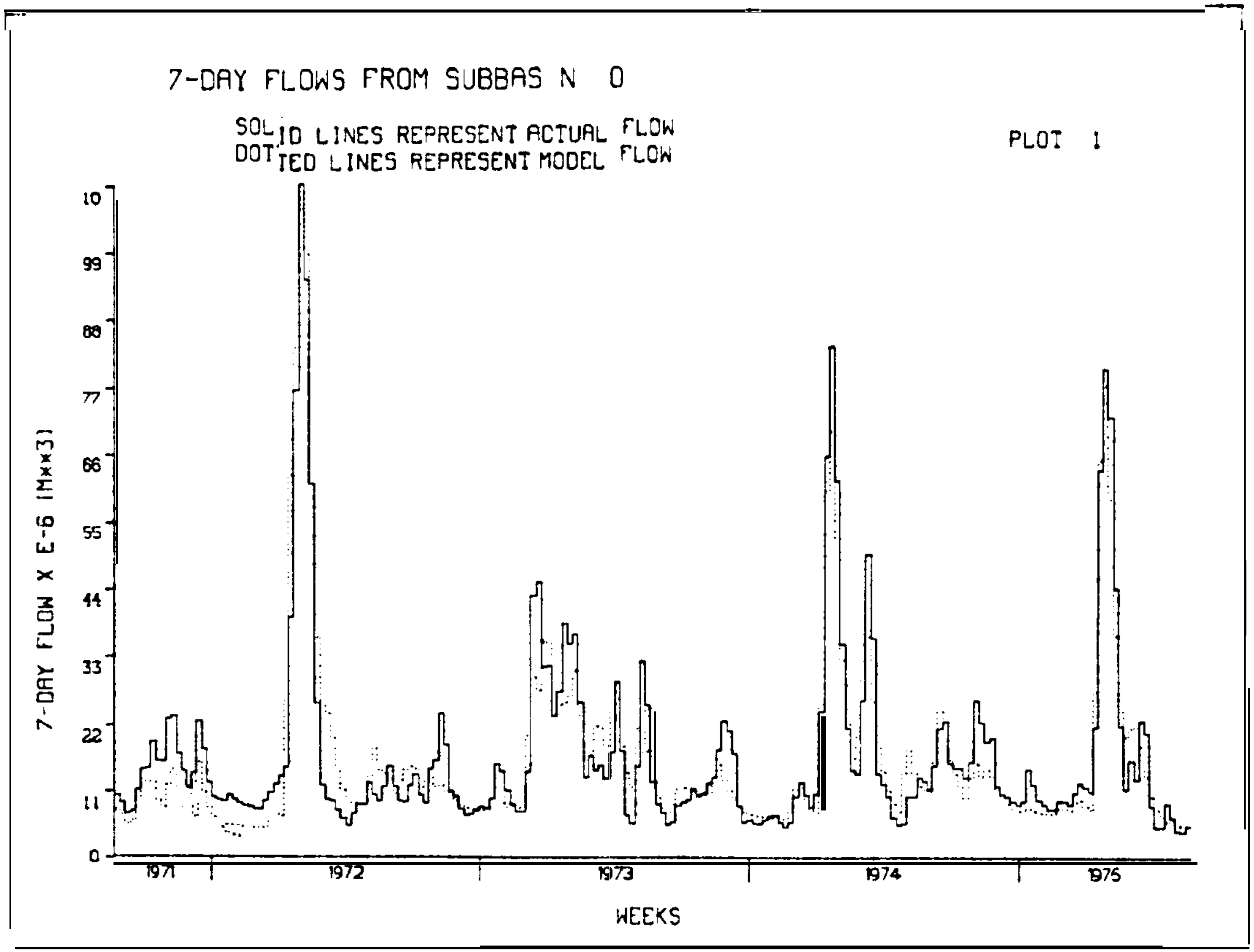


FIGURE 23. -*Hydrograph of 7-d outflow volumes for subbasin 10*

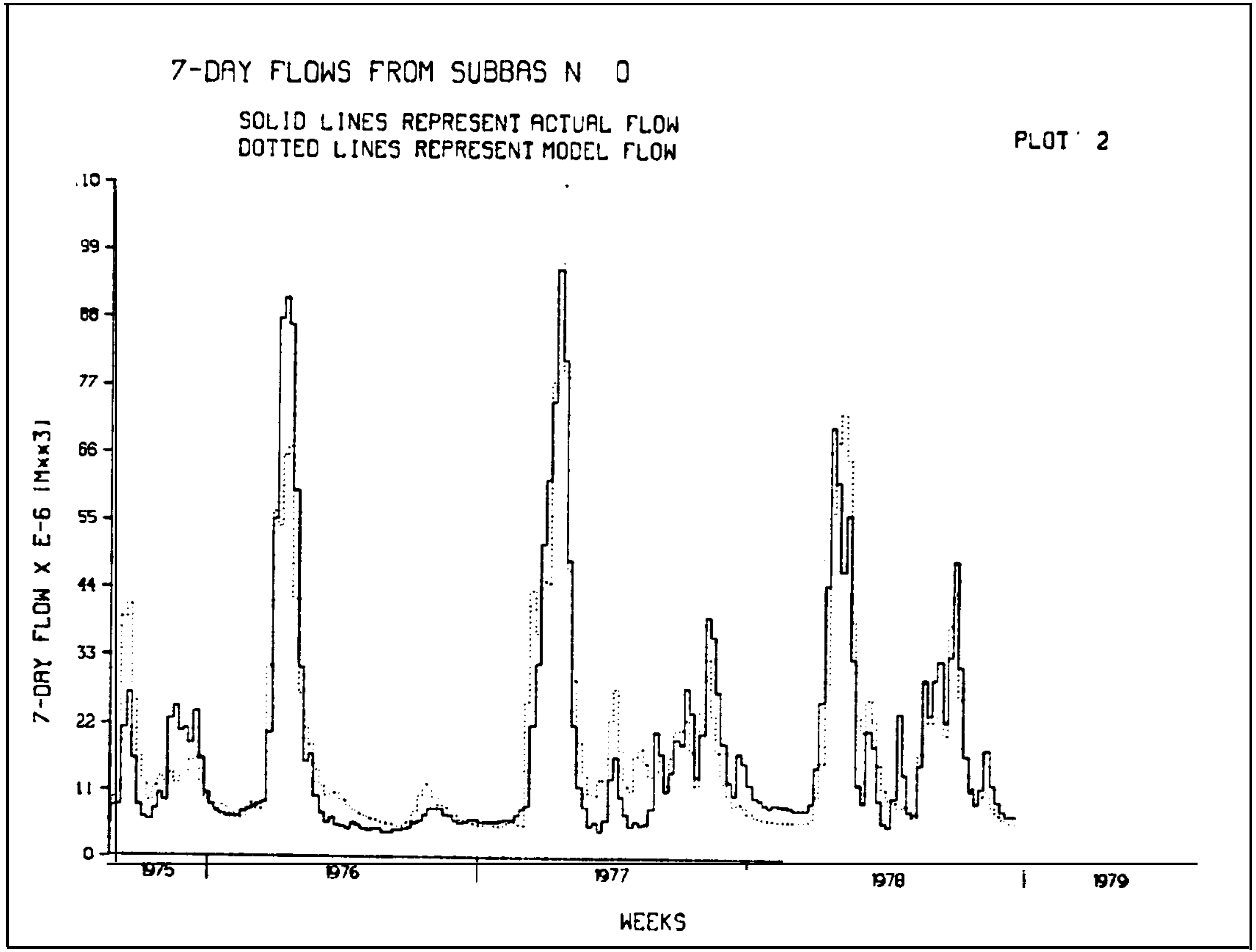


FIGURE 23.- *Hydrograph of 7-d outflow volumes for subbasin 10 (cont. .*

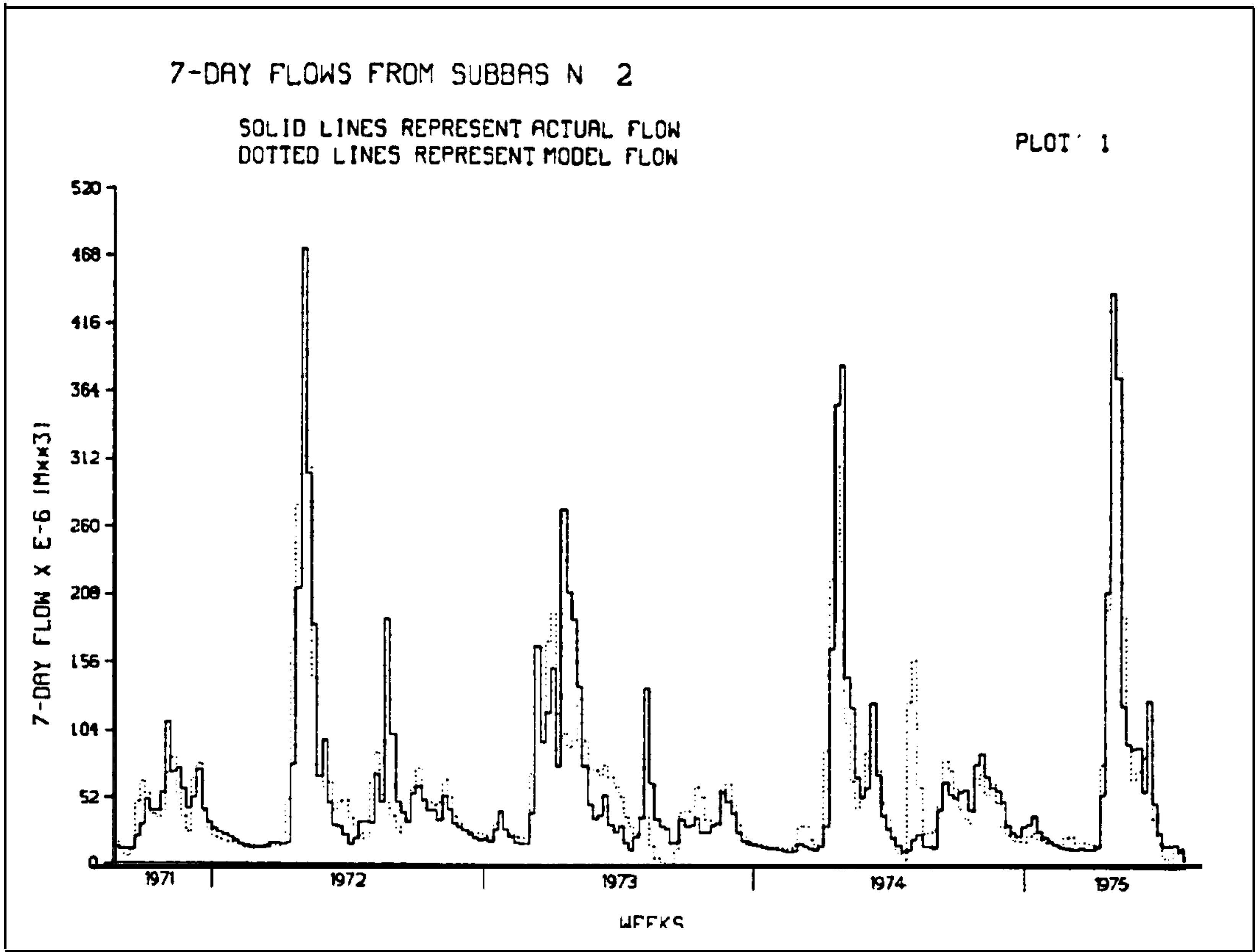


FIGURE 24. *—Hydrograph of 7-d outflow volumes for subbasin 12.*

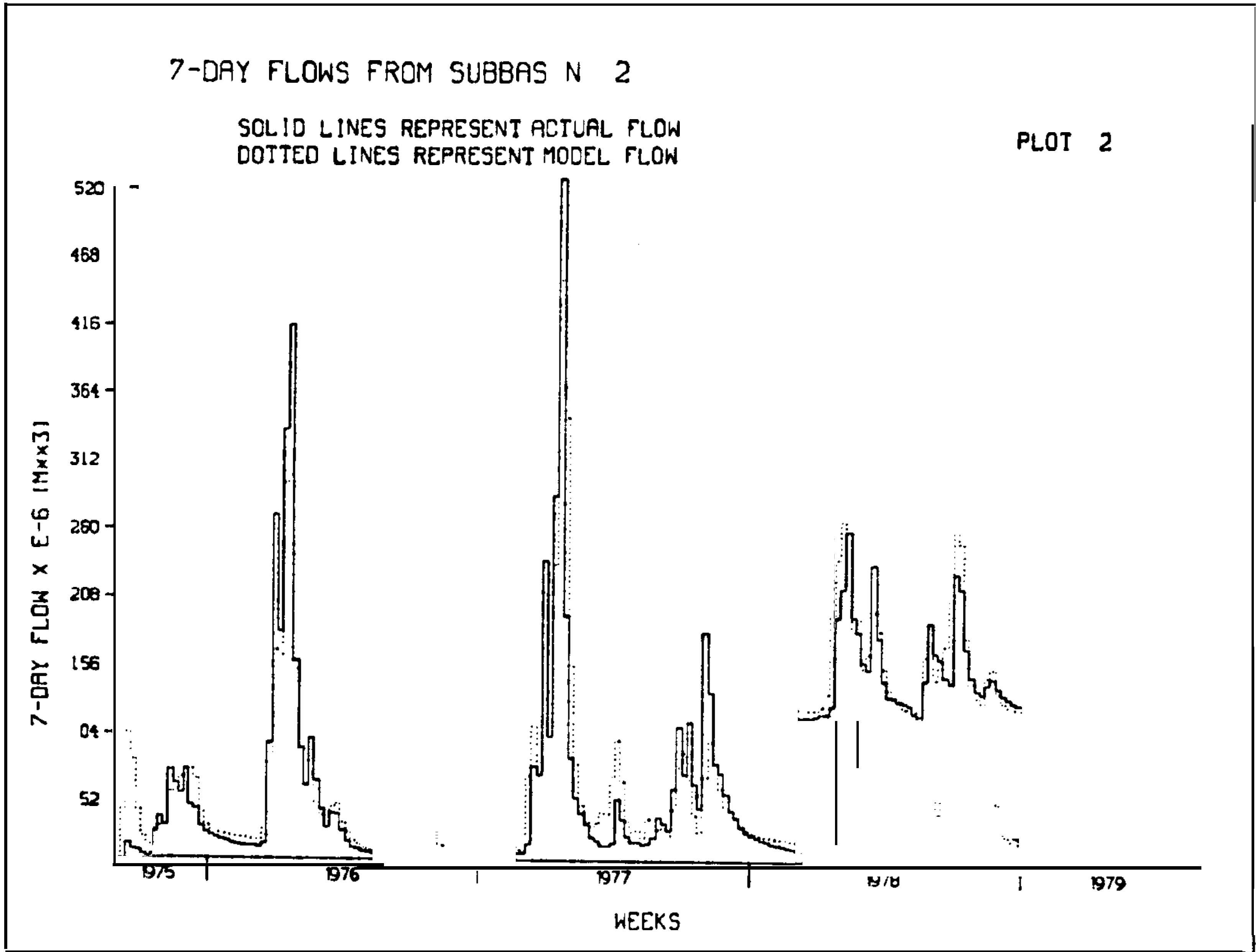


FIGURE 24.- *Hydrograph of 7-d outflow volumes for subbasin 12 (cont. .*

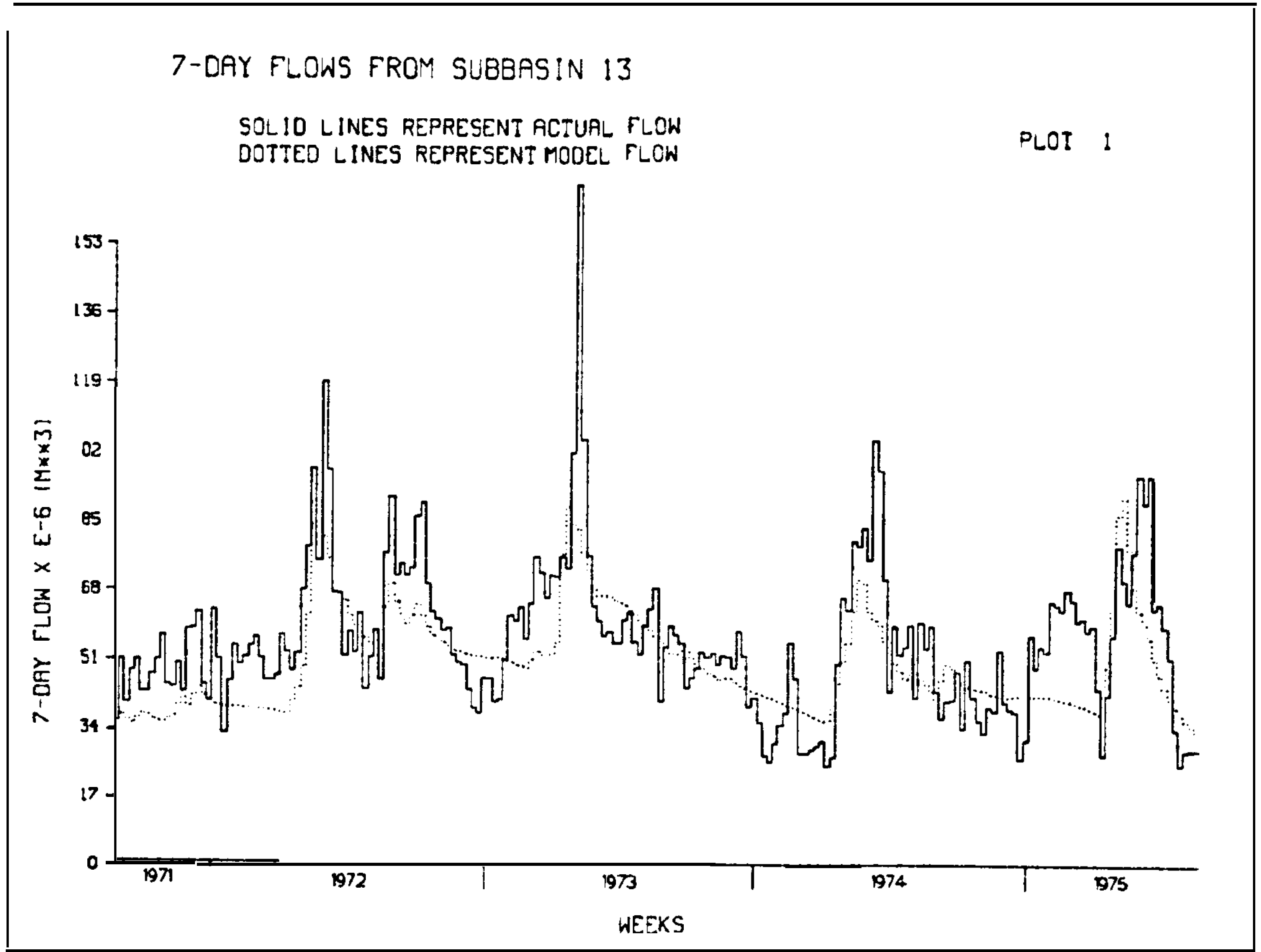


FIGURE *of 7-d* *for subbasin 13.*

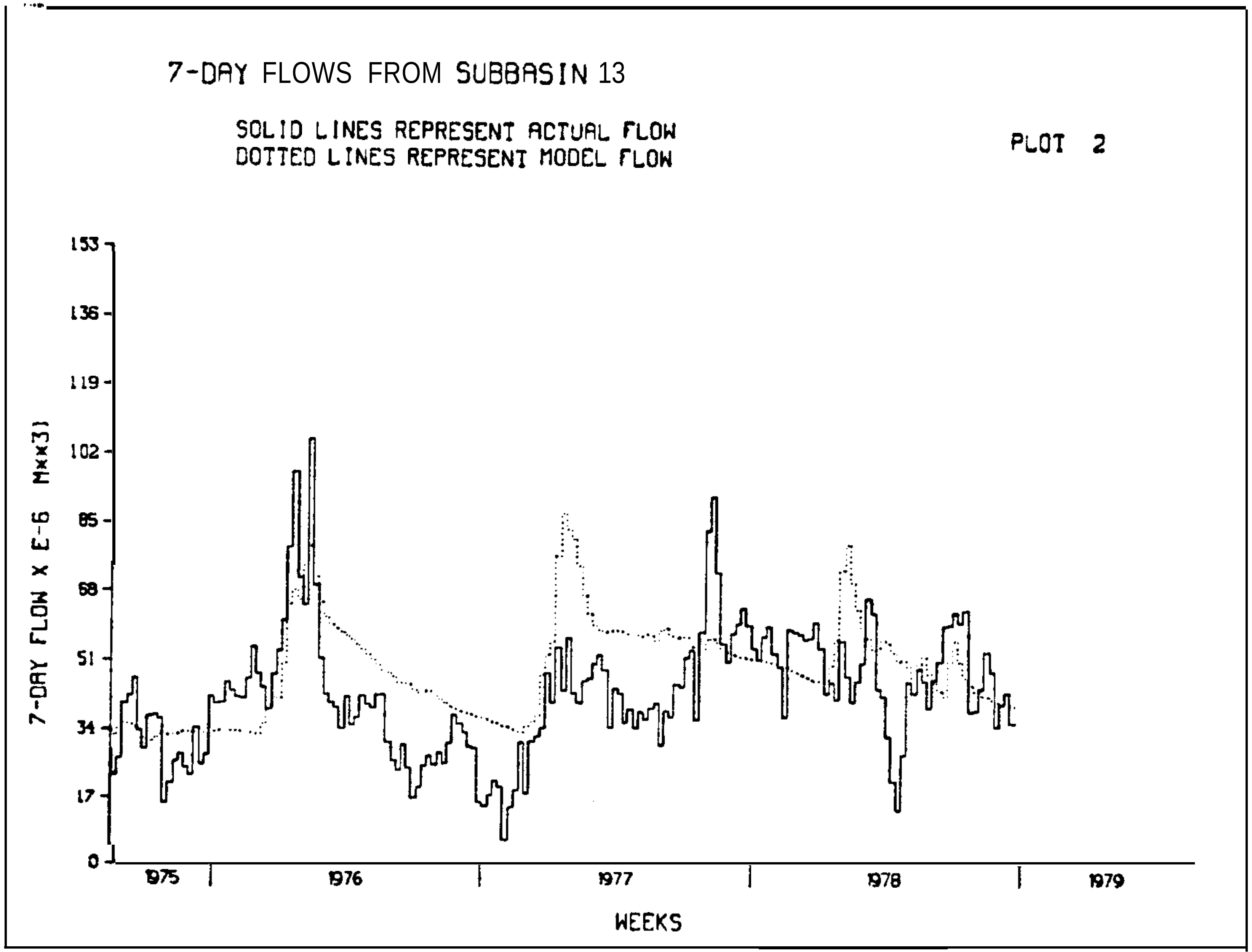


FIGURE 25.--*Hydrograph of 7-d outflow volumes for subbasin 13 (cont.).*

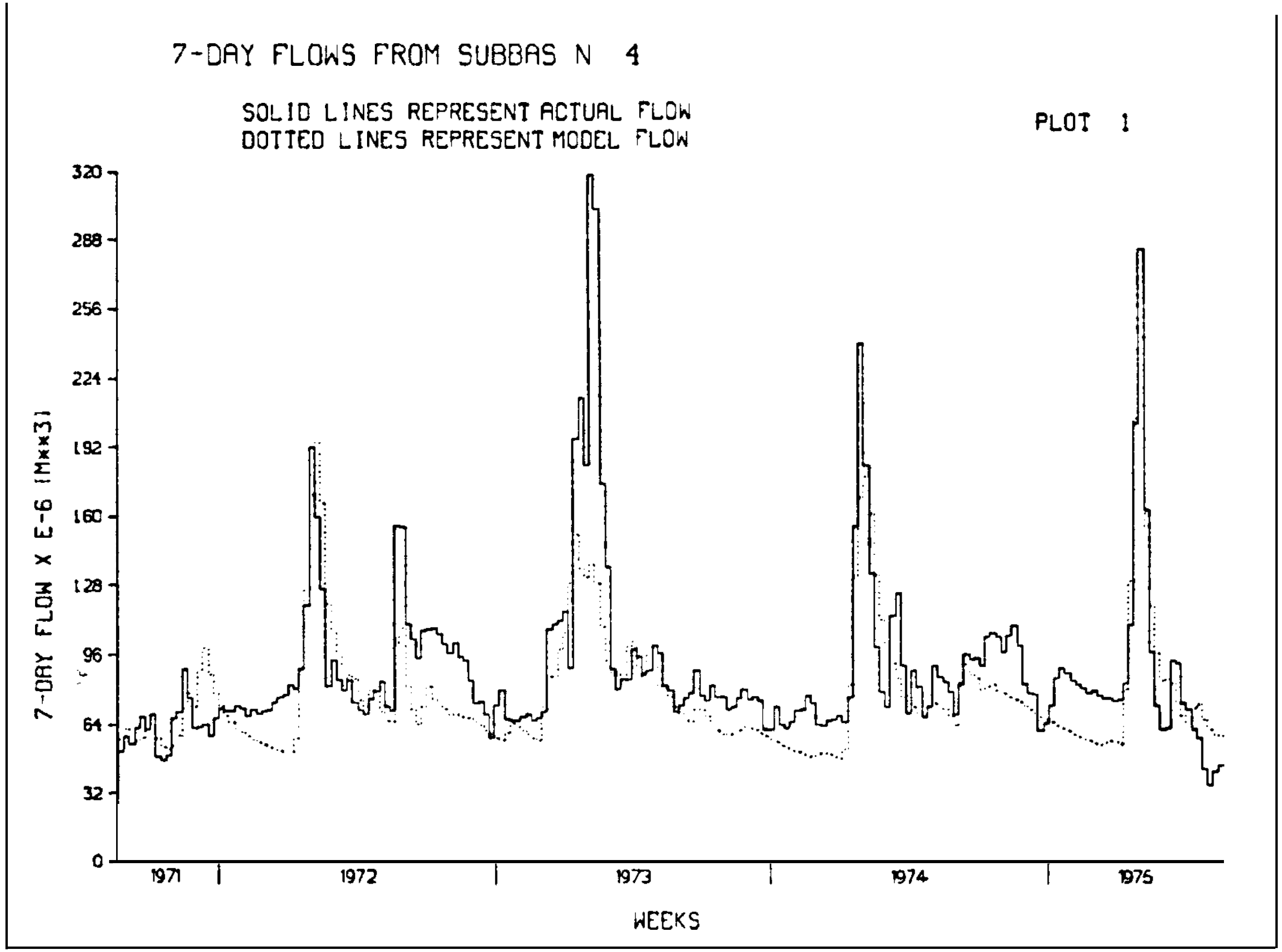


FIGURE 26.- *Hydrograph of 7-d outflow volumes for subbasin 14*

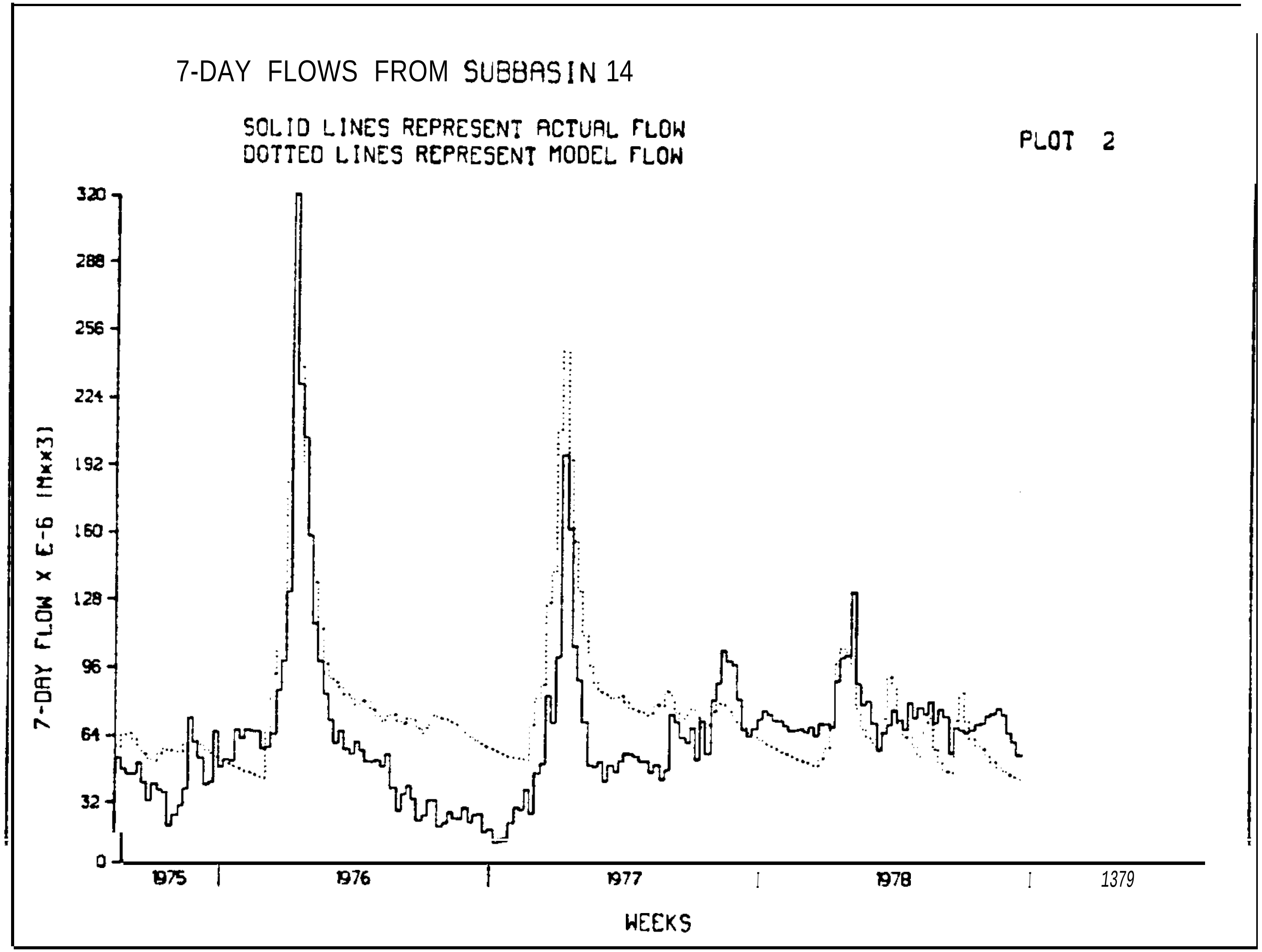


FIGURE 26.--*Hydrograph* of 7-d outflow volumes for *subbasin* 14 *(cont.)*.

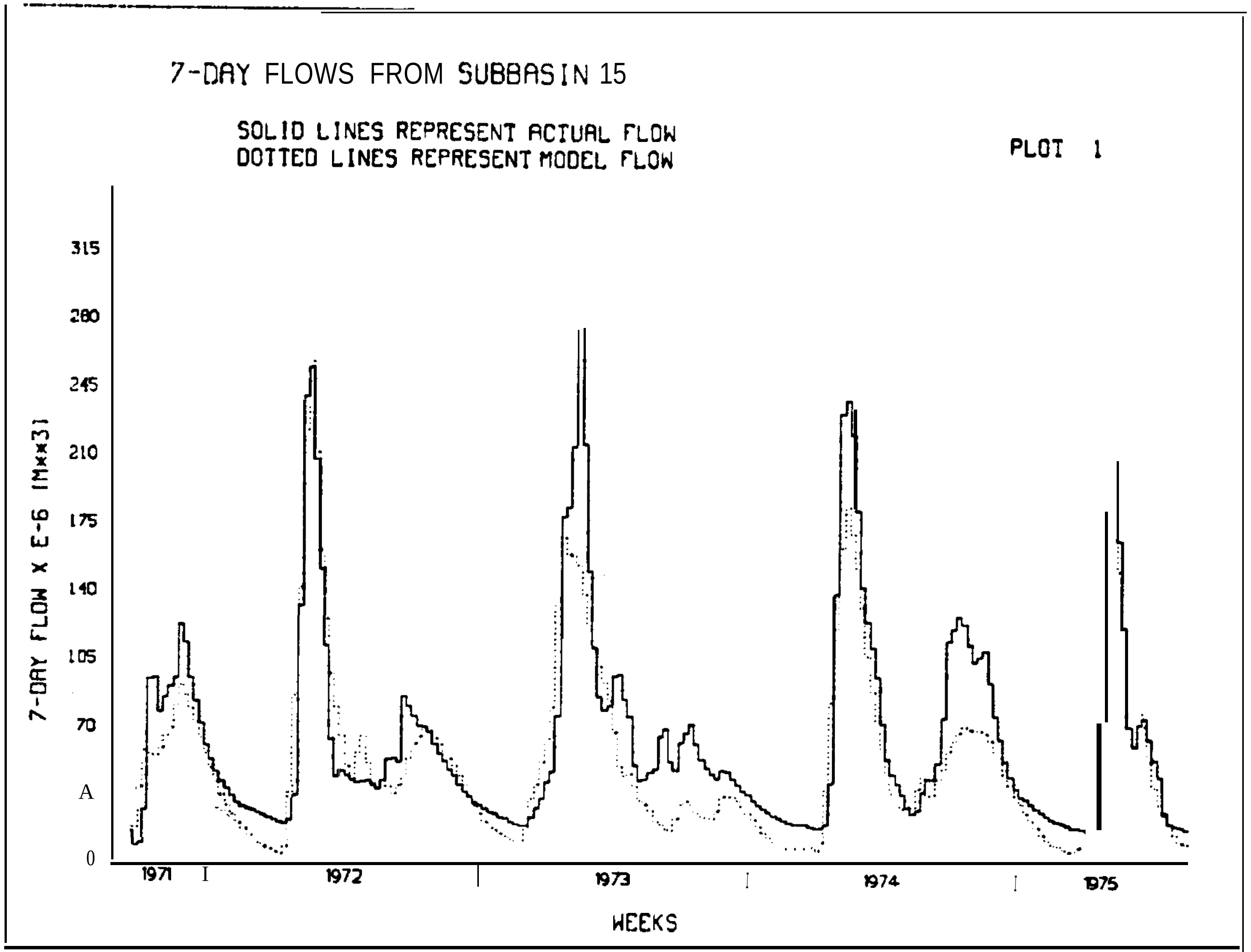


FIGURE 27.--*Hydrograph of 7-d outflow volumes for subbasin 15.*

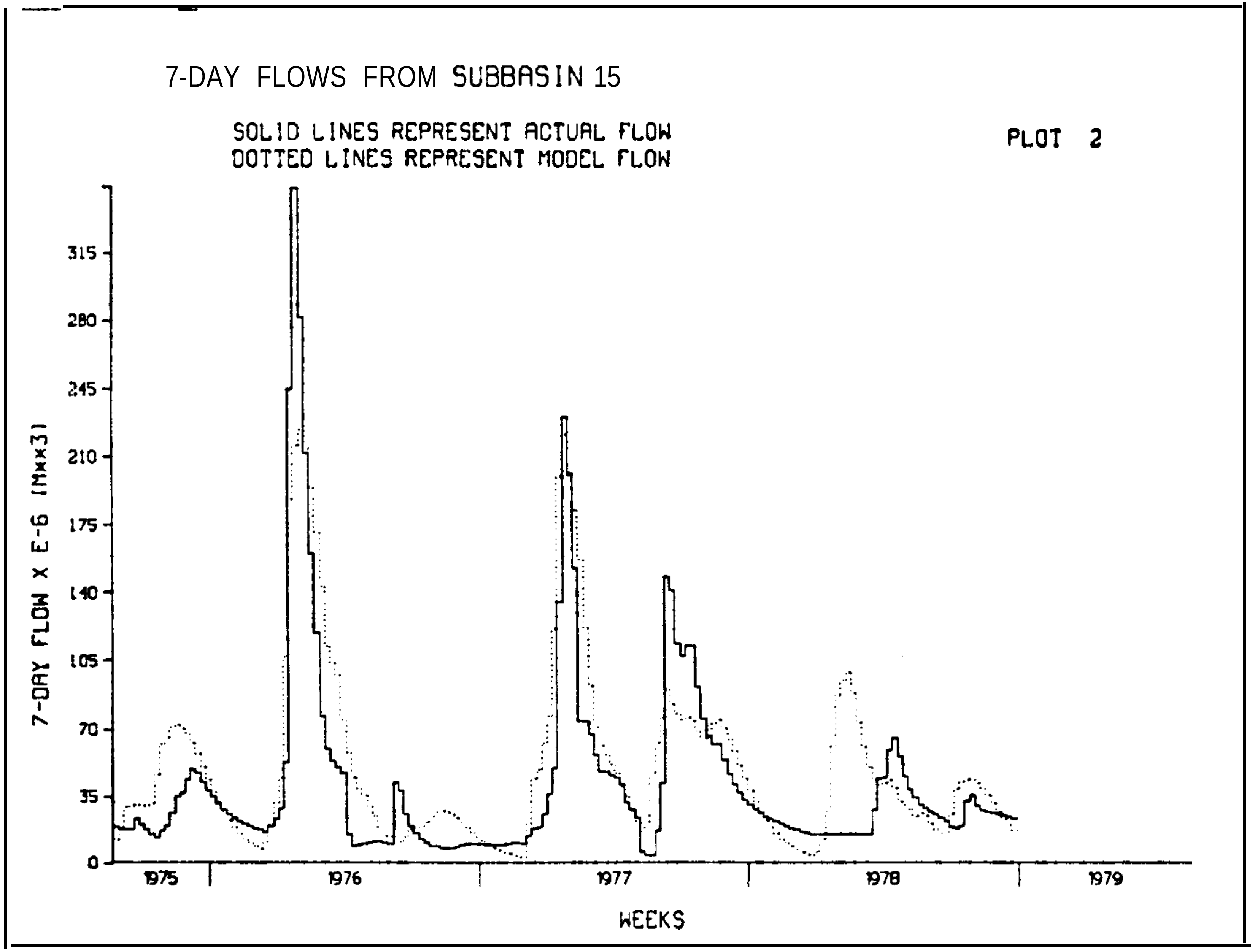


FIGURE 27.--*Hydrograph of 7-d outflow volumes for subbasin 15 (cont.).*

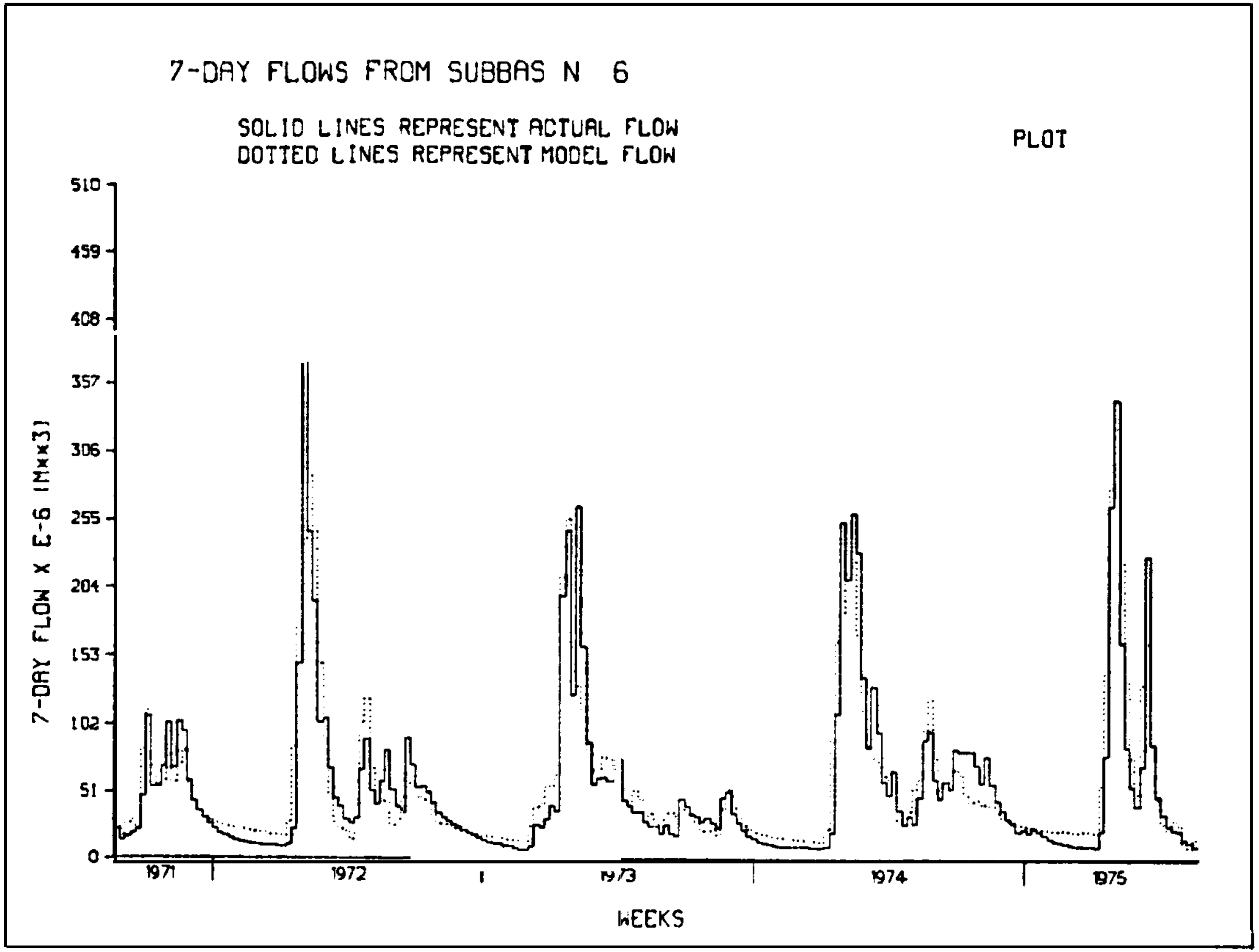


FIGURE 28.- *Hydrograph of 7-d outflow volumes for subbasin 16.*

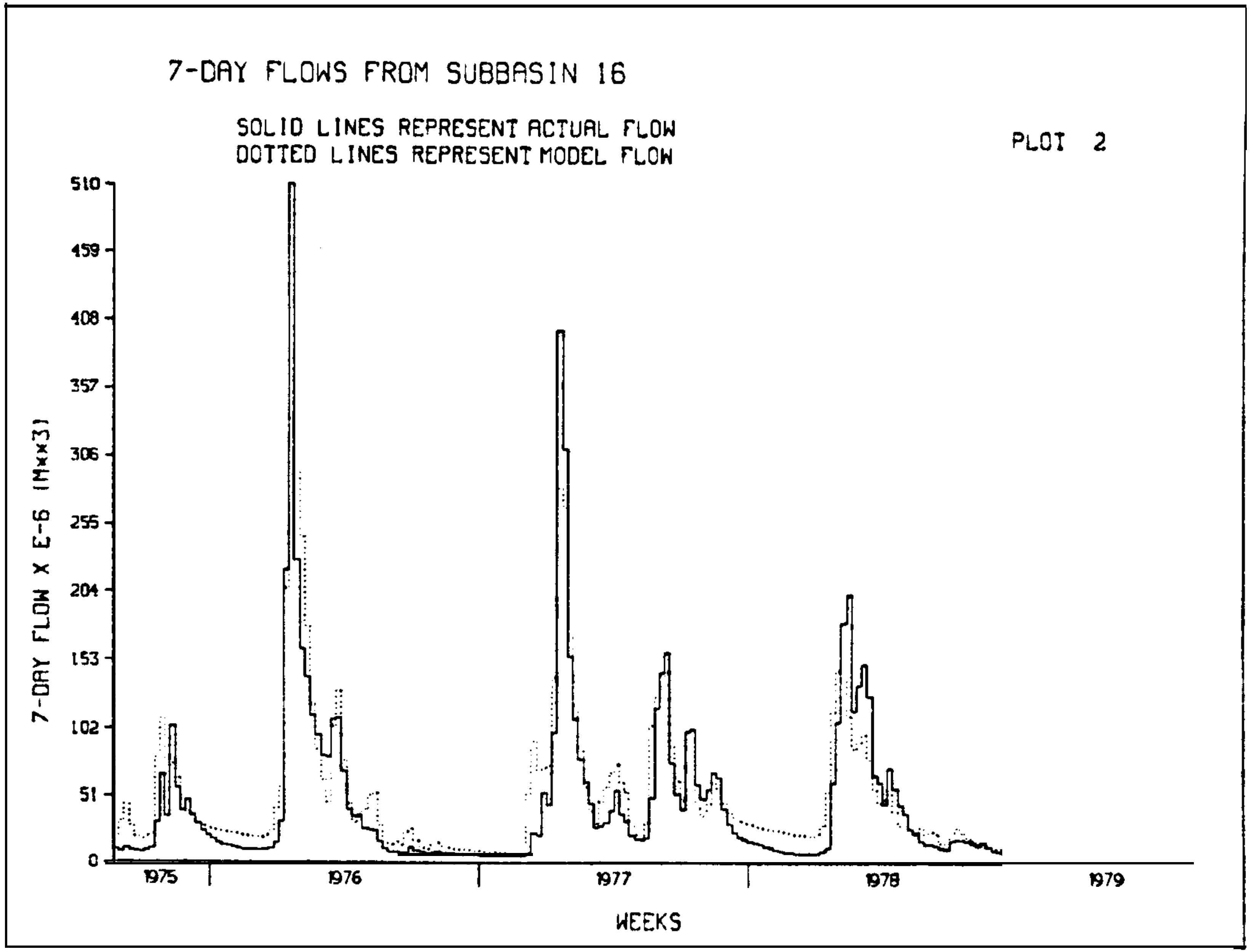
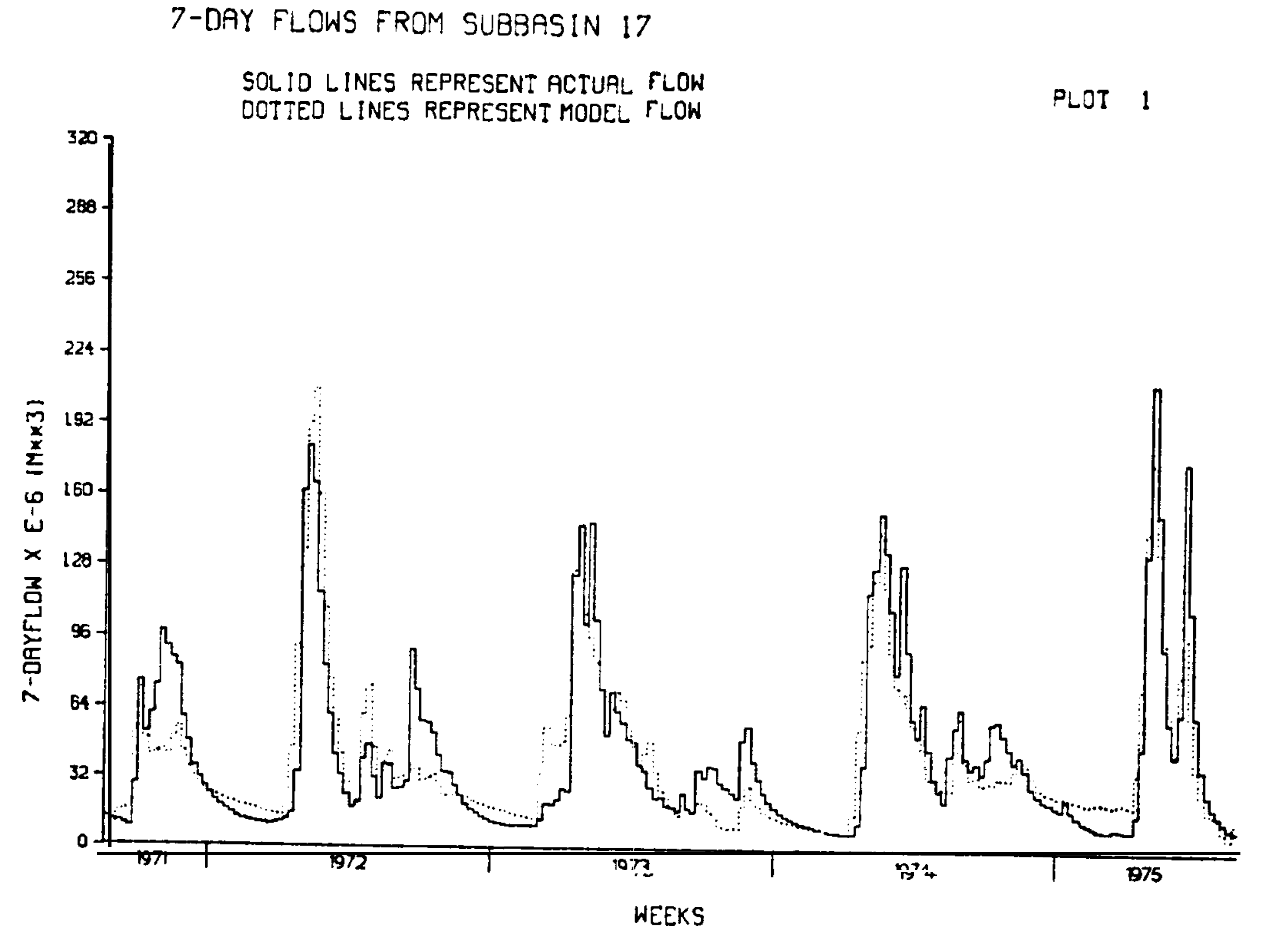


FIGURE 28.- *Hydrograph of 7-d outflow volumes for subbasin 16 (cont. .*



29.--*Hydrograph of 7-d* *for* *17.*

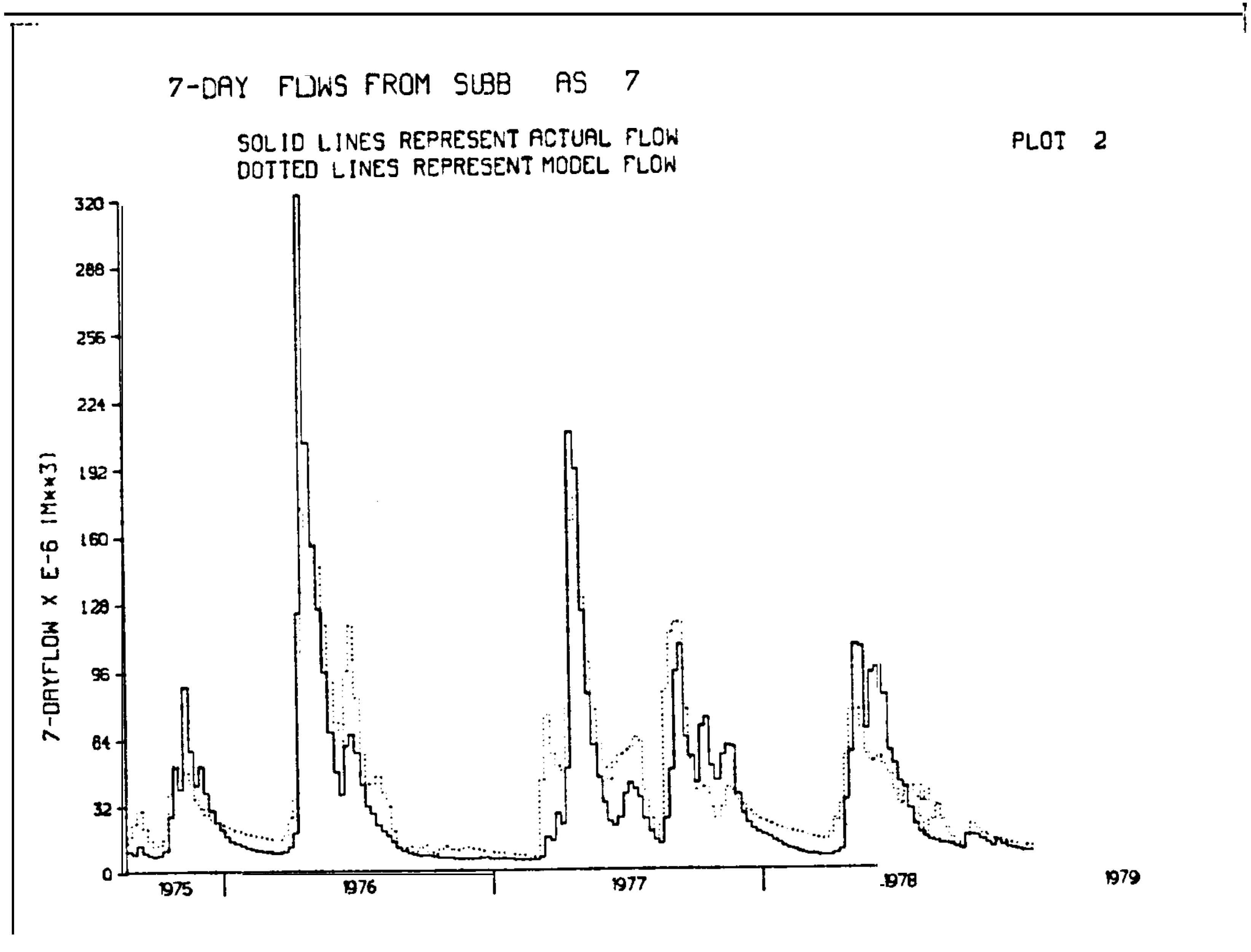


FIGURE 29. -*Hydrograph of 7-d outflow volumes for subbasin 17 (cont*

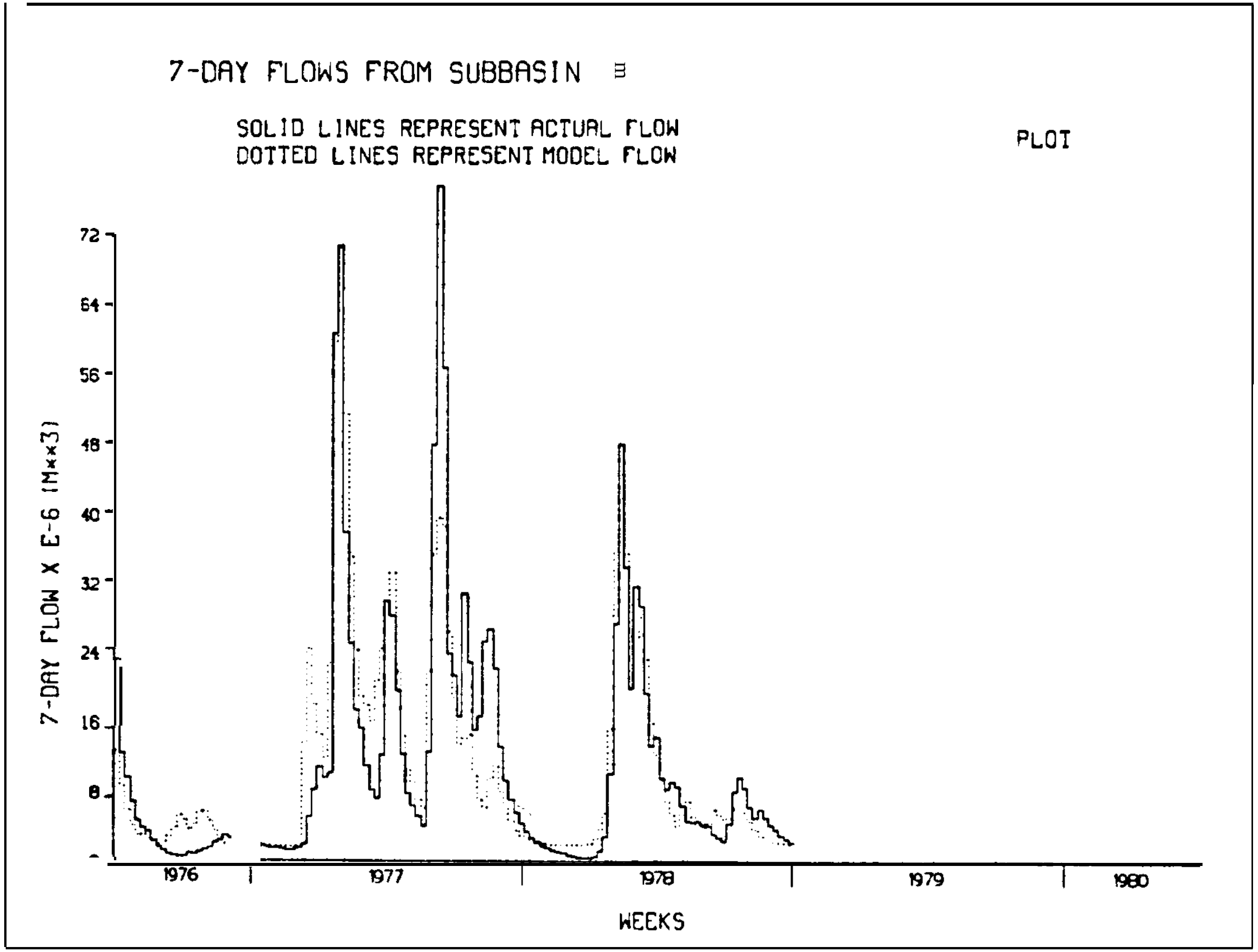


FIGURE 30.- *Hydrograph of 7-d outflow volumes for subbasin 18.*

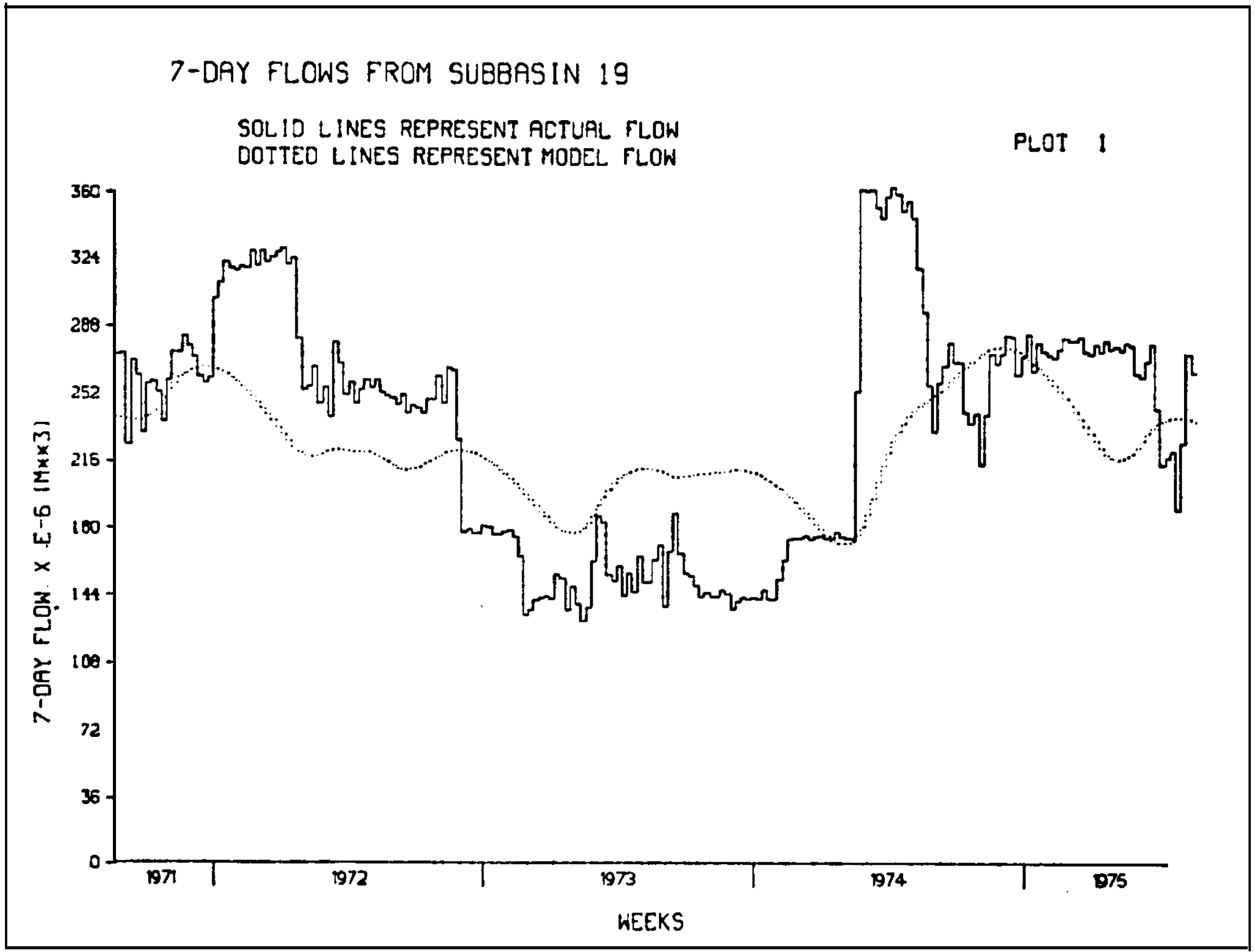


FIGURE *of 7-d outflow volumes for subbasin 19*

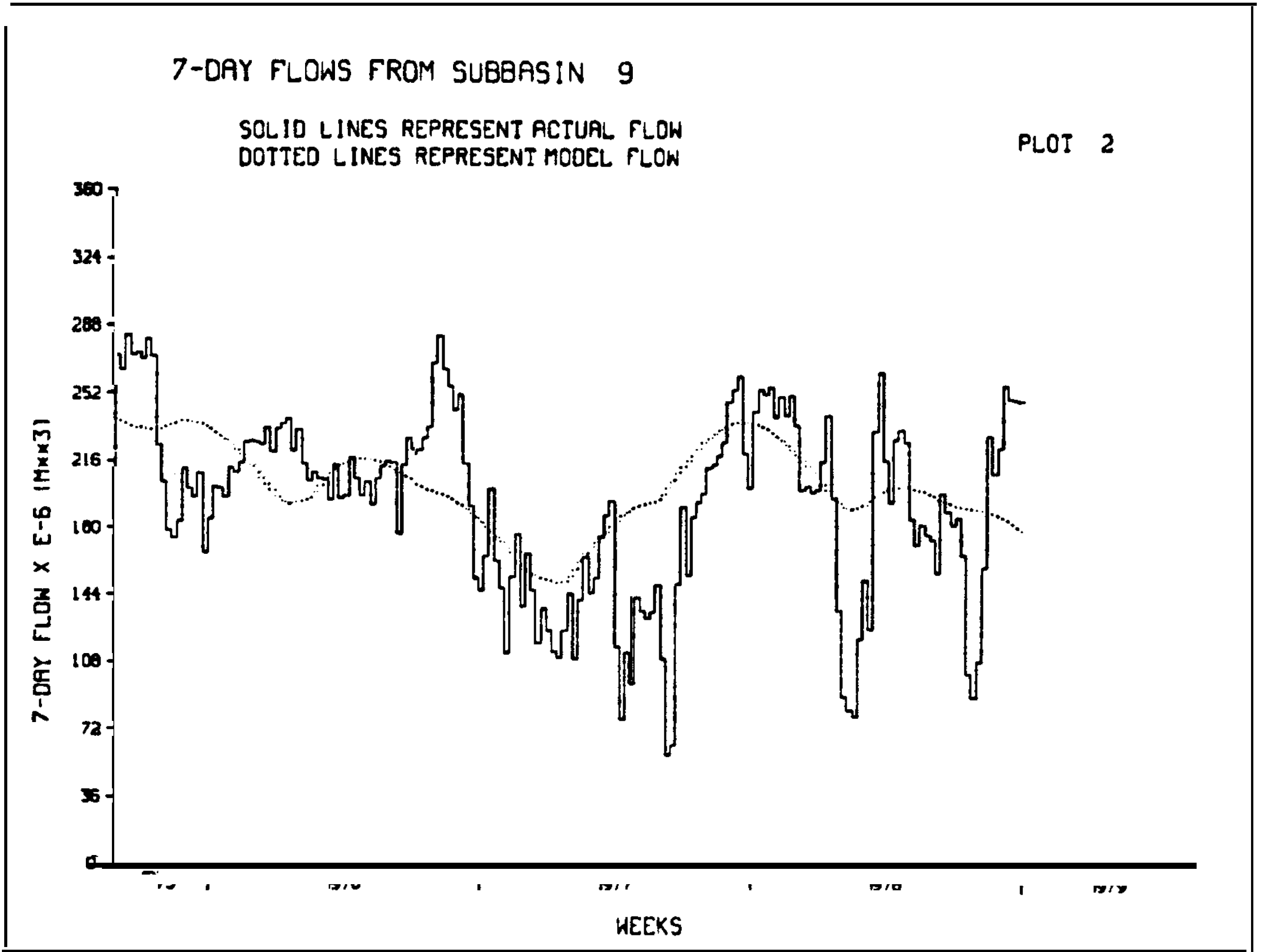


FIGURE 3 . *-Hydrograph of 7-d outflow volumes for subbasin 19 (cont.*

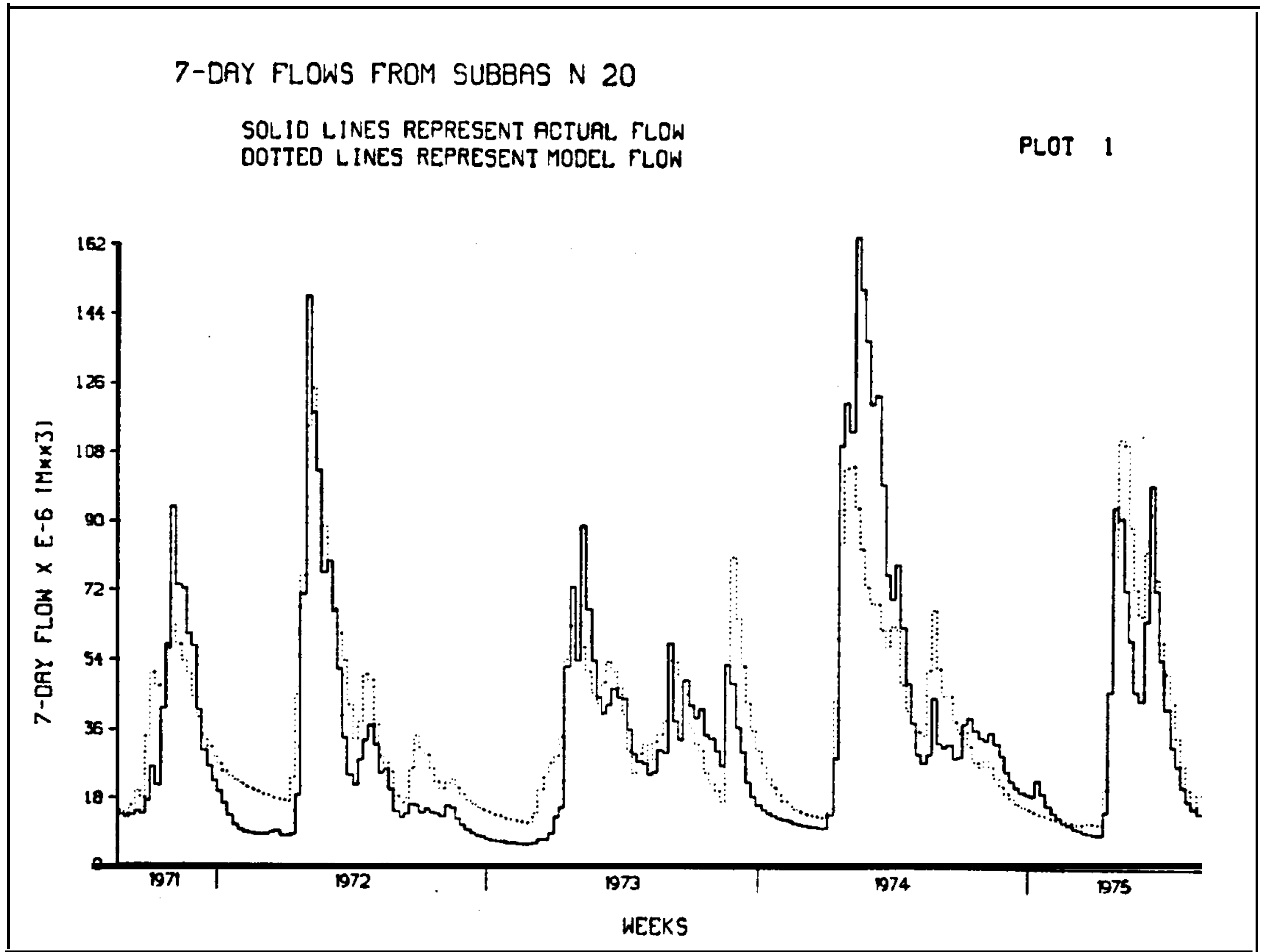


FIGURE 32.- *Hydrograph of 7-d outflow volumes for subbasin 20.*

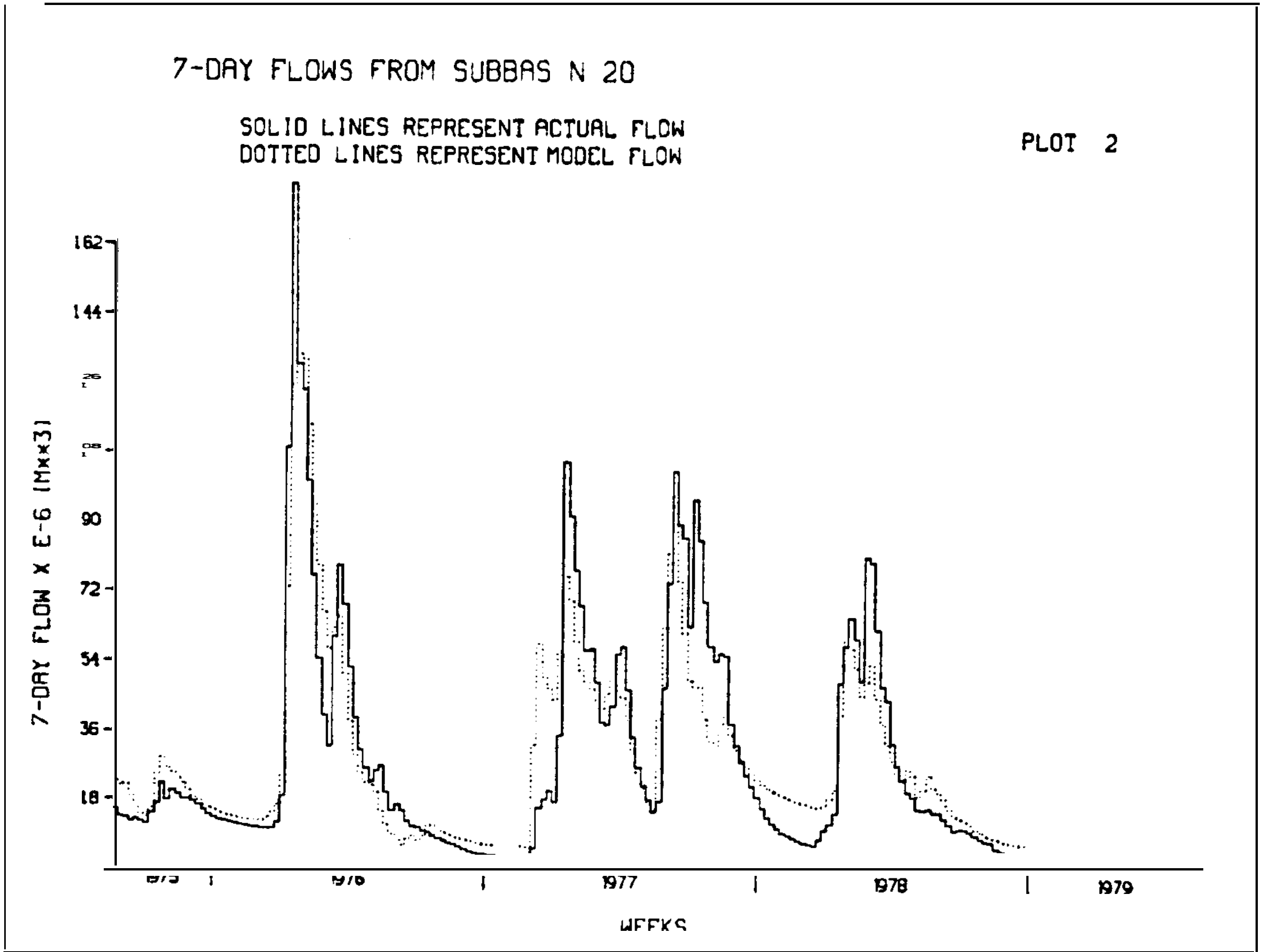


FIGURE 32.- *Hydrograph of 7-d outflow volumes for subbasin 20 cont.).*

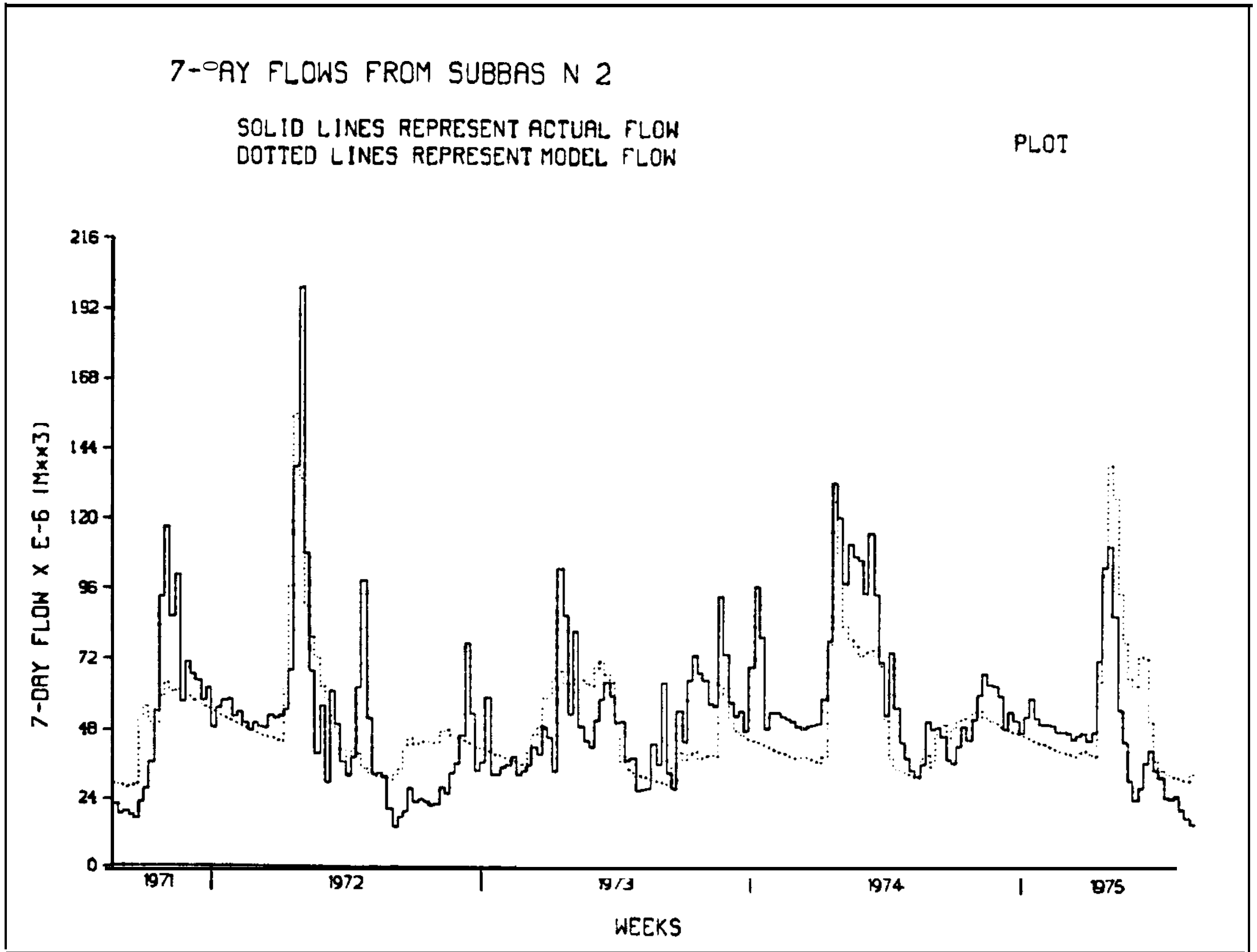


FIGURE 33.- *Hydrograph of 7-d outflow volumes for subbasin 21.*

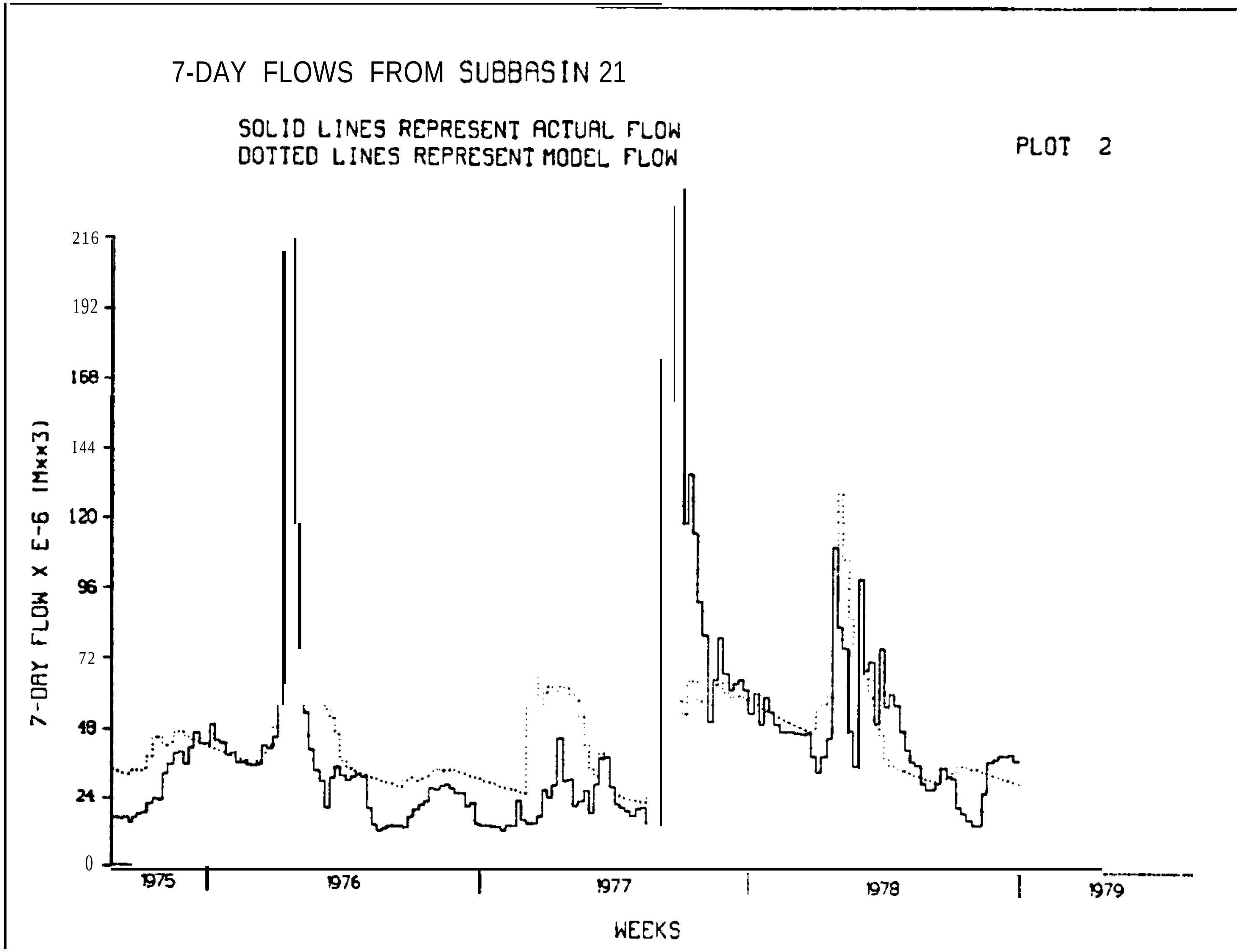


FIGURE 33.--*Hydrograph of 7-d outflow volumes for subbasin 21 (cont.).*

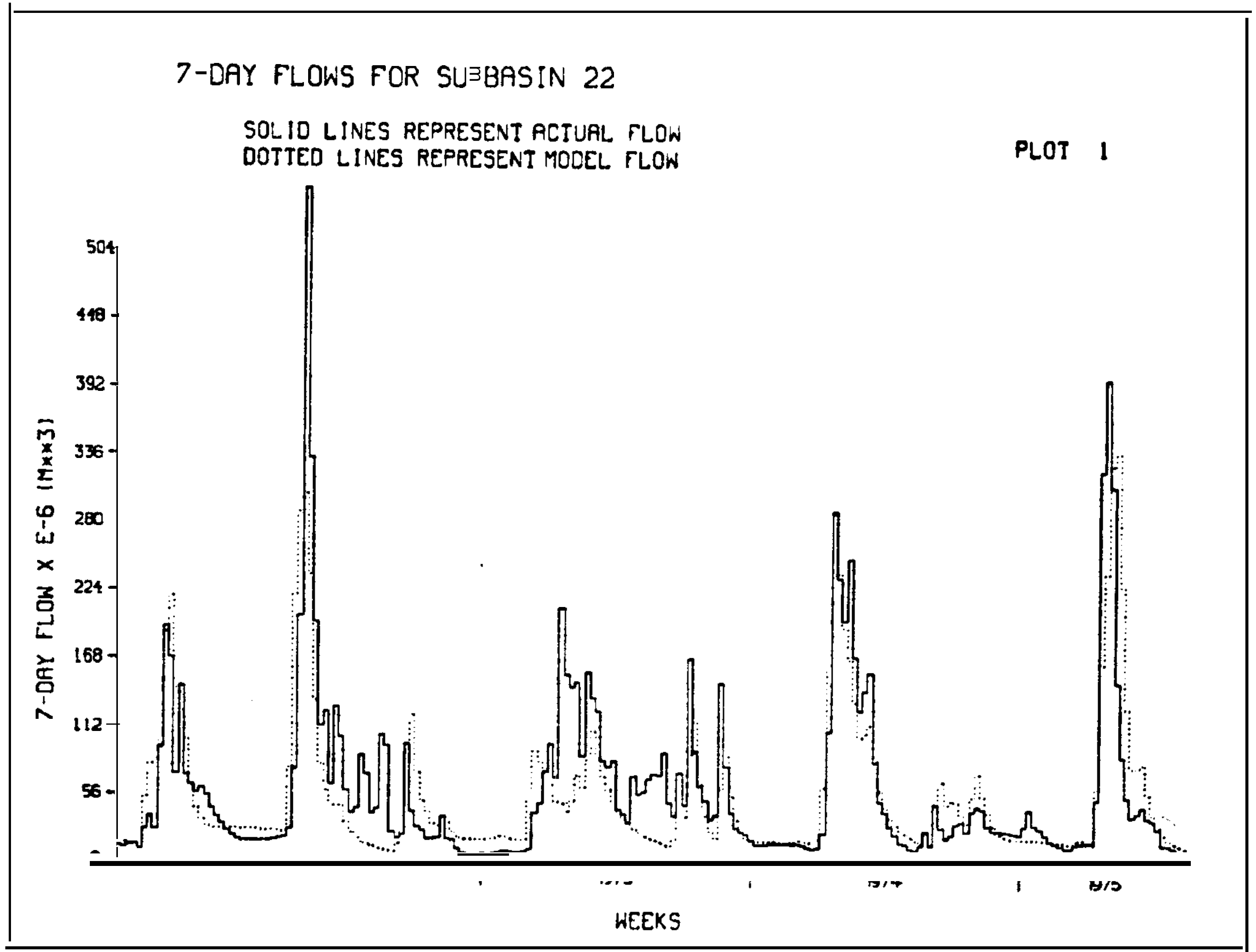


FIGURE 34.- *Hydrograph of 7-d outflow volumes for subbasin 22.*

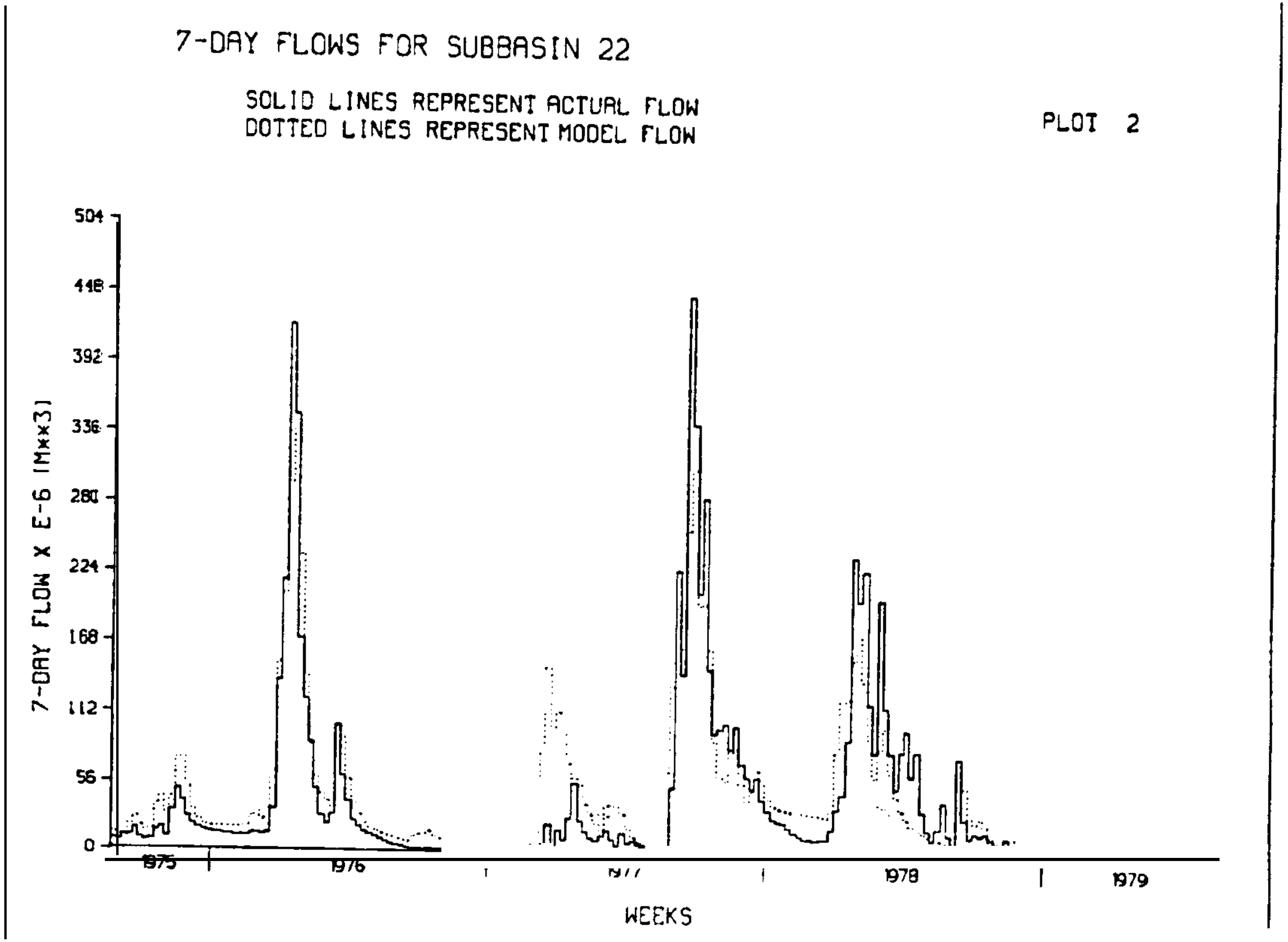


FIGURE .--*Hydrograph of 7-d outflow for subbasin).*

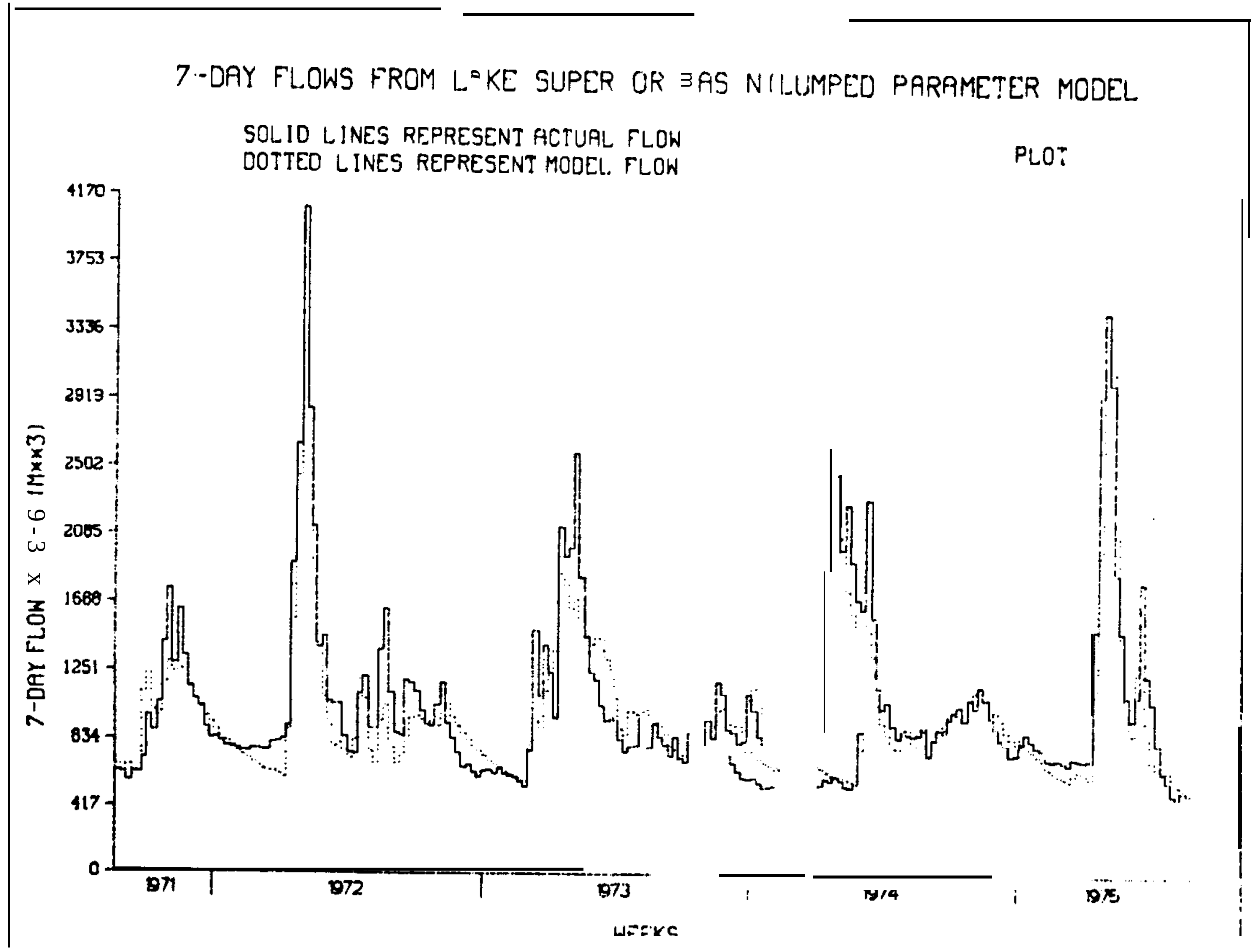


FIGURE 55.--Hydrograph of 7-d outflow volumes for lumped-parameter fit to entire Lake Superior Basin.

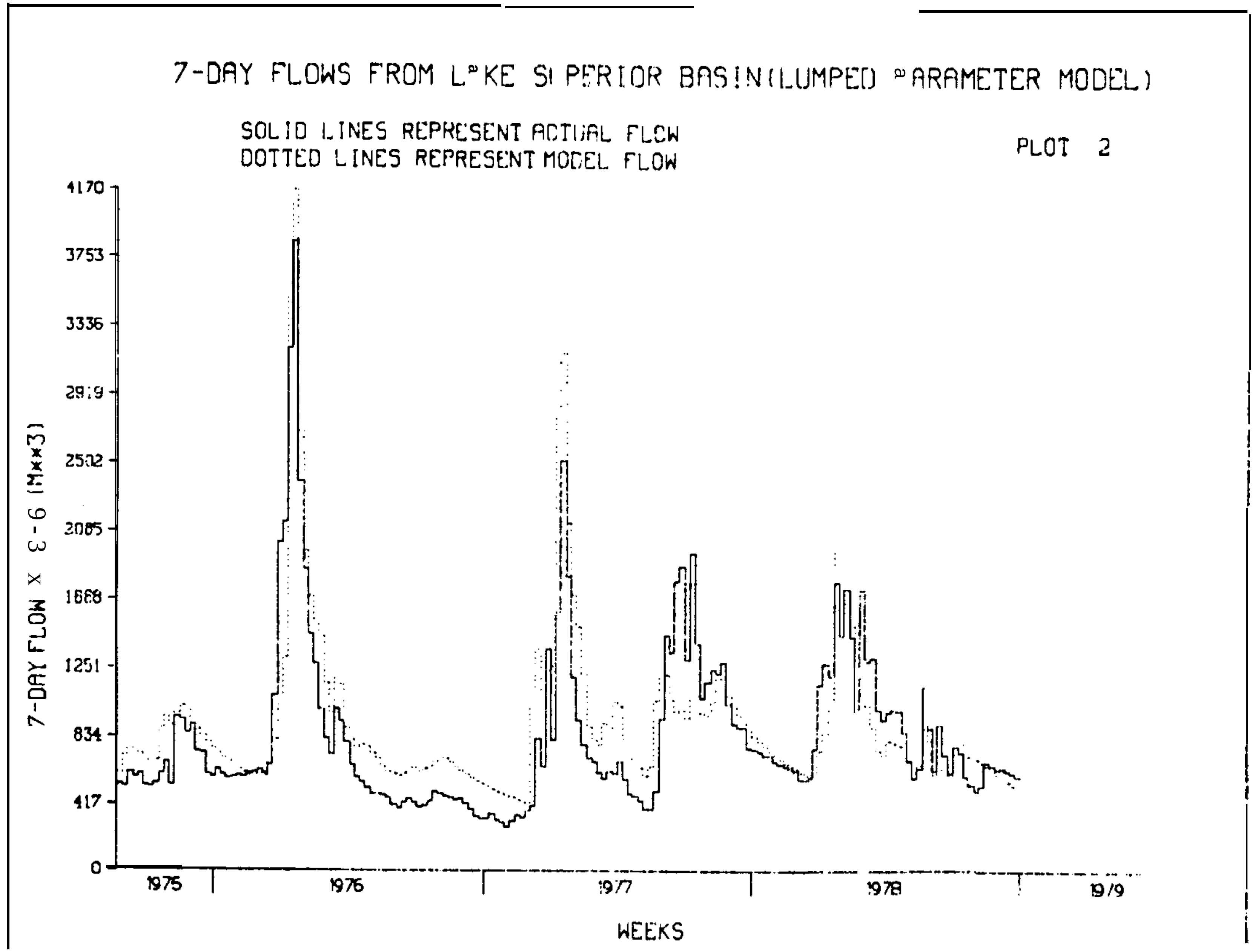


FIGURE 35.--*Hydrograph of 7-d outflow volumes for lumped-parameter fit to entire Lake Superior Basin (cont.).*

Appendix K.--ESP PROGRAMS (WATESP AND MLESP)

K.1 Instructions for ESP Programs

Appendices C and K-N illustrate the use of the Large Basin Runoff Model for generating net basin supply forecasts. This appendix contains instructions on program use and requirements; it also contains source code listings (ANSI Ver. X3.9-1966 FORTRAN) for two versions of the model. The first, WATESP, uses daily meteorological data and the second, MLESP, uses monthly meteorological data. They do not include interbasin diversions that do not pass through gaged tributary streams included in the hydrometeorological data set. Appendix C contains example input files of daily and monthly hydrometeorological data (the files called DATA and MDATA, respectively). Appendix L contains an example input file of monthly overlake evaporation data (the file called ZSEVAP). Appendix M contains an example input parameter file (the file called PARME) for use with WATESP. Appendix N contains an example output file (the file called STAT) resulting from the application of WATESP; it contains an application summary and ordered net basin supplies for each n-month period in the forecast.

K.1.1 Comments on Source Code

No changes to the source code are required for application. In WATESP, lines 00254-00268 describe dimension requirements for arrays defined in lines 00180-00200. In MLESP, lines 00300-00380 describe the requirements for arrays in lines 00190-00210. If evapotranspiration from the groundwater zone or evaporation from surface storage is considered to be important, lines 00490 and 00500, respectively, may be changed in program WATESP, while lines 00650 and 00660, respectively, may be changed in program MLESP. Subroutine OUTFLOW is identical to that in the calibration program (CALIB in appendix F), and is omitted here for brevity. Subroutine LENGTH in WATESP is identical to that in CALIB (appendix F). Subroutine LENGTH in MLESP is identical to that in MMCAL (appendix F).

K.1.2 Model using Daily Meteorological Data (WATESP)

The program WATESP uses daily meteorological data; it allows only a 1-d mass-balance computation interval, so that the simulated basin runoff results can be grouped into calendar months. Therefore, an optimum parameter set for the 1-d model is required. The need for 1-day applications is limited and the optimization can be expensive. The practical approach to obtaining a 1-day optimization is to optimize on a 7-day mass-balance and then use these optimized parameters to complete the 1-day optimization. The 1-day and 7-day optimized parameter sets are similar so that the total computation time is significantly reduced.

The program WATESP requires three input files, one containing calibrated parameter values and other application-specific information (the file called PARME), one containing daily meteorological data (the file called DATA), and one containing monthly overlake evaporation data (ZSEVAP).

K.1.2.1 Input Parameter File (PARME). An example parameter file to be used as input to the program WATESP is given in appendix M. The first line is a header designating the specific lake and basin application, and is skipped over by the program. The second and third lines are the watershed and lake areas, respectively, in square meters. Lines 4 and 5 indicate the beginning and ending dates (DDMMYYYY), respectively, of the period for which a forecast is desired. Lines 6 and 7 indicate the first and last dates (DDMMYYYY), respectively, of that portion of the meteorological data set to be used in the forecast generation. Lines 8 and 9 indicate the first and last dates (MMYYYY), respectively, of that portion of the overlake evaporation data set to be used in the forecast generation. Lines 10-18 provide the optimum parameter set, determined for the l-d model, in this order: T_b, a, α_{per}, β_{eu}, α_{int}, α_{dp}, β_{el}, α_{gw}, α_{sf}. Lines 19-23 represent the conditions on the first date of the forecast period for water stored in the snowpack, upper soil zone, lower soil zone, groundwater zone, and surface storage, respectively, in millimeters over the basin. The initial conditions are determined independently of the model or by using the model in a simulation mode up to the first date of the forecast period. For example, the initial condition for snowpack water storage was determined by the 1982-83 Airborne Gamma Snow Survey Study (Gauthier et al., 1983). Initial conditions for the remaining storages were derived by simulation with the l-d model from December 1, 1969, to March 15, 1983. (Data after December 31, 1978, are based on a reduced meteorological network.) On the last line the unit and proportionality constant for the heat available for evapotranspiration (determined from the long-term heat balance) derived by executing the model (WATERS) over the period for which the optimum parameter values were calibrated; see appendix E. (WATESP requires the constant from the l-d model, but it is similar to that in appendix E from the 7-d model.)

K.1.2.2 Input Meteorological Data File (DATA). DATA is a file identical to that described in appendices B and F, and is listed in appendix C. In this example, a data set covering January 1, 1949, to December 31, 1978, was used; for the period December 1, 1969, to December 31, 1978, it is identical to the data file presented in appendix C. Observed flows contained in DATA are not required for forecasting applications, but their presence will not affect the results.

K.1.2.3 Input Evaporation File (ZSEVAP). ZSEVAP is a file of monthly overlake evaporation or condensation for the lake under study. Values are given in tenths of millimeters and should cover at least the data set length being used in the calculations. ZSEVAP is given in appendix L.

K.1.2.4 Output Order Statistics File (STAT). Appendix N contains the output file (STAT) resulting from the application of WATESP described herein. A discussion of the output format is given on the first page of the output. To check the procedures described in this section by recreating the output file, STAT, it is possible to take WATESP, PARME, DATA, and ZSEVAP as described in this report and make an execution. The only change needed is to modify line 6 in PARME (the starting date of the applicable portion of the meteorological data set) from 01011949 to 01121969. Results will only be output for 1970-78. However, these results should have the same magnitudes of evaporation, runoff, precipitation, and net basin supply as the corresponding year indicated in the output of this example. The relative rankings should also be unchanged.

K.1.3 Model Using Monthly Meteorological Data (MLESP)

The ESP program, MLESP, is also presented in this appendix; it uses monthly meteorological data; the mass-balance interval automatically varies between 28 and 31 days, depending on the month and year. MLESP requires three input files, one containing calibrated parameter values and other application-specific information (the file called MPARME), one containing monthly meteorological data (the file called MDATA), and one containing monthly overlake evaporation data (the file called ZSEVAP). The ESP procedure using monthly meteorological data is not illustrated herein. MPARME is different from PARME in only one respect: the dates specified in lines 4-7 have the format MMYYYY. MDATA is identical to that described in appendices B and F and is listed in appendix C. Observed flows contained in MDATA are not required for forecasting applications, but their presence will not affect the results.

K.2 Source Code for ESP Program Using Daily Data (WATESP)

```
      PROGRAM WATESP(DATA,TAPE5=DATA,OUTPUT,TAPE6=OUTPUT,
+                    STAT,TAPE7=STAT,ZSEVAP,TAPE9=ZSEVAP,
+                    PARME,TAPE4=PARME)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
      DMENSION DATA(3,10957),IDATA(10957),ESPDATA(30,4,210)
      DIMENSION LEVAP(80,12),IORDER(6,30)
      DIMENSION IYEAR(30),INAME(8)
      DMENSION PARM(9),CINIT(5),IMON(12)
      DIMENSION IERR(6)
      DATA IERR/6*0/
      DATA IMON/31,28,31,30,31,30,31,31,30,31,30,31/
CC*****
CC***** PROGRAM FOR E. S. P. FORECAST OF DAILY RUNOFF VOLUMES
CC*****
CC*****
CC        NOTE -- ARRAYS SHOULD SE DIMENSIONED AS FOLLOWS:
CC                DATA(3,NUMBER OF DAYS IN DATA SET)
CC                IDATA(NUMBER OF DAYS IN DATA SET)
CC                ESPDATA(NUMBER OF YEARS IN DATA SET,4,
CC                        NUMBER OF DAYS IN FORECAST PERIOD)
CC                LEVAP(LAST YEAR OF NAPORATION DATA-1899,12)
CC                IORDER(NUMBER OF MONTHS IN FORECAST PERIOD,
CC                       NUMBER OF YEARS IN DATA SET,
CC                IYEAR(NUMBER OF YEARS IN DATA SET)
CC*****
CC  AREA    = WATERSHED AREA, SQ. M.
CC  FLOW    = ACTUAL BASIN OUTFLOW VOLUME, CUB. M.
CC  ID      = CALENDAR DAY OF THE YEAR
CC  IDATE = START DATE FOR ESP FORECAST (DDMM)
CC  IFDDS = FIRST DATE OF DATA SET (DDMMYYYY)
CC  IFDEV = FIRST DATE OF EVAPORATION DATA (MMYYYY)
CC  IFDFP = FIRST DATE OF FORECAST PERIOD (DDMMYYYY)
CC  ILDDS = LAST DATE OF DATA SET (DDMMYYYY)
CC  ILDN = LAST DATE OF EVAPORATION DATA (MMYYYY)
CC  ILDFP = LAST DATE OF FORECAST PERIOD (DDMMYYYY)
CC  ILNGTH = LENGTH OF DSP FORECAST, DAYS
CC  IM      = CALENDAR MONTH OF THE YEAR
CC  INDPGOD= NUMBER OF DAYS PER GROUP OF DAYS, DAYS
CC  INODAYS= NUMBER OF DAYS TO BE CONSIDERED IN DATA SET, DAYS
CC  IY      = CALENDAR YEAR
CC PRECIP = PERIOD PRECIPITATION VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  SNW     = SNOWPACK VOLUME (LIQUID EQUIVALENT), CUB. M.
CC  TA      = AVERAGE DAILY AIR TEMPERATURE, DEC. C.
```

```
CC  TMAX   = MAXIMUM DAILY AIR TEMPERATURE, DEG. C.
CC  TMIN   = MINIMUM DAILY AIR TEMPERATURE, DEG. C.
CC*****
CC*****
CC***** INPUT CONSTANTS
CC*****
CC        NOTE -- SYSTEM SPECIFIC PROCEDURE SUPPLIES ZERO
CC                WHEN EXPONENTIAL UNDERFLOW OCCURS
CC*****
        CALL SYSTEMC(115,IERR)
CC*****
        EPSILON=1.E-7
        DPSILON=1.E-200
        GPSILON=1.E-3
        ALPGEV=0 .
        ALPSEV=0.
        REWIND 4
        READ(4,1000)
        READ(4,559)AREA
        READ(4,559)LAREA
        READ(4,560)IFDFP
        READ(4,560)ILDFP
        CALL LENGTH(IFDFP,ILDFP,ILNGTH)
        READ(4,560)IFDDS
        READ(4,560)ILDDS
        READ(4,560)IFDEV
        READ(4,560)ILDEV
        DO 36 I-1,9
     36 READ(4,557)PARM(I)
        DO 37 I=1,5
     37 READ(4,558)CINIT(I)
        READ(4,559)CONS
        IDATE=IFDFP/10000
    557 FORMAT(E10.3E2)
    558 FORMAT(F10.2)
    559 FORMAT(E13.6E2)
    560 FORMAT(I8)
        IF(IFDFP.LT.1000000.OR.ILDFP.LT.1000000
+          .OR.IFDDS.LT.1000000.OR.ILDDS.LT.1000000
+          .OR.IFDEV.GT.999999.OR.ILDEV.GT.999999) CALL MDERR(1)
CC*****
CC***** SNWINIT = VALUE OF SW ON IDATE
CC*****
        SNWINIT= CINIT(1)*AREA/1000.
        USZINIT= CINIT(2)*AREA/1000.
        LSZINIT= CINIT(3)*AREA/1000.
        GZMINIT= CINIT(4)*AREA/1000.
        SSINIT = CINIT(5)*AREA/1000.
        INDPGOD= 1
        DAY=FLOAT(INDPGOD)
CC*****
CC***** INPUT MONTHLY LAKE EVAPORATION
CC*****
        REWIND 9
```

```
      IFMFP=IFDFP/10000-(IFDFP/1000000)*100
      IF(IFDFP/1000000.GT.1)IFMFP=IFMFP+1
      IF(IFMFP.EQ.13)IFMFP=1
      IFMEV=IFDEV/10000
      IFYEV=IFDEV-(IFDEV/10000)*10000
      IF(IFMFP.LT.IFMEV)IFYEV=IFYEV+1
      ILMFP=ILDFP/10000-(ILDFP/1000000)*100
      IF(ILDFP/1000000.LT.IMON(ILMFP))ILMFP=ILMFP-1
      IF(ILMFP.EQ.0)ILMFP=12
      ILMEV=ILDEV/10000
      ILYEV=ILDEV-(ILDEV/10000)*10000
      IF(ILMFP.GT.ILMEV)ILYEV=ILYEV-1
  555 READ(9,1120) IEVAPYR
 1120 FORMAT(9X,I4)
      IF(IEVAPYR.LT.IFYEV)GOTO 555
      BACKSPACE 9
      DO 500 I=IFYEV,ILYEV
      IZZ=I-1899
  500 READ(9,1030) (LEVAP(IZZ,IJ),IJ=1,12)
 1030 FORMAT(20X,12F5.0)
      REWIND 9
      DO 501 I=IFYEV,ILYEV
      IZZ=I-1899
      DO 501 IJ=1,12
  501 LEVAP(IZZ,IJ)=LEVAP(IZZ,IJ)/10000.
      USZC=AREA*0.02
      TBASE = PARM(1)
      ALBEDS = PARM(2)
      ALPPER = PARM(3)
      ALPUEV = PARM(4)
      ALPINT = PARM(5)
      ALPDPR = PARM(6)
      ALPLEV = PARM(7)
      ALPGW  = PARM(8)
      ALPSF  = PARM(9)
      CALL LENGTH(01010001,IFDDS,IZZ)
      CALL LENGTH(01010001,(IFDFP/10000)*10000+IFYEV,IJ)
      IF(IZZ.LT.IJ)IFDDS=(IFDFP/10000)*10000+IFYEV
      CALL LENGTH(01010001,ILDDS,IZZ)
      CALL LENGTH(01010001,(ILDFP/10000)*10000+ILYEV,IJ)
      IF(IZZ.GT.IJ)ILDDS=(ILDFP/10000)*10000+ILYEV
      INVFDDS=(IFDDS/10000-(IFDDS/1000000)*100)*100+IFDDS/1000000
      INVLDDS=(ILDDS/10000-(ILDDS/1000000)*100)*100+ILDDS/1000000
      IFYDS=IFDDS-(IFDDS/10000)*10000
      ILYDS=ILDDS-(ILDDS/10000)*10000
      IF(IFMFP*100+IFDFP/1000000.LT.INVFDDS)IFYDS=IFYDS+1
      IF(ILMFP*100+ILDFP/1000000.GT.INVLDDS)ILYDS=ILYDS-1
      IFDDS=(IFDFP/10000)*10000+IFYDS
      ILDDS=(ILDFP/10000)*10000+ILYDS
      CALL LENGTH(01010001,IFDDS,IZZ)
      CALL LENGTH(01010001,ILDDS,IJ)
      IF(IJ-IZZ+1.LT.ILNGTH)CALL MDERR(2)
      CALL LENGTH(IFDDS,ILDDS,INODAYS)
      REWIND 5
```

```
      READ(5,1000) INAME
      READ(5,1000)
      READ(5,1000)
      READ(5,1000)
 1000 15 FORMAT(8A10)
      READ(5,1010) ID,IM,IY
      IF(ID*1000000+IM*10000+IY.NE.IFDDS)GOTO 15
      BACKSPACE 5
      READ(5,1010) ID, IM, IY, TMIN, TMAX, PRECIP
      BACKSPACE 5
CC*****
CC***** DAILY LOOP -DATA PREPARATION (BEGINNING)
CC*****
      DO 300 I=1,INODAYS
CC*****
CC*****        INPUT AND FILL IN DAILY DATA
CC*****
      READ(5,1010) ID, IM, IY, NTMIN, NTMAX, NPRECIP
 1010 FORMAT(1X,I3,I3,I5,5X,2F10.2,2F20.0)
      IF(NTMIN.GT.NTMAX.OR.NTMIN.LT.-900..OR.NTMAX.LT.-900.) GOTO 920
      GOTO 921
  920 NTMIN=TMIN
      NTMAX=TMAX
  921 TMIN=NTMIN
      TMAX=NTMAX
      IF(NPRECIP.LT.-900.) NPRECIP=PRECIP
      PRECIP=NPRECIP
      DATA(1,I)=PRECIP
      DATA(2,I)=TMAX
      DATA(3,I)=TMIN
  300 IDATA(I)=ID*1000000+IM*10000+IY
      I=1
      IESP=0
  400 ID=IDATA(I)/10000
      IF(ID.EQ.IDATE)GOTO 401
  402 I=I+1
      IF(I.GT.INODAYS)GOTO 403
      GOTO 400
CC*****
CC*****        CONVERT TO GROUPS OF DAYS INPUTS
CC*****
  401 SNW=SNWINIT
      NS=0.
      HPLSE=0.
      P=0.
      II=0
      III=0
      DO 404 IZ=1.ILNGTH
      IZZ=I-1+IZ
      IF(IZZ.GT.INODAYS)GOTO 404
      PRECIP=DATA(1,IZZ)
      TMAX=DATA(2,IZZ)
      TMIN=DATA(3,IZZ)
CC*****
```

```
CC*****             "EAT  BALANCE
CC*****
           TA=(TMIN+TMAX)/2.
           MELT=0.
           IF(TA.LE.0.)GOTO 903
           IF(SNW.LT.1.)GOTO 904
           IF(TMIN.LT.0.)GOTO 950
           DD-TA
           GOTO 951
       950 DD=TMAX**2/(TMAX-TMIN)/2.
       951 MELT=ALBEDS*DD
           IF(MELT.GT.SNW) MELT-SW
       904 SNW=SNW-MELT
           NS=NS+PRECIP+MELT
           GOT0 905
       903 SNW=SNW+PRECIP
           NS=NS+0.
       905 HPLSE=HPLSE+EXP(TA/TBASE)/(596.-.52*TA)/1000000.*CONS
           P=P+PRECIP
           II=II+1
           IF(II.NE.INDPGOD)GOTO 404
           III=III+1
           ESPDATA(IESP+1,1,III)=NS
           ESPDATA(IESP+1,2,III)=HPLSE
           ESPDATA(IESP+1,3,III)=P
           NS=0.
           HPLSE=0.
           P-0.
           II=0
       404 CONTINUE
           IF(III.EQ.ILNGTH/INDPGOD) IESP=IESP+1
           GOT0 402
       403 III=ILNGTH/INDPGOD
CC*****
CC***** DAILY LOOP -DATA PREPARATION (END)
CC*****
CC*****
CC***** SIMULATE (IESP RUNS)
CC*****
           DO 100 IZ=1,IESP
CC*****
CC*****          INPUT INITIAL VARIABLE VALUES
CC*****
           USZM=USZINIT
           LSZM=LSZINIT
           GZM=GZMINIT
           SS-SSINIT
CC*****
CC*****          INDPGOD-DAY LOOP (BEGINNING)
CC*****
           DO 100 I=1,III
CC*****
CC*****              INPUT PREPARED DATA
CC*****
```

```
      NS     = ESPDATA(IZ,1,I)
      HPLSE  = ESPDATA(IZ,2,I)
CC*****
CC*****            "ASS BALANCE
CC*****
      CALL OUTFLOW(NS)
CC*****
      ESPDATA(IZ,2,I)=NS
  100 CONTINUE
CC*****
CC*****       INDPGOD-DAY LOOP (END)
CC*****
CC*****
CC*****
CC***** END OF SIMULATIONS
CC*****
CC*****
CC***** ACCUMULATE OVER MONTHS (ASSUMES INDPGOD = 1)
CC*****
      I-1
      DO 960 IZ=1,IESP
      IK=0
      IIIJ=-1
  961 ID=IDATA(I)/10000
      IF(ID.EQ.IDATE)GOTO 962
      I=I+1
      GOTO 961
  962 IS=I
      IJ=IS-1
  963 IJ=IJ+1
      IIIJ=IIIJ+1
      IF(IIIJ.GT.III)GOTO 960
      ID=IDATA(IJ)/10000
      IF(IDATA(IJ).EQ.ILDDS) GOTO 967
      IF(ID/100.NE.1)GOTO 963
      IJ=IJ-1
  968 IF(IK.EQ.0)GOTO 964
      SUM2=0.
      SUM3=0.
      DO 965 II=IS,IJ
      SUM2=SUM2+ESPDATA(IZ,2,II-I+1)
  965 SUM3=SUM3+ESPDATA(IZ,3,II-I+1)
      ESPDATA(IZ,2,IK)=SUM2/LAREA*1000.
      ESPDATA(IZ,3,IK)=SUM3/AREA*1000.
      IZZ=IDATA(IS)
      IY=IZZ-(IZZ/10000)*10000
      IZZ=IZZ/10000
      IM=IZZ-(IZZ/100)*100
      ESPDATA(IZ,1,IK)=LEVAP(IY-1899,IM)*1000.
      ESPDATA(IZ,4,IK)=(IY-(IY/100)*100)+0.5
  964 IS=IJ+1
      IJ=IS
      IK=IK+1
      GOT0 963
```

```
  960 I=I+1
      III-IK-I
      GOTO 969
  967 IMON(2)=28
      IF(INT((FLOAT(IDATA(IJ))+.5)/4.)*4.EQ.IDATA(IJ))IMON(2)=29
      IF(ID/100.EQ.IMON(ID-(ID/100)*100))GOTO 968
      GOTO 960
CC*****
CC***** END OF ACCUMULATIONS OVER MONTHS (UNITS ARE MM OVER LAKE)
CC*****
CC*****
CC***** STATISTICAL SUMMARY (QUANTILE ESTIMATION FOR EACH PERIOD)
CC*****
CC*****
CC*****        ACCUMULATE OVER FORECAST HORIZON
CC*****
  969 DO 762 IZ=1,IESP
      SUM=0.
      IYEAR(IZ)=ESPDATA(IZ,4,1)
      DO 762 I=1,III
      SUM=SUM+ESPDATA(IZ,2,I)+ESPDATA(IZ,3,I)-ESPDATA(IZ,1,I)
  762 ESPDATA(IZ,4,I)=SUM
CC*****
CC*****        ORDER STATISTICS FOR EACR PERIOD OF FORECAST HORIZON
CC*****
      DO 750 I=1,III
      DO 753 IJ=1,IESP
  753 IORDER(I,IJ)=IJ
CC*****
CC*****               BUBBLE SORT FOR ONE PERIOD
CC*****
      IF(IESP.EQ.1) GOTO 750
      IESPM1=IESP-1
      DO 751 IJ=1,IESPM1
      TMIN=ESPDATA(IJ,4,I)
      IMIN=IJ
      IJPl=IJ+1
      DO 752 IK=IJPl,IESP
      IF(ESPDATA(IK,4,I).GE.TMIN)GOTO 752
      TMIN=ESPDATA(IK,4,I)
      IMIN=IK
  752 CONTINUE
      ESPDATA(IMIN,4,I)=ESPDATA(IJ,4,I)
      ESPDATA(IJ,4,I)=TMIN
      IK=IORDER(I,IMIN)
      IORDER(I,IMIN)=IORDER(I,IJ)
  751 IORDER(I,IJ)=IK
  750 CONTINUE
CC*****
CC*****               RESTORE N.B.S. ARRAY (NON-CUMULATIVE)
CC*****
      DO 763 IZ=1,IESP
      DO 763 I=1,III
  763 ESPDATA(IZ,4,I)=ESPDATA(IZ,2,I)+ESPDATA(IZ,3,I)-ESPDATA(IZ,1,I)
```

```
CC*****
CC*****      SUMMARY OUTPUT
CC*****
      REWIND 7
      WRITE(7.1060) INAME
 1060 FORMAT(1H1,37HEXTENDED STREAMFLOW PREDICTION FOR    ,8A10)
      WRITE(7,1070) TBASE,ALBEDS,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV,
                  ALPGW,ALPGEV,ALPSF,ALPSEV,CONS,USZC,AREA,LAREA
 1070 FORMAT(/,1X,18HPARAMETER SUMMARY:,/,
            6X,17HTBASE (C)        = ,E13.6E2,/,
            6X,17HALBEDS (M3/DD)   = ,E13.6E2,/,
            6X,17HALPPER (D-l)     = ,E13.6E2,/,
            6X,17HALPUEV (M-3)     = ,E13.6E2,/,
            6X,17HALPINT (D-l)     = ,E13.6E2,/,
            6X,17HALPDPR (D-l)     = ,E13.6E2,/,
            6X,17HALPLEV (M-3)     = ,E13.6E2,/,
            6X,17HALPGW (D-l)      = ,E13.6E2,/,
            6X,17HALPGEV M-3)      = ,E13.6E2,/,
            6X,17HALPSF (d-l,      = ,E13.6E2,/,
            6X,17HALPSEV (M-3)     = ,E13.6E2,/,
            6X,17HCONS (CAL)       = ,E13.6E2,/,
            6X,17HUSZC (M3)        = ,E13.6E2,/,
            6X,17HAREA ("2)        = ,E13.6E2,/,
            6X,17HLAKE AREA [HZ)   = ,E13.6E2,/,/)
      ID=IDATE/100
      IM=IDATE-ID*100
      ISTART=IM
      IF(ID.NE.1)ISTART=IM+1
      IF(ISTART.EQ.13)ISTART=1
      ILNGTH=ILNGTH/INDPGOD
      IF(ISTART.EQ.1)IMO=7HJANUARY
      IF(ISTART.EQ.2)IMO=8HFEBRUARY
      IF(ISTART.EQ.3)IMO=5HMARCH
      IF(ISTART.EQ.4)IMO=5HAPRIL
      IF(ISTART.EQ.5)IMO=3HMAY
      IF(ISTART.EQ.6)IMO=4HJUNE
      IF(ISTART.EQ.7)IMO=4HJULY
      IF(ISTART.EQ.8)IMO=6HAUGUST
      IF(ISTART.EQ.9)IMO=9HSEPTEMBER
      IF(ISTART.EQ.10)IMO=7HOCTOBER
      IF(ISTART.EQ.11)IMO=8HNOVEMBER
      IF(ISTART.EQ.12)IMO=8HDECEMBER
      WRITE(7,1080) ID,IM,INDPGOD ILNGTH,IMO
 1080 FORMAT(1X,20HSTARTING DATE:  DAY ,I2,10H OP MONTH ,I2,/,
             1X,21HSIMULATION LENGTH IN ,I2,15H-DAY PERIODS = ,I5,/,
             1X,35HFIRST MONTH OF OUTPUT STATISTICS = ,A10,//)
      WRITE(7,1090) INODAYS,INDPGOD
 1090 FORMAT(1X,22HDATA SET LENGTH (D) = ,I10,/,
             1X,40HMASS BALANCE COMPUTATION INTERVAL (D) = ,I2,//)
      SNWINIT=SNWINIT/AREA*1000.
      USZINIT=USZINIT/AREA*1000.
      LSZINIT=LSZINIT/AREA*1000.
      GZMINIT=GZMINIT/AREA*1000.
      SSINIT = SSINIT/AREA*1000.
```

```
      WRITE(7,1100) SNWINIT,USZINIT,LSZINIT,GZMINIT,SSINIT
 1100 FORMAT(1X,32HINITIAL VALUES ON STARTING DATE:,/,
+            6X,12HSNW (MM) = ,F6.1,/,
+            6X,12HUSZM (MM) = ,F6.1,/,
+            6X,12HLSZM (MM) = ,F6.1,/,
+            6X,12HGZM (MM) = ,F6.1,/,
+            6X,12HSS (MM)   = ,F6.1,//)
      WRITE(7.1110)
 1110  FOR&(;,
+/,1X,65HMONTHLY LAKE EVAPORATION IS TAKEN FROM PREVIOUS LAKE EVAPORATION ,
+     65HSTUDIES BY QUINN AND REPRESENTS AERODYNAMIC EQUATION APPLICATIONS,
+/,1X,65HTO MONTHLY DATA.
+/,1X,65H
+/,1X,65HDAILY PRECIPITATION AND MAXIMUM AND MINIMUM TEMPERATURES CAME FRO,
+     65HM 54 METEOROLOGICAL STATIONS ABOUT THE LAKE SUPERIOR BASIN, AFTER,
+/,1X,65HCROLEY.  THE DATA SET IS AVAILABLE ON THE GLERL COMPUTER.
+/,1X,65H
+/,1X,65HTHE FOLLOWING OUTPUT STATISTICS ARE PRESENTED FOR SUCCESSIVELY LO,
-b    65HNGER FORECAST PERIODS.  THE FIRST PAGE IS FOR THE FIRST MONTH OF ,
+/,1X,65HTHE FORECAST PERIOD.  THE SECOND PAGE IS FOR THE FIRST TWO MONTHS,
+     65H OF THE FORECAST PERIOD.  THE THIRD PAGE IS FOR THE FIRST THREE ,
+/,1X,65HMONTHS OF THE FORECAST PERIOD, ETC. THE HISTORICAL METEOROLOGICA,
-k    65HL DATA IS USED TO COMPUTE RUNOFF FOR EACH YEAR (PORTION OF WHICH ,
+/,1X,65HMATCHES THE FORECAST PERIOD); THE RUNOFF AND PRECIPITATION ARE SU,
+     65HMMED OVER EACH MONTH AND COMBINED WITH MONTHLY EVAPORATION TO    )
      WRITE(7,1111)
 1111 FORMAT(
+ 1X,65HCOMPUTE NET BASIN SUPPLY.  THE NET BASIN-SUPPLY IS ACCUMULATED OV,
+     65HER THE FIRST N MONTHS, FOR PAGE N, AND THE YEARS OF RECORD ARE   ,
+/,1X,65HSORTED BASED ON THE ACCUMULATED NET BASIN SUPPLY FOR THE N-MONTH ,
+     65HPERIOD FROM SMALLEST TO LARGEST. THE ORDER STATISTICS ARE THUS ,
+/,1X,65HOBTAINED BASED UPON THE N-MONTH ACCUMULATED NET BASIN SUPPLY FOR ,
+     65HTHE FIRST N MONTHS.  THE ACCUMULATED NET BASIN SUPPLY IS NOT   ,
+/,1X,65HPRINTED OUT, BUT THE LAKE EVAPORATION, RUNOFF, PRECIPITATION, AND,
+     6% NET BASIN SUPPLY FOR EACH MONTH ARE PRINTED IN UNITS OF MILLI- ,
+/,1X,65HMETERS OVER THE LAKE SURFACE.  QUANTILE PROBABILITIES ARE GIVEN B,
+     65HY THE ORDER NUMBER (NO) DIVIDED BY THE NUMBER OF YEARS USED IN   ,
+/,1X,65HTHE PROCEDURE (LARGEST NO).  THESE PROBABILITIES REPRESENT THE NO,
+     65HN-EXCEEDANCE PROBABILITIES AND THEIR COMPLEMENTS REPRESENT THE
+/,1X,65HEXCEEDANCE PROBABILITIES.                                         i
      DO 754 I-1.111
      WRITE(7.1020) I
 1020 FORMAT(1H1,5HFIRST,I2,17H (WHOLE)MONTH(S),//,6X,
+            6(1X,20H(EVAP.) (RUN-  (PRE-),/.1X.5HNO YR.
+            6(2X,19H(NBS) OFF)    CIP.)))
      DO 754 IZ=1,IESP
      IJ=IORDER(I,IZ)
      WRITE(7,1050) IZ,IYEAR(IJ),((ESPDATA(IJ,IK,IL),IK=1,3),IL=1,I)
 1050 FORMAT(1X,I2,I3,18F7.1)
  754 WRITE(7,1040) (ESPDATA(IJ,4,IL),IL=1,I)
 1040 FORMAT(6X,F7.1,5F21.1)
      REWIND 7
      STOP
      END
```

```
      SWROUTINE OUTFLOW (NS)

       (SEE LISTING FOR CALIB)

      SWROUTINE LENGTH(IFDP,ILDP,INODAYS)

       (SEE LISTING FOR CALIB)

      SUBROUTINE MDERR(I)
CC*****
CC***** THIS ROUTINE PRINTS A (FATAL) ERROR MESSAGE AND STOPS THE JOB
CC*****
      IF(I.LT.1.OR.I.GT.2)GOTO 3
      GOTO (1,2),I
    1 WRITE(6,1001)
 1001 FORMAT(1X,
     +65HFORECAST PERIOD AND MET DATA DATES ""ST BE EIGHT DIGITS: DDMMYYYY,
     +/,1X,49HEVAPORATION DATA DATES MUST BE SIX DIGITS: MMYYYY)
      GOTO 100
    2 WRITE(6,1002)
 1002 FORMAT(1X,
     +58HTHE COMMON DATA PERIOD IS INSUFFICIENT FOR ANY SIMULATIONS)
      GOTO 100
    3 WRITE(6,1003)
 1003 FORMAT(1X,17HUNSPECIFIED ERROR)
      GOTO 100
  100 REWIND 5
      REWIND 7
      REWIND 9
      REWIND 4
      WRITE(6,1000)
 1000 FORMAT(1X,
     +38HFATAL USER ERROR: PROGRAM RUN ABORTED!)
      STOP
      END
```

K.3 Source Code for ESP Program Using Monthly Data (MLESP)

```
      PROGRAM MLESP (MDATA,TAPE5=MDATA,OUTPUT,TAPE6=OUTPUT,
+                  STAT,TAPE7=STAT,ZSEVAP,TAPE9=ZSEVAP,
+                  MPARME, TAPE4=MPARME)
      IMPLICIT REAL (A-H,J-Z)
      COMMON/VAROF/USZM,LSZM,GZM,SS,EVAP,HPLSE,USZMAVG,LSZMAVG
      COMMON/PAROF/USZC,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV
      COMMON/PAROF2/ALPGW,ALPGEV,ALPSF,ALPSEV
      COMMON/INDICAT/DAY,EPSILON,DPSILON,GPSILON
      COMMON/VAROF2/VRUN,VINT,VPER,VGW,VUEV,VLEV
      DIMENSION DATA(3,360),IDATA(360),ESPDATA(30,4,6)
      DIMENSION LEVAP(80,12),IORDER(6,30)
      DIMENSION IYEAR(30),INAME(8)
      DIMENSION PARM(9),CINIT(5)
      DIMENSION IERR(6)
      DATA IERR/6*0/
CC*****
CC***** PROGRAM FOR E. S. P. FORECAST OF MONTHLY RUNOFF VOLUMES
CC***** FRM MONTHLY DATA ONLY.
CC*****
CC*****
CC          NOTE -- ARRAYS SHOULD SE DIMENSIONED AS FOLLOWS:
CC                  DATA(3,NUMBER OF MONTHS IN DATA SET)
CC                  IDATA(NUMBER OF MONTHS IN DATA SET)
CC                  ESPDATA(NUMBER OF YEARS IN DATA SET.4,
CC                          NUMBER OF MONTHS IN FORECAST PERIOD)
CC                  LEVAP(LAST YEAR OF EVAPORATION DATA-1899,12)
CC                  IORDER(NUMBER OF MONTHS IN FORECAST PERIOD,
CC                         NUMBER OF YEARS IN DATA SET)
CC                  IYEAR(NUMBER OF YEARS IN DATA SET)
CC*****
CC AREA   = WATERSHED AREA, SQ. M.
CC FLOW   = ACTUAL BASIN OUTFLOW VOLUME, CUB. M.
CC IDATE  = START DATE FOR ESP FORECAST (MM)
CC IFDDS = FIRST DATE OF DATA SET TO SE USED HERE (MMYYYY)
CC IFDEV = FIRST DATE OF EVAPORATION DATA (MMYYYY)
CC IFDFP = FIRST DATE OF FORECAST PERIOD (MMYYYY)
CC ILDDS -LAST DATE OF DATA SET TO BE USED HERE (MMYYYY)
CC ILDEV = LAST DATE OF EVAPORATION DATA (MMYYYY)
CC ILDFP = LAST DATE OF FORECAST PERIOD (MMYYYY)
CC ILNGTH = LENGTH OF ESP FORECAST, MONTHS
CC IM     = CALENDAR MONTH OF THE YEAR
CC INDIM = NUMBER OF DAYS IN THE CURRENT MONTH
CC INODAYS= NUMBER OF MONTHS TO SE CONSIDERED IN DATA SET
CC IY     = CALENDAR YEAR
CC PRECIP = PERIOD PRECIPITATION VOLUME (LIQUID EQUIVALENT), "JR. M.
CC SNW    = SNOWPACK VOLUME (LIQUID EQUIVALENT), CUB. M.
CC TA     -MONTHLY AVERAGE AIR TEMPERATURE, DEG. C.
CC*****
```

```
CC*****
CC***** INPUT CONSTANTS
CC*****
CC        NOTE -- SYSTEM SPECIFIC PROCEDURE SUPPLIES ZERO
CC                WHEN EXPONENTIAL UNDERFLOW OCCURS
CC*****
      CALL SYSTEMC(115,IERR)
CC*****
      EPSILON-I.E-7
      DPSILON=1.E-200
      GPSILON=1.E-3
      ALPGEV=0.
      ALPSEV=0.
      REWIND 4
      READ(4,1000)
      READ(4,559)AREA
      READ(4,559)LAREA
      READ(4,560)IFDFP
      READ(4,560)ILDFP
      CALL LENGTH(IFDFP,ILDFP,ILNGTH)
      READ(4,560)IFDDS
      READ(4,560)ILDDS
      READ(4,560)IFDEV
      READ(4,560)ILDEV
      DO 36 I=1,9
   36 READ(4,557)PARM(I)
      DO 37 I=1,5
   37 READ(4,558)CINIT(I)
      READ(4,559)CONS
      IDATE=IFDFP/10000
  557 FORMAT(E10.3E2)
  558 FOP.MAT(F10.2)
  559 FORMAT(E13.6E2)
  560 FORMAT(I8)
      REWIND 4
      IF(IFDFP.GT.999999.OR.ILDFP.GT.999999
+     .OR.IFDDS.GT.999999.OR.ILDDS.GT.999999
+     .OR.IFDEV.GT.999999.OR.ILDEV.GT.999999) CALL MDERR(1)
CC*****
CC*****  SNWINIT = VALUE OF SNW ON IDATE
CC*****
      SNWINIT= CINIT(1)*AREA/1000.
      USZINIT= CINIT(2)*AREA/1000.
      LSZINIT= CINIT(3)*AREA/1000.
      GZMINIT= CINIT(4)*AREA/1000.
      SSINIT = CINIT(5)*AREA/1000.
CC*****
CC***** INPUT MONTHLY LAKE EVAPORATION
CC*****
      REWIND 9
      IFMFP=IDATE
      IFMEV=IFDEV/10000
      IFYEV=IFDEV-(IFDEV/10000)*10000
      IF(IFMFP.LT.IFMEV)IFYEV=IFYEV+1
```

```
      IIMFP=ILDFP/10000
      IIMEV=ILDEV/10000
      ILYEV=ILDEV-(ILDEV/10000)*10000
      IF(IIMFP.GT.IIMEV)ILYEV=ILYEV-1
  555 READ(9,1120) IEVAPYR
 1120 FORMAT(9X,I4)
      IF(IEVAPYR.LT.IFYEV)GOTO 555
      BACKSPACE 9
      DO 500 I=IFYEV,ILYEV
      IZZ=I-1899
  500 READ(9,1030) (LEVAP(IZZ,IJ),IJ=1,12)
 1030 FORMAT(20X,12F5.0)
      REWIND 9
      DO 501 I=IFYEV,ILYEV
      IZZ=I-1899
      DO 501 IJ=1,12
  501 LEVAP(IZZ,IJ)=LEVAP(IZZ,IJ)/10000.
      USZC=AREA*0.02
      TBASE = PARM(1)
      ALBEDS = PARM(2)
      ALPPER = PARM(3)
      ALPUEV = PARM(4)
      ALPINT = PARM(5)
      ALPDPR = PARM(6)
      ALPLEV = PARM(7)
      ALPGW = PARM(8)
      ALPSF = PARM(9)
      CALL LENGTH(010001,IFDDS,IZZ)
      CALL LENGTH(010001,IFMFP*10000+IFYEV,IJ)
      IF(IZZ.LT.IJ) IFDDS=IFMFP*10000+IFYEV
      CALL LENGTH(010001,ILDDS,IZZ)
      CALL LENGTH(010001,IIMFP*10000+ILYEV,IJ)
      IF(IZZ.GT.IJ) ILDDS=IIMFP*10000+ILYEV
      IFMDS=IFDDS/10000
      IFYDS=IFDDS-IFMDS*10000
      IIMDS=ILDDS/10000
      ILYDS=ILDDS-IIMDS*10000
      IF(IFMFP.LT.IFMDS)IFYDS=IFYDS+1
      IF(IIMFP.GT.IIMDS)ILYDS=ILYDS-1
      IFDDS=IFMFP*10000+IFYDS
      ILDDS=IIMFP*10000+ILYDS
      CALL LENGTH(010001,IFDDS,IZZ)
      CALL LENGTH(010001,ILDDS,IJ)
      IF(IJ-IZZ+1.LT.ILNGTH) CALL MDERR(2)
      CALL LENGTH(IFDDS.ILDDS.INODAYS)
      REWIND 5
      READ(5,1000) INAME
      READ(5,1000)
      READ(5,1000)
      READ(5.1000)
 1000 FORMAT(8A10)
   15 READ(5,1010) IM,IY
      IF(IM*10000+IY.NE.IFDDS)GOTO 15
      BACKSPACE 5
```

```
CC*****
CC***** MONTHLY LOOP -DATA PREPARATION (BEGINNING)
CC*****
      DO 300 I-1,INODAYS
CC*****
CC*****       INPUT AND FILL IN MONTHLY DATA
CC*****
      READ(5,1010) IM,IY,INDIM,TA,PRECIP
 1010 FORMAT(1X,I3,I5,2X,I3,5X,F10.2,2F20.0)
      DATA(1,I)=PRECIP
      DATA(2,I)=TA
      DATA(3,I)=FLOAT(INDIM)
  300 IDATA(I)=IM*10000+IY
CC*****
CC*****       PREPARE ARRAYS FOR SIMULATIONS
CC*****
      I-1
      IESP=0
  400 ID=IDATA(I)/10000
      IF(ID.EQ.IDATE)GOTO 401
  402 I=I+1
      IF(I.GT.INODAYS)GOTO 403
      GOTO 400
  401 SNW=SNWINIT
      DO 404 IZ=1,ILNGTH
      IZZ=I-1+IZ
      IF(IZZ.GT.INODAYS)GOTO 404
      PRECIP=DATA(1,IZZ)
      TA=DATA(2,IZZ)
      INDIM=DATA(3,IZZ)+0.1
CC*****
CC*****             "EAT BALANCE
CC*****
      MELT-0.
      IF(TA.LE.0.)GOTO 903
      IF(SNW.LT.1.)GOTO 904
      DD=TA*FLOAT(INDIM)
  951 MELT=ALBEDS*DD
      IF(MELT.GT.SNW) MELT-SEW
  904 SNW=SNW-MELT
      NS=PRECIP+MELT
      GOTO 905
  903 SNW=SNW+PRECIP
      NS=0.
  905 HPLSE=EXP(TA/TBASE)/(596.-.52*TA)/1000000.*CONS
      ESPDATA(IESP+1,1,IZ)=NS
      ESPDATA(IESP+1,2,IZ)=HPLSE
      ESPDATA(IESP+1,3,IZ)=PRECIP/AREA*1000.
      ESPDATA(IESP+1,4,IZ)=FLOAT(INDIM)
  404 CONTINUE
      IF(IZZ-I+1.EQ.ILNGTH) IESP=IESP+1
      GOTO 402
  403 CONTINUE
CC*****
```

```
CC***** MONTHLY LOOP -DATA PREPARATION (END)
CC*****
CC*****
CC***** SIMULATE (IESP RUNS)
CC*****
      DO 100 IZ=1.IESP
CC*****
CC*****       INPUT INITIAL VARIABLE VALUES
CC*****
      USZM=USZINIT
      LSZM=LSZINIT
      GZM=GZMINIT
      SS=SSINIT
CC*****
CC*****       MONTHLY LOOP (BEGINNING)
CC*****
      DO 100 I-l,ILNGTH
CC*****
CC*****             INPUT PREPARED DATA
CC*****
      NS    = ESPDATA(IZ,1,I)
      HPLSE = ESPDATA(IZ,2,I)
      MY    = ESPDATA(IZ,4,I)
CC*****
CC*****             MASS BALANCE
CC*****
      CALL OUTFLOW(NS)
CC*****
      ESPDATA(IZ,2,I)=NS/LAREA*1000.
  100 CONTINUE
CC*****
CC*****       MONTHLY LOOP (END)
CC*****
CC*****
CC*****
CC***** END OF SIMULATIONS
CC*****
CC*****
CC***** FILL IN LAKE EVAPORATION AND DATE ARRAYS
CC*****
      I-l
      DO 960 IZ=1,IESP
      IK=1
  961 ID=IDATA(I)/10000
      IF(ID.EQ.IDATE)GOTO 962
      I=I+1
      GOTO 961
  962 IS=I
  963 IZZ=IDATA(IS)
      IM=IZZ/10000
      IY=IZZ-IM*10000
      ESPDATA(IZ,1,IK)=LEVAP(IY-1899,IM)*1000.
      ESPDATA(IZ,4,IK)=(IY-(IY/100)*100)+0.5
      IS=IS+1
```

```
      IK=IK+1
      IF(IK.LE.ILNGTH)GOTO 963
  960 I=I+1
CC*****
CC***** END OP FILL IN (ALL UNITS EXCEPT YEAR ARE MM OVER LAKE)
CC*****
CC*****
CC***** STATISTICAL SUMMARY (QUANTILE ESTIMATION FOR EACH PERIOD)
CC*****
CC*****
CC*****         ACCUMULATE OVER FORECAST HORIZON
CC*****
      DO 762 IZ=1,IESP
      SUM-0.
      IYEAR(IZ)=ESPDATA(IZ,4,1)
      DO 762 I=1,ILNGTH
      SUM=SUM+ESPDATA(IZ,2,I)+ESPDATA(IZ,3,I)-ESPDATA(IZ,1,I)
  762 ESPDATA(IZ,4,I)=SUM
CC*****
CC*****         ORDER STATISTICS FOR EACH PERIOD OF FORECAST HORIZON
CC*****
      DO 750 I-1,ILNGT"
      DO 753 IJ=1,IESP
  753 IORDER(I,IJ)=IJ
CC*****
CC*****             BUBBLE SORT FOR ONE PERIOD
CC*****
      IF(IESP.EQ.1)GOTO 750
      IESPM1=IESP-1
      DO 751 IJ=1,IESPM1
      TMIN=ESPDATA(IJ,4,I)
      IMIN=IJ
      IJP1=IJ+1
      DO 752 IK=IJP1,IESP
      IF(ESPDATA(IK,4,I).GE.TMIN)GOTO 752
      TMIN=ESPDATA(IK,4,I)
      IMIN=IK
  752 CONTINOE
      ESPDATA(IMIN,4,I)=ESPDATA(IJ,4,I)
      ESPDATA(IJ,4,I)=TMIN
      IK=IORDER(I,IMIN)
      IORDER(I,IMIN)=IORDER(I,IJ)
  751 IORDER(I,IJ)=IK
  750 CONTINUE
CC*****
CC*****             RESTORE N.B.S. ARRAY (NON-CUMULATIVE)
CC*****
      DO 763 IZ=1,IESP
      DO 763 I=1,ILNGTH
  763 ESPDATA(IZ,4,I)=ESPDATA(IZ,2,I)+ESPDATA(IZ,3,I)-ESPDATA(IZ,1,I)
CC*****
CC*****         SUMMARY OUTPUT
CC*****
      REWIND 7
```

```
      WRITE(7,1060) INAME
 1060 FORMAT(1H1,37HEXTENDED STREAMFLOW PREDICTION FOR   ,8A10)
      WRITE(7,1070) TBASE,ALBEDS,ALPPER,ALPUEV,ALPINT,ALPDPR,ALPLEV,
 1070 FORMAT(/,1X,18HPARAMETER ALPGW,ALPGEV,ALPSF,ALPSEV,CONS,USZC,AREA,LAREA
               6X,17HTBASE (C)SUMMARY:,,E13.6E2,/,
               6X,17HALBEDS (M3/DD) = ,E13.6E2,/,
               6X,17HALPPER (D-1)   = ,E13.6E2,/,
               6X,17HALPUEV (M-3)   = ,E13.6E2,/,
               6X,17HALPINT (D-l)   = ,E13.6E2,/,
               6X,17HALPDPR (D-l)   = ,E13.6E2,/,
               6X,17HALPLEV (M-3)   = ,E13.6E2,/,
               6X,17HALPGW  (D-l)   = ,E13.6E2,/,
               6X,17HALPGEV (M-3)   = ,E13.6E2,/,
               6X,17HALPSF  (D-l)   = ,E13.6E2,/,
               6X,17HALPSEV (M-3)   = ,E13.6E2,/,
               6X,17HCONS  (CAL)    = ,E13.6E2,/,
               6X,17HUSZC   (M3)    = ,E13.6E2,/,
               6X,17HAREA   (M2)    = ,E13.6E2,/,
               6X,17HLAKE AREA (M2) = ,E13.6E2,/,/)
      IM=IDATE
      ISTART=IM
      IF(ISTART.EQ.1)IMO=7HJANUARY
      IF(ISTART.EQ.2)IMO=8HFEBRUARY
      IF(ISTART.EQ.3)IMO=5HMARCH
      IF(ISTART.EQ.4)IMO=5HAPRIL
      IF(ISTART.EQ.5)IMO=3HMAY
      IF(ISTART.EQ.6)IMO=4HJUNE
      IF(ISTART.EQ.7)IMO=4HJULY
      IF(ISTART.EQ.8)IMO=6HAUGUST
      IF(ISTART.EQ.9)IMO=9HSEPTEMBER
      IF(ISTART.EQ.10)IMO=7HOCTOBER
      IF(ISTART.EQ.11)IMO=8HNOVEMBER
      IF(ISTART.EQ.12)IMO=8HDECEMBER
      WRITE(7,1080) IMO,ILNGTH
 1080 FORMAT(1X,18HSTARTING MONTH IS ,A10,/,
               1X,2lHSIMULATION LENGTH IS ,I2,7H MONTHS,//)
      IFDDS=IFDDS-(IFDDS/10000)*10000
      ILDDS=ILDDS-(ILDDS/10000)*10000
      WRITE(7,1090) IFDDS,ILDDS
 1090 FORMAT(1X,19HDATA SET RUNS FROM ,I4,9H THROUGH ,I4,/,
               1X,48HWITH A MONTHLY "ASS-BALANCE COMPUTATION INTERVAL,//)
      SNWINIT=SNWINIT/AREA*1000.
      USZINIT=USZINIT/AREA*1000.
      LSZINIT=LSZINIT/AREA*1000.
      GZMINIT=GZMINIT/AREA*1000.
      SSINIT = SSINIT/AREA*1000.
      WRITE(7,1100) SNWINIT,USZINIT,LSZINIT,GZMINIT,SSINIT
 1100 FORMAT(1X,46HINITIAL VALUES AT BEGINNING OF STARTING MONTH:,/,
               6X,12HSNW (MM) = ,F6.2,/,
               6X,12HUSZM (MM) = ,F6.2,/,
               6X,12HLSZM (MM) = ,F6.2,/,
               6X,12HGZM  (MM) = ,F6.2,/,
               6X,12HSS (MM)   = ,F6.2,//)
```

```
      WRITE(7,1110)
 1110 FORMAT(/,
+/,1X,65HMONTHLY LAKE EVAPORATION IS TAKEN FROM PREVIOUS LAKE EVAPORATION ,
+     65HSTUDIES BY QUINN AND REPRESENTS AERODYNAMIC EQUATION APPLICATIONS.
+/,1X,65HTO MONTHLY DATA.
+/,1X,65H
+/,1X,65HLUMPED MONTHLY PRECIPITATION AND MONTHLY AIR TEMPERATURE CAME PRO,
+     65HM 54 METEOROLOGICAL STATIONS ABOUT THE LAKE SUPERIOR BASIN, AFTER,
+/,1X,65HCROLEY. THE DATA SET IS AVAILABLE ON THE GLERL COMPUTER.
+/,1X,65H
+/,1X,65HTHE FOLLOWING OUTPUT STATISTICS ARE PRESENTED FOR SUCCESSIVELY LO,
+     65HNGER FORECAST PERIODS. THE FIRST PAGE IS FOR THE FIRST MONTH OF ,
+/,1X,65HTHE FORECAST PERIOD. THE SECOND PAGE IS POR THE PIRST TWO MONTHS,
+     65H OF THE FORECAST PERIOD. THE THIRD PAGE IS POR THE FIRST THREE ,
+/,1X,65HMONTHS OF THE FORECAST PERIOD, ETC. THE HISTORICAL METEOROLOGICA,
+     65HL DATA IS USED TO COMPUTE RUNOFF FOR EACH YEAR (PORTION OF WHICH ,
+/,1X,65HMATCHES THE FORECAST PERIOD); THE RUNOFF AND PRECIPITATION ARE SU,
+     65HMMED OVER EACH MONTH AND COMBINED WITH MONTHLY EVAPORATION TO    )
      WRITE(7,1111)
 1111 FORMAT(
+ 1X,65HCOMPUTE NET BASIN SUPPLY. THE NET BASIN SUPPLY IS ACCUMULATED OV,
+     65HER THE PIRST N MONTHS, FOR PAGE N, AND THE YEARS OF RECORD ARE  ,
+/,1X,65HSORTED BASED ON THE ACCUMULATED NET BASIN SUPPLY FOR THE N-MONTH ,
+     65HPERIOD FROM SMALLEST TO LARGEST. THE ORDER STATISTICS ARE THUS  ,
+/,1X,65HOBTAINED BASED UPON THE N-MONTH ACCUMULATED NET BASIN SUPPLY FOR ,
+     65HTHE FIRST N MONTHS. THE ACCUMULATED NET BASIN SUPPLY IS NOT     ,
+/,1X,65HPRINTED OUT, BUT THE LAKE EVAPORATION, RUNOFF, PRECIPITATION, AND,
+     65H NET BASIN SUPPLY FOR EACH MONTH ARE PRINTED IN UNITS OF MILLI- ,
+/,1X,65HMETERS OVER THE LAKE SURFACE. QUANTILE PROBABILITIES ARE GIVEN a,
+     65HYTHE ORDER NUMBER (NO) DIVIDED BY THE NUMBER OF YEARS USED IN   ,
+/,1X,65HTHE PROCEDURE (LARGEST NO). THESE PROBABILITIES REPRESENT THE NO,
+     65HN-EXCEEDANCE PROBABILITIES AND THEIR COMPLEMENTS REPRESENT THE  ,
+/,1X,65HEXCEEDANCE PROBABILITIES.                                       )
      DO 754 I=1,ILNGTH
      WRITE(7,1020) I
 1020 FORMAT(1H1,5HFIRST,I2,9H MONTH(S),//,6X,
h             6(1X,20H(EVAP.) (RUN- (PRE-),/,1X,5HNO YR,
+             6(2X,19H(NBS)   OFF)  CIP.)))
      DO 754 IZ=1,IESP
      IJ=IORDER(I,IZ)
      WRITE(7,1050) IZ,IYEAR(IJ),((ESPDATA(IJ,IK,IL),IK=1,3),IL=1,I)
 1050 FORMAT(1X,I2,I3,18F7.1)
  754 WRITE(7,1040) (ESPDATA(IJ,4,IL),IL=1,I)
 1040 FORMAT(6X,F7.1,5F21.1)
      REWIND 7
      STOP
      END
CC*****
CC*****
      SUBROUTINE OUTFLOW (NS)
```

(SEE LISTING FOR CALIB)

```
      SUBROUTINE LENGTH(IFDP,ILDP,INODAYS)


      (SEE LISTING FOR MMCAL)


      SUBROUTINE MDERR(I)
CC*****
CC***** THIS ROUTINE PRINTS A (FATAL) ERROR MESSAGE AND STOPS THE JOE.
CC*****
      IF(I.LT.1.OR.I.GT.2)GOTO 3
      GOTO (1,2),I
    1  WRITE(6,1001)
 1001 FORMAT(1X.42HALL INPUT DATES MUST BE SIX DIGITS: MMYYYY)
      GOTO 100
    2 WRITE(6,1002)
 1002 FORMAT(1X,
+58HTHE COMMON DATA PERIOD IS INSUFFICIENT FOR ANY SIMULATIONS)
      GOTO 100
    3 WRITE(6,1003)
 1003 FORMAT(1X,17HUNSPECIFIED ERROR)
      GOTO 100
  100 REWIND 5
      REWIND 7
      REWIND 9
      REWIND 4
      WRITE(6,1000)
 1000 FORMAT(1X,
+38HFATAL USER ERROR: PROGRAM RUN ABORTED!)
      STOP
      END
```

Appendix L.--EXAMPLE INPUT FILE OF OVERLAKE EVAPORATION (ZSEVAP)

		1900													
		1901													
		1902													
		1903													
		1904													
		1905													
		1906													
		1907													
		1908													
		1909													
		1910													
		1911													
		1912													
		1913													
		1914													
		1915													
		1916													
		1917													
		191.5													
		1919													
		1920													
		1921													
		1922													
		1923													
		1924													
		1925													
		1926													
		1927													
		1928													
		1929													
		1930													
		1931													
		1932													
		1933													
		1934													
		1935													
		1936													
		1937													
		1938													
		1939													
		1940													
		1941													
S	EV-MT	1942	MM*10	1107	659	263	-15	-60	-142	-112	-88	169	587	1296	1302
s	EV-MT	1943	MM*10	1010	630	763	140	-58	-111	-173	-146	169	490	1182	1355
s	EV-MT	1944	MM*10	697	809	491	123	-76	-138	-265	-104	157	507	690	1147
s	EV-MT	1945	MM*10	887	498	95	59	8	-68	-198	-126	189	709	1085	950
S	EV-MT	1 9 4 6 ~ 1 0		861	505	97	40	-3	-71	-154	-63	151	380	1244	1251
s	EV-MT	1947	MM*10	1146	760	360	90	-50	-157	-203	-220	107	147	992	1020
s	EV-MT	1948	MM*10	913	475	315	-33	-2	-65	-112	-124	171	554	784	1164
S	EV-MT	1949	MM*10	1117	618	472	13	-32	-150	-146	-90	242	419	1402	1375
s	EV-MT	1950	MM*10	1276	528	627	264	-47	-81	-127	-9	-3	276	1161	1124
S	EV-MT	1951	MM*10	1023	56%	539	-4	-43	-126	-197	-96	108	334	1044	1172
s	EV-MT	1952	MM*10	932	616	505	0	-37	-102	-129	-124	-45	850	899	841
S	EV-MT	1953	MM*10	1168	621	343	121	-43	-119	-185	-97	493	496	866	1309
S	EV-MT	1954	MM*10	1020	413	839	78	-25	-90	-138	-35	92	530	588	896

S	EV-MT	1955	MM*10	1135	571	627	-44	-30	-151	-215	-91	380	444	1428	1266
S	EV-MT	1956	MM*10	924	678	552	186	-15	-78	-180	-111	239	290	1143	1160
S	EV-MT	1957	MM*10	1048	437	362	22	16	-100	-196	5	428	692	1036	1022
S	EV-MT	1958	MM*10	918	739	207	76	-2	-57	-214	-68	42	386	1199	1204
S	EV-MT	1959	MM*10	1047	391	288	85	-9%	-76	-91	-153	106	1039	1365	842
S	EV-MT	1960	MM*10	947	652	608	28	-52	-60	-152	-122	334	563	1029	1285
S	EV-MT	1961	MM*10	935	502	383	89	-7	-43	-166	1	400	574	896	1087
S	EV-MT	1962	MM*10	1173	330	242	96	-62	-90	103'	-47	496	571	747	1248
S	EV-MT	1963	MM*10	945	271	257	32	-24	-161	-134	-11	106	275	1093	1377
S	EV-MT	1964	MM*10	1043	742	664	47	-36	-64	-122	-22	251	665	1011	1436
S	EV-MT	1965	MM*10	1097	466	328	51	-53	-55	-157	-34	411	507	1051	912
S	EV-MT	1966	MM*10	1046	481	436	98	27	-72	-134	-49	474	845	1105	1078
S	EV-MT	1967	MM*10	1143	391	232	114	56	-138	-127	37	385	762	1014	1135
S	EV-MT	1968	MM*10	940	669	297	43	-23	-88	-104	-92	150	548	1138	1243
S	EV-MT	1969	MM*10	1097	614	546	26	-14	-52	-105	-15	775	1027	1063	1293
S	EV-MT	1970	MM*10	1357	420	359	70	-34	-52	-145	3	517	612	1079	1128
S	EV-MT	1971	MM*10	1124	478	446	116	15	-79	-58	75	285	418	1176	1351
s	EV-MT	1972	MM*10	1192	460	351	176	-22	-84	-105	-65	495	630	764	1409
s	EV-MT	1973	MM*10	852	711	188	163	-4	-171	-139	-78	542	363	1056	1385
s	EV-MT	1974	MM*10	903	538	426	62	-15	-119	-166	-82	579	628	744	945
S	EV-MT	1975	MM*10	1183	628	703	265	-49	-220	-237	25	571	534	1050	1427
S	EV-MT	1976	MM*10	1041	588	796	36	29	-51	-94	26	583	996	1253	1156
S	EV-MT	1977	MM*10	970	573	301	42	-26	-55	-146	72	337	852	1369	1445
S	EV-MT	1978	MM*10	1091	480	415	192	-47	-90	-98	-9	265	633	1453	1311
S	EV-MT	1979	MM*10	1303	256	197	121	3	-85	-73	-13	315	1047	1460	1157

Appendix M.--EXAMPLE ESP INPUT PARAMETER FILE (PARME)

SUPERIOR: ALL BASINS 1-22

.128925E+12
.828874E+11
15031983
30091983
01011949
31121978
011942
121979
.170E+01
.390E+09
.280E+01
.140E-09
.410E-02
.780E-02
.250E-03
.420E-02
.990E-01
103.30
0.00
64.30
131.00
10.20
.352141E+14

Appendix N.--EXAMPLE ESP OUTPUT (STAT)

EXTENDED STREAMFLOW PREDICTION FOR COMBINED SUBBASINS: 1111111111111111111111

PARAMETER SUMMARY:

TBASE (C) = .170000E+01
ALBEDS (M3/DD) = .390000E+09
ALPPER (D-1) = .280000E+01
ALPUEV (H-3) = .140000E-09
ALPINT (D-l, = .410000E-02
ALPDPR (D-l) = .780000E-02
ALPLW (H-3) = .250000E-03
ALPGW (D-l) = .420000E-02
ALPGEV (M-3) = 0.
ALRF (D-l) = .990000E-01
ALPSEV (M-3) = 0.
CONS (CAL) = .352141E+14
USZC (M3) = .257850E+10
AREA (M2) = .128925E+12
LAKE AREA (M2) = .828874E+11

STARTING DATE: DAY 15 OF MONTH 3
SIMULATION LENGTH IN l-DAY PERIODS = 200
FIRST MONTH OF OUTPUT STATISTICS = APRIL

DATA SET LENGTH (D) = 10792
"ASS BALANCE COMPUTATION INTERVAL (D) = 1

INITIAL VALUES ON STARTING DATE:

SNW (MM) = 103.3
USZM (MM) = 0.0
LSZM (MM) = 64.3
GZM (MM) = 131.0
SS (MM) = 10.2

MONTHLY LAKE EVAPORATION IS TAKEN FROM PREVIOUS LAKE EVAPORATION STUDIES BY QUINN AND REPRESENTS AERODYNAMIC EQUATION APPLICATIONS TO MONTHLY DATA.

DAILY PRECIPITATION AND MAXIMUM AND MINIMUM TEMPERATURES CAME FROM 54 METEOROLOGICAL STATIONS ABOUT THE LAKE SUPERIOR BASIN, AFTW CROLEY. THE DATA SET IS AVAILABLE ON THE GLERL COMPUTER.

THE FOLLOWING OUTPUT STATISTICS ARE PRESENTED FOR SUCCESSIVELY LONGER FORECAST PERIODS. THE FIRST PACE IS FOR THE FIRST MONTH OF THE FORECAST PERIOD. THE SECOND PAGE IS FOR THE FIRST TWO MONTHS OF THE FORECAST PERIOD. THE THIRD PAGE IS FOR THE FIRST THREE MONTHS OF THE FORECAST PERIOD, ETC. THE HISTORICAL METEOROLOGICAL DATA IS USED TO COMPUTE RUNOFF FOR EACH YEAR (PORTION OF WHICH MATCHES THE FORECAST PERIOD); THE RUNOFF AND PRECIPITATION ARE SUMMED OVER EACH MONTH AND COMBINED WITH MONTHLY EVAPORATION TO COMPUTE NET BASIN SUPPLY. THE NET BASIN SUPPLY IS ACCUMULATED OVER THE FIRST N MONTHS, FOR PAGE N, AND THE YEARS OF RECORD ARE SORTED BASED ON THE ACCUMULATED NET BASIN SUPPLY FOR THE N-MONTH PERIOD FROM SMALLEST TO LARGEST. THE ORDER STATISTICS ARE THUS OBTAINED BASED UPON THE N-MONTH ACCUMULATED NET BASIN SUPPLY FOR THE FIRST N MONTHS. THE ACCUMULATED NET BASIN SUPPLY IS NOT PRINTED OUT, BUT THE LAKE EVAPORATION, RUNOFF. PRECIPITATION, AND NET BASIN SUPPLY FOR EACH MONT" ARE PRINTED IN "NITS OF MILLI-METERS OVER THE LAKE SURFACE. QUANTILE PROBABILITIES ARE GIVEN BY THE ORDER NUMBER (NO) DIVIDED BY THE NUMBER OF YEARS USED IN THE PROCEDURE (LARGEST NO). THESE PROBABILITIES REPRESENT THE NON-EXCEEDANCE PROBABILITIES AND THEIR COMPLEMENTS REPRESENT THE EXCEEDANCE PROBABILITIES.

FIRST 1 (WHOLE) MONTH(S)

NO	YR	(EVAP.) (NBS)	(RUN- OFF)	(PRE- CIP.)	(EVAP.) (NBS)	(RUN- OFF)	(PRE- CIP.)	(EVAP.) (NBS)	(RUN- OFF)	(PRE- CIP.)	(EVAP.) (NBS)	(RUN- OFF)	(WE- CIP.)	(EVAP.) (NBS)	(RUN- OFF)	(PRE- CIP.)	(EVAP.) (NBS)	(RUN- OFF)	(PRE- CIP.)
1	72	17.6	69.0	28.7															
		SO.1																	
2	7%	19.2	64.8	34.6															
		80.2																	
3	75	26.5	70.6	39.7															
		83.7																	
4	59	8.5	68.5	33.3															
		93.2																	
5	56	18.6	63.4	4%.7															
		93.5																	
6	50	26.4	53.3	71.2															
		9%.1																	
7	58	7.6	71.4	36.5															
		100.3																	
8	65		72.0	37.2															
		10:::																	
9	71	11.6	83.2	34.0															
		105.5																	
10	49	1.3	86.5	22.1															
		107.3																	
11	73	16.3	75.0	50.3															
		109.0																	
12	62	9.6	70.6	53.1															
		114.1																	
13	66	9.8	73.0	51.0															
		114.3																	
14	76	3.6	81.8	43.5															
		121.6																	
15	53	12.1	78.0	56.3															
		122.2																	
16	69	2.6	79.4	47.2															
		124.0																	
17	70	7.0	70.3	63.6															
		126.9																	
1%	61	8.9	81.4	57.2															
		129.7																	
19	55	-4.4	89.5	39.0															
		132.9																	
20	52	0.0	89.6	46.9															
		136.5																	
21	51	-.4	87.1	49.2															
		136.7																	
22	57	2.2	84.8	55.6															
		138.2																	

23	63	3.2	87.2	55.8
		139.8		
24	67	11.4	87.0	64.1
		139.8		
25	77	4.2	97.9	54.0
		147.8		
26	74	6.2	81.3	75.1
		150.2		
27	64	4.7	94.4	75.7
		165.4		
2%	54	7.8	85.5	90.6
		168.4		
29	68	4.3	95.7	95.4
		186.9		
30	60	2.8	97.7	107.3
		202.3		

FIRST 2 (WHOLE) MONTH(S)

NO	YR	(EVAP.) (NBS)	(RUN-OFF)	(WE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)
1	72	17.6	69.0	28.7	-2.2	70.5	51.0
		80.1			1 2.9		
2	76	3.6	81.8	43.5	83.7	66.1	20.6
		121.6					
3	5%	7.6	71.4	36.5	-.2	61.1	54.1
		100.3			115.4		
4	75	26.5	70.6	39.7	-4.9	75.8	54.1
		83.7			134.8		
5	66	9.8	73.0	51.0	2.7	74.2	42.1
		114.3			lJ3.6		
6	67	11.4	87.0	64.1	5.6	70.7	42.4
		139.8			107.5		
7	7%	19.2	64.8	34.6	-4.7	73.3	92.1
		80.2			170.1		
8	56	18.6	63.4	48.7	-1.5	76.2	84.0
		93.5			161.6		
9	52	0.0	89.6	46.9	-3.7	70.4	50.7
		136.5			124.9		
10	51	-.4	87.1	49.2	-4.3	67.6	55.0
		136.7			126.9		
11	77	4.2	97.9	54.0	-2.6	65.9	54.9
		147.8			123.4		
12	69	2.6	79.4	47.2	-1.4	71.0	75.4
		124.0			147.7		
13	73	16.3	75.0	50.3	-.4	77.1	85.4
		109.0			162.9		

(EVAP.) (NBS) (RUN-OFF, (PRE-CIP.) (EVAP.) (NBS) (RUN-OFF) (WE-CIP.) (EVAP.) (NBS) (RUN-OFF) (PRE-CIP.) (EVAP.) (NBS) (RUN-OFF) (PRE-CIP.)

14	63	3.2 139.8	87.2	55.8	-2.4 133.4	67.6	63.4
15	65	5.1 104.1	72.0	37.2	-5.3 174.3	75.0	94.0
16	59	8.5 93.2	68.5	33.3	-9.8 185.5	68.8	106.9
17	57	2.2 138.2	84.8	55.6	1.6 141.0	79.7	62.9
18	49	1.3 107.3	86.5	22.1	-3.2 173.3	81.9	88.3
19	61	8.9 129.7	81.4	57.2	-.7 160.8	81.7	78.4
20	53	12.1 122.2	78.0	56.3	-4.3 175.0	73.6	97.1
21	71	11.6 105.5	83.2	34.0	1.5 192.6	83.2	110.9
22	62	9.6 114.1	70.6	53.1	-6.2 196.2	77.4	112.6
23	68	4.3 186.9	95.7	95.4	-2.3 143.3	78.6	62.4
24	74	6.2 150.2	81.3	75.1	-1.5 181.8	94.8	85.5
25	50	26.4 98.1	53.3	71.2	-4.7 241.0	135.3	101.0
26	55	-4.4 132.9	89.5	39.0	-3.0 215.6	87.0	125.6
27	70	7.0 126.9	70.3	63.6	-3.4 222.3	89.4	129.5
28	54	7.8 168.4	85.5	90.6	-2.5 191.5	97.0	91.2
29	64	4.7 165.4	94.4	75.7	-3.6 204.7	92.3	108.8
30	60	2.8 202.3	97.7	107.3	-5.2 185.7	97.3	83.2

FIRST 3 (WHOLE) MONTH(S)

NO	YR	(EVAP.) (NBS)	OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)
1	72	17.6 80.1	69.0	28.7	-2.2 123.7	70.5	51.0	-8.4 118.7	50.6	59.7									
2	76	3.6 121.6	81.8	43.5	2.9 83.7	66.1	20.6	-5.1 165.3	58.3	102.0									
3	66	9.8 114.3	73.0	51.0	2.7 113.6	74.2	42.1	-7.2 148.2	65.8	75.2									
4	58	7.6 100.3	71.4	36.5	-.2 115.4	61.1	54.1	-5.7 172.8	67.6	99.5									
5	56	18.6 93.5	63.4	48.7	-1.5 161.6	76.2	84.0	-7.8 141.9	60.2	73.9									

6	78	19.2	64.8	34.6	-4.7	73.3	92.1	-9.0	57.3	81.9
		80.2			170.1			148.2		
7	61	8.9	81.4	57.2	-.7	81.7	78.4	-4.3	65.6	50.5
		129.7			160.8			120.4		
8	75	26.5	70.6	39.7	-4.9	75.8	54.1	-22.0	60.4	116.1
		83.7			134.8			198.5		
9	65	5.1	72.0	37.2	-5.3	75.0	94.0	-5.5	69.3	73.7
		104.1			174.3			148.5		
10	69	2.6	79.4	47.2	-1.4	71.0	75.4	-5.2	66.2	85.3
		124.0			147.7			156.8		
11	77	4.2	97.9	54.0	-2.6	65.9	54.9	-5.5	46.5	109.0
		147.8			123.4			160.9		
12	67	11.4	87.0	64.1	5.6	70.7	42.4	-13.8	68.6	104.7
		139.8			107.5			187.2		
13	62	9.6	70.6	53.1	-6.2	77.4	112.6	-9.0	59.4	58.2
		114.1			196.2			126.7		
14	59	8.5	68.5	33.3	-9.8	68.8	106.9	-7.6	62.0	91.1
		93.2			185.5			160.7		
15	51	-.4	87.1	49.2	-4.3	67.6	55.0	-12.6	61.6	108.0
		136.7			126.9			182.2		
16	52	0.0	89.6	46.9	-3.7	70.4	50.7	-10.2	66.3	110.1
		136.5			124.9			186.6		
17	71	11.6	83.2	34.0	1.5	83.2	110.9	-7.9	73.6	75.8
		105.5			192.6			157.3		
18	63	3.2	87.2	55.8	-2.4	67.6	63.4	-16.1	68.4	105.3
		139.8			133.4			189.7		
19	49	1.3	86.5	22.1	-3.2	81.9	88.3	-15.0	60.9	106.9
		107.3			173.3			182.8		
20	73	16.3	75.0	50.3	-.4	77.1	85.4	-17.1	69.7	105.0
		109.0			162.9			191.7		
21	57	2.2	84.8	55.6	1.6	79.7	62.9	-10.0	73.0	111.8
		138.2			141.0			194.8		
22	70	7.0	70.3	63.6	-3.4	89.4	129.5	-5.2	75.0	70.6
		126.9			222.3			150.8		
23	55	-4.4	89.5	39.0	-3.0	87.0	125.6	-15.1	77.2	63.5
		132.9			215.6			155.8		
24	74	6.2	81.3	75.1	-1.5	94.8	85.5	-11.9	75.3	87.5
		150.2			181.8			174.8		
25	53	12.1	78.0	56.3	-4.3	73.6	97.1	-11.9	88.1	126.3
		122.2			175.0			226.4		
26	54	7.8	85.5	90.6	-2.5	97.8	91.2	-9.0	76.9	84.1
		168.4			191.5			170.0		
27	50	26.4	53.3	71.2	-4.7	135.3	101.0	-8.1	80.4	106.3
		98.1			241.0			194.9		
28	60	2.8	97.7	107.3	-5.2	97.3	83.2	-6.0	75.6	76.2
		202.3			185.7			157.8		
29	68	4.3	95.7	95.4	-2.3	78.6	62.4	-8.8	‘90.1	135.0
		186.9			143.3			233.9		
30	64	4.7	94.4	75.7	-3.6	92.3	108.8	-6.4	85.9	120.7
		165.4			204.7			213.0		

FIRST 4 (WHOLE) **MONTH(S)**

NO	YR	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP .) (NBS)	(RUN-OFF,	(PRE-CIP.)	(EVAP .) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)
1	76	3.6 121.6	81.8	43.5	2.9 83.7	66.1	20.6	-5.1 165.3	58.3	102.0	-9.4 116.0	40.3	66.3						
2	72	17.6 80.1	69.0	2%. 7	-2.2 123.7	70.5	51.0	-8.4 118.7	50.6	59.7	-10.5 186.2	48.6	127.0						
3	66	9.8 114.3	73.0	51.0	2.7 113.6	74.2	42.1	-7.2 148.2	65.8	75.2	-13.4 147.3	45.5	88.4						
4	56	18.6 9.6	63.4	48.7	-1.5 161.6	76.2	84.0	-7.8 141.9	60.2	73.9	-18.0 137.7	46.2	73.5						
5	62	114.1	70.6	53.1	-6.2 196.2	77.4	112.6	-9.0 126.7	59.4	5%. 2	10.3 104.5	40.4	74.4						
6	75	26.5 83.7	70.6	39.7	-4.9 134.8	75.8	54.1	-22.0 198.5	60.4	116.1	-23.7 127.4	37.7	66.0						
7	61	8.9 129.7	81.4	57.2	-.7 160.8	81.7	78.4	-4.3 120.4	65.6	50.5	-16.6 135.5	45.7	73.3						
8	67	11.4 139.8	87.0	64.1	5.6 107.5	70.7	42.4	-13.8 187.2	68.6	104.7	-12.7 125.3	49.4	63.2						
9	7%	19.2 80.2	64.8	34.6	-4.7 170.1	73.3	92.1	-9.0 148.2	57.3	81.9	-9.8 176.3	47.7	118.8						
10	69	2.6 124.0	79.4	47.2	-1.4 147.7	71.0	75.4	-5.2 156.8	66.2	85.3	-10.5 149.0	55.9	82.6						
11	59	8.5 93.2	68.5	33.3	-9.8 185.5	68.8	106.9	-7.6 160.7	62.0	91.1	-9.1 138.9	44.7	85.1						
12	77	4.2 147.8	97.9	54.0	-2.6 123.4	65.9	54.9	-5.5 160.9	46.5	109.0	-14.6 146.5	45.2	86.8						
13	5%	7.6 100.3	71.4	36.5	-.2 115.4	61.1	54.1	-5.7 172.8	67.6	99.5	-21.4 192.1	70.8	99.8						
14	71	11.6 105.5	83.2	34.0	1.5 192.6	83.2	110.9	-7.9 157.3	73.6	75.8	-5.8 131.5	47.5	78.2						
15	63	3.2 139.8	87.2	55.8	-2.4 133.4	67.6	63.4	-16.1 189.7	68.4	105.3	-13.4 125.6	41.4	70.9						
16	65	5.1 104.1	72.0	37.2	-5.3 174.3	75.0	94.0	-5.5 148.5	69.3	73.7	-15.7 167.8	62.9	89.1						
17	51	-.4 136.7	87.1	49.2	-4.3 126.9	67.6	55.0	-12.6 182.2	61.6	108.0	-19.7 153.3	48.6	85.0						
18	73	16.3 109.0	75.0	50.3	-.4 162.9	77.1	85.4	-17.1 191.7	69.7	105.0	-13.9 156.4	55.3	87.2						
19	57	2.2 138.2	84.8	55.6	1.6 141.0	79.7	62.9	-10.0 194.8	73.0	111.8	-19.6 163.6	61.5	82.4						
20	54	7.8 168.4	85.5	90.6	-2.5 191.5	97.8	91.2	-9.0 170.0	76.9	84.1	-13.8 108.5	43.1	51.7						
21	74	6.2 150.2	81.3	75.1	-1.5. 181.8	94.8	85.5	-11.9- 174.8	75.3	87.5	-16.6 152.8	51.0	85.2						
22	49	1.3 107.3	86.5	22.1	-3.2 173.3	81.9	88.3	-15.0 182.8	60.9	106.9	-14.6 196.7	49.9	132.2						

23	70	7.0	70.3	63.6	-3.4	89.4	129.5	-5.2	75.0	70.6	-14.5	48.7	98.3
		126.9			222.3			150.8			161.5		
24	55	-4.4	89.5	39.0	-3.0	87.0	125.6	-15.1	77.2	63.5	-21.5	40.1	100.3
		132.9			215.6			155.8			161.8		
25	60	2.8	97.7	107.3	-5.2	97.3	83.2	-6.0	75.6	76.2	-15.2	51.9	61.2
		202.3			185.7			157.8			128.3		
26	52	0.0	89.6	46.9	-3.7	70.4	50.7	-10.2	66.3	110.1	-12.9	63.1	160.7
		136.5			124.9			186.6			236.7		
27	50	26.4	53.3	71.2	-4.7	135.3	101.0	-8.1	80.4	106.3	-12.7	61.4	97.4
		9%. 1″			241.0			194.9			171.5		
2%	64	4.7	94.4	75.7	-3.6	92.3	108.8	-6.4	85.9	120.7	-12.2	52.9	61.5
		165.4			204.7			213.0			126.6		
29	53	12.1	78.0	56.3	-4.3	73.6	97.1	-11.9	**88.1**	126.3	-18.5	66.5	115.5
		122.2			175.0			226.4			200.6		
30	68	4.3	95.7	95.4	-2.3	78.6	62.4	-8.8	90.1	135.0	-10.4	75.9	133.5
		186.9			143.3			233.9			219.8		

FIRST 5 (WHOLE) MONTH(S)

NO	YR	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)
1	76	3.6	81.8	43.5	2.9	66.1	20.6	-5.1	58.3	102.0	-9.4	40.3	66.3	2.6	32.5	42.0			
		121.6			83.7			165.3			116.0			71.9					
2	75	26.5	70.6	39.7	-4.9	75.8	54.1	-22.0	60.4	116.1	-23.7	37.7	66.0	**2.5**	29.3	55.0			
		83.7			134.8			198.5			127.4			**81.8**					
3	61	8.9	81.4	57.2	**-.7**	81.7	78.4	-4.3	65.6	50.5	-16.6	45.7	73.3	.l	34.5	56.6			
		129.7			160.8			120.4			135.5			91.0					
4	56	18.6	63.4	48.7	-1.5	76.2	84.0	-7.8	60.2	73.9	-18.0	46.2	73.5	-11.1	34.6	82.9			
		93.5			161.6			141.9			137.7			128.6					
5	71	11.6	83.2	34.0	1.5	83.2	110.9	-7.9	73.6	75.8	-5.8	47.5	78.2	7.5	35.5	57.4			
		105.5			192.6			157.3			131.5			85.4					
6	72	17.6	69.0	2%. 7	-2.2	70.5	51.0	-8.4	50.6	59.7	-10.5	48.6	127.0	-6.5	48.4	122.8			
		80.1			123.7			118.7			186.2			177.7					
7	67	11.4	87.0	64.1	5.6	70.7	42.4	-13.8	68.6	104.7	-12.7	49.4	63.2	3.7	42.7	89.0			
		139.8			107.5			187.2			125.3			127.9					
8	66	9.8	73.0	51.0	2.7	74.2	42. 1	-7.2	65.8	75.2	-13.4	45.5	88.4	-4.9	4%. 9	113.5			
		114.3			113.6			148.2			147.3			167.3					
9	62	9.6	70.6	53.1	-6.2	77.4	112.6	-9.0	59.4	58.2	10.3	40.4	74.4	-4.7	41.0	109.3			
		114.1			196.2			126.7			104.5			155.0					
10	63	3.2	87.2	55.8	-2.4	**67.6**	63.4	-16.1	68.4	105.3	-13.4	41.4	70.9	-1.1	39.3	71.9			
		139.8			133.4			189.7			125.6			112.4					
11	69	2.6	79.4	47.2	-1.4	71.0	75.4	-5.2	66.2	85.3	-10.5	55.9	82.6	-1.5	42.8	85.2			
		124.0			147.7			156.8			149.0			129.5					
12	57	2.2	84.8	55.6	1.6	79.7	62.9	-10.0	**73.0**	**111.8**	**-19.6**	61.5	82.4	**.5**	33.9	42.7			
		138.2			141.0			194.8			163.6			76. 1					
13	65	5.1	72.0	37.2	-5.3	75.0	94.0	-5.5	69.3	73.7	-15.7	62.9	89.1	-3.4	41.7	84.4			
		104.1			174.3			148.5			167.8			129.5					
14	78	19.2	64.8	34.6	-4.7	73.3	92.1	-9.0	57.3	81.9	-9.8	47.7	118.8	9	44.8	116.9			
		80.2			170.1			148.2			176.3			162.6					

15	58	7.6	71.4	36.5	-.2	61.1	54.1	-5.7	67.6	99.5	-21.4	70.8	99.8	-6.8	44.2	108.1
		100.3			115.4			172.8			192.1			159.1		
16	77	4.2	97.9	54.0	-2.6	65.9	54.9	-5.5	46.5	109.0	-14.6	45.2	86.8	7.2	40.3	133.1
		147.8			123.4			160.9			146.5			166.2		
17	70	7.0	70.3	63.6	-3.4	89.4	129.5	-5.2	75.0	70.6	-14.5	48.7	98.3	.3	33.2	55.5
		126.9			222.3			150.8			161.5			88.4		
18	51	-.4	87.1	49.2	-4.3	67.6	55.0	-12.6	61.6	108.0	-19.7	48.6	85.0	-9.6	37.6	108.0
		136.7			126.9			182.2			153.3			155.2		
19	54	7.8	85.5	90.6	-2.5	97.8	91.2	-9.0	76.9	84.1	-13.8	43.1	51.7	-3.5	39.1	75.6
		168.4			191.5			170.0			108.5			118.3		
20	49	1.3	86.5	22.1	-3.2	81.9	88.3	-15.0	60.9	106.9	-14.6	49.9	132.2	-9.0	37.2	60.0
		107.3			173.3			182.8			196.7			106.1		
21	59	8.5	68.5	33.3	-9.8	68.8	106.9	-7.6	62.0	91.1	-9.1	44.7	85.1	-15.3	42.0	137.2
		93.2			185.5			160.7			138.9			194.5		
22	73	lb.3	75.0	50.3	-.4	77.1	85.4	-17.1	69.7	105.0	-13.9	55.3	87.2	-7.8	48.3	107.4
		109.0			162.9			191.7			156.4			163.5		
23	60	2.8	97.7	107.3	-5.2	97.3	83.2	-6.0	75.6	76.2	-15.2	51.9	61.2	-12.2	40.8	76.6
		202.3			185.7			157.8			128.3			129.7		
24	55	-4.4	89.5	39.0	-3.0	87.0	125.6	-15.1	77.2	63.5	-21.5	40.1	100.3	-9.1	37.7	98.3
		132.9			215.6			155.8			161.8			145.0		
25	50	26.4	53.3	71.2	-4.7	135.3	101.0	-8.1	80.4	106.3	-12.7	61.4	97.4	-.9	42.2	67.2
		98.1			241.0			194.9			171.5			110.3		
26	52	0.0	89.6	46.9	-3.7	70.4	50.7	-10.2	66.3	110.1	-12.9	63.1	160.7	-12.4	41.4	90.9
		136.5			124.9			186.6			236.7			144.7		
27	74	6.2	81.3	75.1	-1.5	94.8	85.5	-11.9	75.3	87.5	-16.6	51.0	85.2	-8.2	48.0	130.0
		150.2			181.8			174.8			152.8			186.2		
28	64	4.7	94.4	75.7	-3.6	92.3	108.8	-6.4	85.9	120.7	-12.2	52.9	61.5	-2.2	49.3	119.3
		165.4			204.7			213.0			126.6			170.8		
29	53	12.1	78.0	56.3	-4.3	73.6	97.1	-11.9	88.1	126.3	-18.5	66.5	115.5	-9.7	51.9	117.9
		122.2			175.0			226.4			200.6			179.5		
30	68	4.3	95.7	95.4	-2.3	78.6	62.4	-8.8	90.1	135.0	-10.4	75.9	133.5	-9.2	52.0	80.5
		186.9			143.3			233.9			219.8			141.7		

FIRST 6 (WHOLE) MONTH(S)

NO	YR	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(WE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	(EVAP.) (NBS)	(RUN-OFF)	(PRE-CIP.)	WAP.) (NBS)	(RUN-OFF)	(PRE-CIP.:)
1	76	3.6	81.8	43.5	2.9	66.1	20.6	-5.1	58.3	102.0	-9.4	40.3	66.3	2.6	32.5	42.0	58.3	27.2	47.7
		121.6			83.7			165.3			116.0			71.9			16.6		
2	75	26.5	70.6	39.7	-4.9	75.8	54.1	-22.0	60.4	116.1	-23.7	37.7	66.0	2.5	29.3	55.0	57.1	34.6	78.3
		83.7			134.8			198.5			127.4			81.8			55.8		
3	67	11.4	87.0	64.1	5.6	70.7	42.4	-13.8	68.6	104.7	-12.7	49.4	63.2	3.7	42.7	89.0	38.5	30.1	32.6
		139.8			107.5			187.2			125.3			127.9			24.2		
4	66	9.8	73.0	51.0	2.7	74.2	42.1	-7.2	65.8	75.2	-13.4	45.5	88.4	-4.9	48.9	113.5	47.4	31.0	47.2
		114.3			113.6			148.2		73.9	-18.0			167.3			30.8		
5	56	18.6	63.4	48.7	-1.5	76.2	84.0	-7.8	60.2		137.7	46.2	73.5	-11.1	34.6	82.9	23.9	33.5	66.0
		93.5			161.6			141.9						128.6			75.6		

6	61	8.9	129.7	81.4	57.2	-.7	160.8	81.7	78.4	-4.3	120.4	65.6	50.5	-16.6	135.5	45.7	73.3	.1	91.0	34.5	56.6	40.0	108.1	40.7	107.4
7	69	2.6	124.0	79.4	47.2	-1.4	147.7	71."	75.6	-5.2	I56.8	66.2	85.3	-10.5	149."	55.9	82.6	-1.5	129.5	62.8	85.2	77.5	48.0	37.0	88.5
8	62	9.6	114.1	70.6	53.1	-6.2	196.2	77.4	112.6	-9.0	126.7	59.4	58.2	10.3	104.5	40.4	74.4	-4.7	155.0	41.0	109.3	49.6	6%.1	39.3	78.3
9	71	11.6	105.5	83.2	34.0	1.5	192.6	83.2	110.9	-7.9	157.3	73.6	75.8	-5.8	131.5	47.5	78.2	7.5	85.4	35.5	57.4	28.5	108.8	32.4	104.8
10	63	3.2	139.8	87.2	55.8	-2.4	133.4	67.6	63.4	-16.1	189.7	68.4	105.3	-13.4	125.6	41.4	70.9	-1.1	112.4	39.3	71.9	10.6	81.8	30.9	61.5
11	72	17.6	80.1	69.0	28.7	-2.2	123.7	70.5	51.0	-8.4	118.7	50.6	59.7	-10.5	186.2	4%.6	127.0	-6.5	177.7	48.4	122.8	49.5	99.0	43.7	104.8
12	7%	19.2	80.2	64.8	34.6	-4.7	170.1	73.3	92.1	-9.0	148.2	57.3	81.9	-9.8	176.3	47.7	118.8	-.9	162.6	44.8	116.9	26.5	77.2	36.5	67.2
13	57	2.2	138.2	84.8	55.6	1.6	141.0	79.7	62.9	-10.0	194.8	73.0	111.8	-19.6	163.6	61.5	82.4	.5	76.1	33.9	42.7	42.8	116.4	49.8	109.4
14	49	1.3	107.3	86.5	22.1	-3.2	173.3	81.9	88.3	-15.0	182.8	60.9	106.9	-14.6	196.7	49.9	132.2	-9.0	106.1	37.2	60.0	24.2	85.4	34.5	75.2
15	73	16.3	109.0	75.0	50.3	-.4	162.9	77.1	85.4	-17.1	191.7	69.7	105.0	-13.9	156.4	55.3	87.2	-7.8	163.5	48.3	107.4	54.2	75.9	40.9	89.2
16	70	7.0	126.9	70.3	63.6	-3.4	222.3	89.4	129.5	-5.2	150.8	75.0	70.6	-14.5	161.5	48.7	98.3	.3	88.4	33.2	55.5	51.7	117.1	45.2	123.6
17	54	7.8	168.4	85.5	90.6	-2.5	191.5	97.8	91.2	-9.0	170.0	76.9	84.1	-13.8	10%.5	43.1	51.7	-3.5	118.3	39.1	75.6	9.2	120.8	37.4	92.6
18	65	5.1	104.1	72.0	37.2	-5.3	174.3	75.0	94.0	-5.5	148.5	69.3	73.7	-15.7	167.8	62.9	89.1	-3.4	129.5	41.7	84.4	41.1	155.1	51.9	144.3
19	5%	7.6	100.3	71.4	36.5	-.2	115.4	61.1	54.1	-5.7	172.8	67.6	99.5	-21.4	192.1	70.8	99.8	-6.8	159.1	44.2	10%.1	4.2	142.9	54.2	92.9
20	60	2.8	202.3	97.7	107.3	-5.2	185.7	97.3	83.2	-6.0	157.8	75.6	76.2	-15.2	128.3	51.9	61.2	-12.2	129.7	40.8	76.6	33.4	79.9	38.4	74.9
21	55	-4.4	132.9	89.5	39.0	-3.0	215.6	87.0	125.6	-15.1	155.8	77.2	63.5	-21.5	161.8	40.1	100.3	-9.1	145.0	37.7	98.3	38.0	88.6	39.1	87.5
22	50	26.4	98.1	53.3	71.2	-4.7	241.0	135.3	101.0	-8.1	194.9	80.4	106.3	-12.7	171.5	61.4	97.4	-.9	110.3	42.2	67.2	-.3	87.4	36.9	50.3
23	77	4.2	147.8	97.9	54.0	-2.6	123.4	65.9	54.9	-5.5	160.9	46.5	109.0	-14.6	146.5	45.2	86.8	7.2	166.2	40.3	133.1	33.7	158.4	67.1	125.0
24	52	0.0	136.5	89.6	46.9	-3.7	124.9	70.4	50.7	-10.2	186.6	66.3	110.1	-12.9	236.7	63.1	160.7	-12.4	144.7	41.4	90.9	-4.5	82.1	34.8	42.7
25	74	6.2	1 8.5	81.3	75.1	-1.5	181.8	94.8	85.5	-11.9	174.8	75.3	87.5	-16.6	152.8	51.0	85.2	-8.2	186.2	48.0	130.0	57.9	69.0	45.7	81.3
26	59	93.2		68.5	[illegible]	[illegible]	185.5	68.8	106.9	-7.6	160.7	62.0	91.1	-9.1	138.9	44.7	85.1	-15.3	194.5	42.0	137.2	10.6	154.7	43.4	121.9
27	51	-.4	136.7	[illegible]	[illegible]	[illegible]	126.9	[illegible]	55.0	-12.6	182.2	61.6	108.0	-19.7	153.3	48.6	85.0	-9.6	155.2	37.6	108.0	10.8	175.9	58.1	128.6
28	53	12.1	122.2	78.0	56.3	-4.3	175.0	73.6	97.1	-11.9	226.4	88.1	126.3	-18.5	200.6	66.5	115.5	-9.7	179.5	51.9	117.9	49.3	69.5	37.9	81.0
29	64	4.7	165.4	94.4	75.7	-3.6	204.7	92.3	108.8	-6.4	213.0	85.9	120.7	-12.2	126.6	52.9	61.5	-2.2	170.8	49.3	119.3	25.1	136.7	49.7	112.1
30	68	4.3	186.9	95.7	95.4	-2.3	143.3	78.6	62.4	-8.8	233.9	90.1	135.0	-10.4	219.8	75.9	133.5	-9.2	141.7	52.0	80.5	15.0	133.6	49.9	98.7