DIRECTIONS IN WATER SUPPLY FORECASTING

By

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The requirement for effective water supply forecasts is clearly confirmed by the existence of this forum. The continuing search for the best manner to make water supply forecasts and the expanding demands of water management have been responsible for this forum's continuing existence. Once the demands of water resources management people can regularly be met with effective information, this forum may have served its purpose.

Water supply forecasting during the past decades has been largely the determination of a seasonal volume of flow based on periodic inventories of the snow supply. At our office in Sacramento, increasing inquiries are being received for more specific flow information. The distribution of flow, probability of given discharges and specific projections of flow conditions for days, weeks and months are all desired by water resource managers not only during snow melt, but during other periods as well. It became quite apparent in the oversupply seasons of 1967 and 1969 that water management personnel could mitigate flood damages if they could obtain expanded flow information of a reliable nature. During periods of lesser runoff, utilizing detailed forecasts allows well managed water systems to improve the economics of harvesting the water crop. Providing this information raises a significant question about the proper direction of this forum. No longer does the term "Snow Conference" adequately describe the function required by water management. This trend has been defining itself for some years, and the proceedings of recent conferences have pointed quite clearly to a new direction.

In 1962 Peak attempted to account for the effects of evaporation from the snowpack on subsequent streamflow. At the 1954 meeting in British Columbia, Mitchell stated, "The fact remains that we are not equipped to make forecasts.....with the degree of accuracy required for our present day operations." He pointed out that temperature, soil moisture and evaporation need to be considered in water supply techniques, as well as the commonly accepted snow survey data. At the 1965 meeting in Colorado Springs, Anderson and West attempted to introduce terrain features and a consideration of wet and dry years to water supply forecasting. At the same meeting Stockwell also indicated that soil moisture was a significant forecasting variable. At the 1966 meeting, Fletcher pointed to the problem of soil moisture measurement as a significant element in determining the water supply volumes. The attempt to use these parameters was largely one of evaluating runoff volumes with little regard to runoff distribution. Unfortunately many of these factors are time dependent and there is no satisfactory technique of "lumping their characteristics".

It has been previously stated that an effective water management program requires not only total volume information, but also its distribution in time. The proper use of some of the most significant parameters lends itself to a time dependent application. In his paper presented at the 1955 Western Snow Conference session, Blanchard clearly pointed out the economic advantages, in planning, of distributing the flow several months in advance. Riley, Chadwick and Eggleston in 1969 indicated the need for "a practical and dynamic model of the snowmelt process" to provide flow information on a continuous time basis. Only recently through the advent of high speed computers, have practical attempts been made to provide the input required by the operating agencies for solving their water management problems.

At the last conference three papers attempted to deal with the characteristics which are required for a forecast which is both volume and time coordinated. These were the papers on the development and application of a hydrologic model by Hannaford, Busch and Barsch. Another paper was given on using all available hydrologic data by Russell and Obedkoff. The most comprehensive approach, Simulation of Runoff from a Rain and Snow Basin, by Rockwood and Anderson, attempted to illustrate the characteristics which must be considered. These papers, as well as several presented at this conference, undoubtedly reflect the new direction in water supply forecasting. That direction points to a continuing volume vs time analysis based upon the consideration of the significant characteristics of temperature, soil moisture, evaporation, rainfall, as well as the preexisting snowpack. Forecast procedures based solely upon snow surveys and precipitation have been recognized as only considering a small portion of the hydrologic problems involved in making an adequate water supply forecast.

It is time to define the direction in which water supply forecasting must go. It is time to clarify formally the requirements of water management. It is time to recognize that only a comprehensive and continuous hydrologic model can properly evaluate the significant time dependent parameters to which earlier authors have pointed.

An analysis of this situation has led the Sacramento River Forecast Center to develop simulation techniques based upon parameters involving the physical characteristics of basin parameters. It is recognized that the many procedures now extant utilize indices which, although serving as an approximation of, do not do justice to the physical realities which are required for dependable time volume forecasts.

In an attempt to develop more meaningful analyses, we have done extensive simulation work which has resulted in procedures which allow us to reproduce snowpacks at any needed location and elevation and to generate a continuing record of that snowpack over the entire season, verified by periodic snow surveys. This simulation study which has been conducted by R. Burnash of the NWS, and G. Baird of the U. S. Bureau of Reclamation, is based upon the physical characteristics of snow accumulation and melt. It is based primarily upon a report by Winston and data supplied from tests conducted at Central Sierra Snow Laboratory in Soda Springs, California. This application of snow simulation techniques has led to the discovery of many significant errors in past snow records which has previously been unchallenged.

In addition to working on snow simulation techniques, considerable time has been spent on basin modeling methods which consider, on a continuing time frame, the soil moisture, moisture drainage in varying layers of the soil mantle, the water retention characteristic of various soil mantles, runoff response which comes from snow and rainfall input and the effect of evaporation. The integration of these simulations provides a capability based on a consideration of physical laws which apply to snow accumulation, melt, rainfall, percolation, basin soil moisture storage, snow mantle moisture storage, and a composite modeling of the basin characteristics. By utilizing such a technique, it is possible to overcome the weaknesses inherent in any modeling technique which relies upon indices instead of a time dependent analysis of snow and soil physics.

A common technique of determining the volume of spring melt is based upon utilizing an April 1 snow survey and assuming normal precipitation after April 1. The weakness of such a system can be demonstrated with simulation techniques. A composite basin, with soil characteristics similar to those encountered in California was programmed to determine what outflow could be expected in the April-July period from a given snow pack and a predetermined precipitation regime in the April-July period.

Starting with identical snow conditions on April 1 and subjecting the basin to identical subsequent precipitation amounts and distribution, we computed the April-July flow utilizing two initial soil moisture conditions and nine different temperature regimes. The resulting April-July volumes were significantly different. Table 1 indicates how the individual cases deviated from the average of all 18 conditions tested.

The average deviation is in excess of 5 percent and the extreme ratio of highest to lowest, shows a volume shift of 28 percent even though initial conditions and subsequent precipitation are identical in all cases. The volumetric differences are due to changes in effective evapotranspiration and differences in soil moisture storage which result from melt occurring in response to the various temperature regimes.

From these facts it can be established that any procedure which relies on the standard April-July volume forecast has an implicit error which can be evaluated using a synthesis system. The ability to put time dependent variables in their proper perspective is the feature of synthesis systems which produces these long sought results. An example of the spring-summer hydrographs for the extreme volume shifts indicated in Table 1 is shown as Figure 1.

A procedure of the type described is necessary to answer the questions water management is asking. This total hydrologic system provides the Sacramento River Forecast Center with a new dimension in water analysis which is as useful in providing flood warnings on the low elevation Russian River as it is in predicting discharge volumes from a snowbound tributary of the Sacramento.

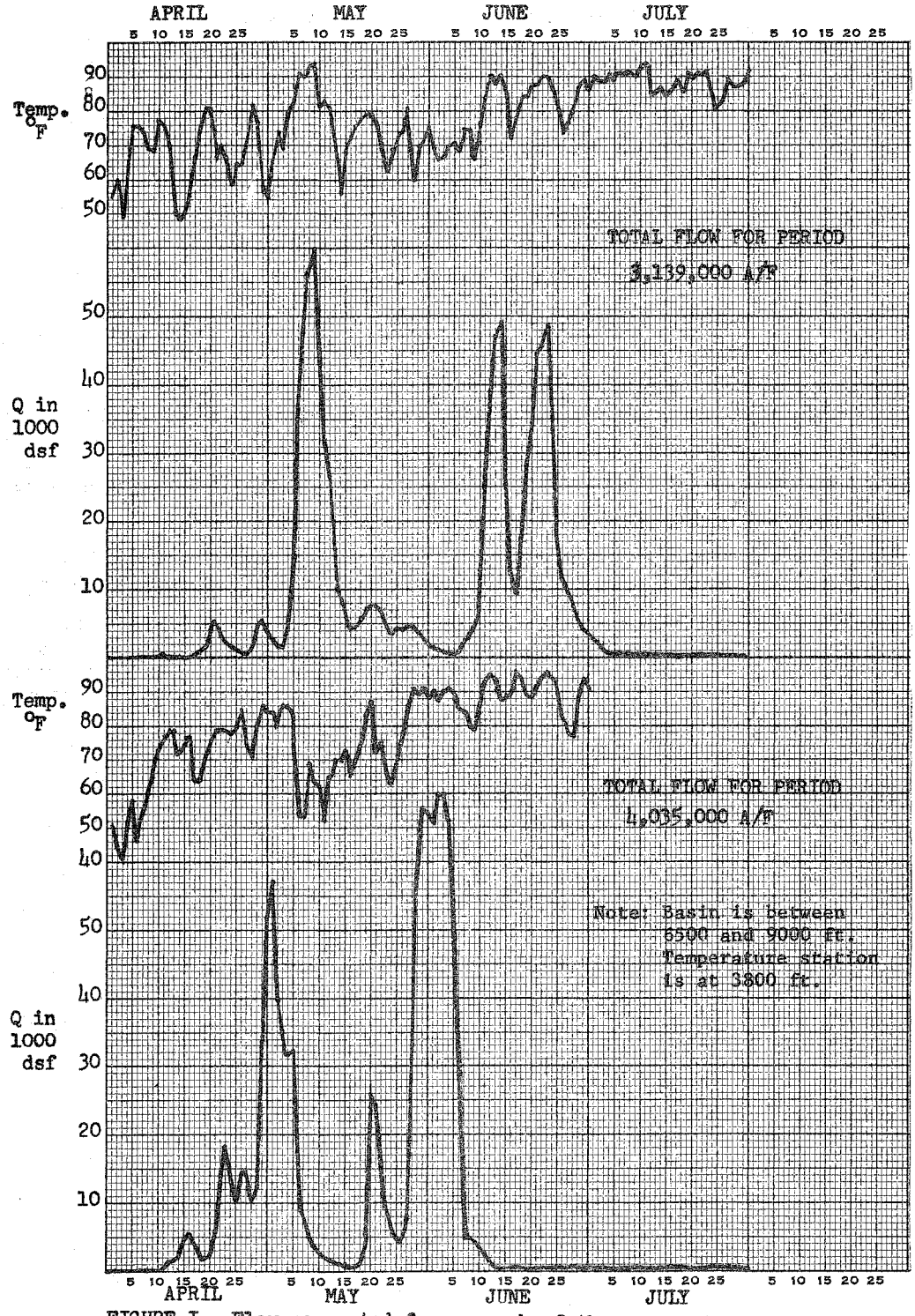

FIGURE I. Flow generated from a pack of the same water content but differing temperature regimes.

TABLE 1

Percent Deviation from Normal April-July Volume Associated with Identical April 1 Packs and Subsequent Precipitation.

	INITIAL SOIL CONDITIONS	
Temp Regime	Moist	Dry
1	+6	-5
2	+11	-2
3	+8	-4
4	+6	-3
5	+2	-8
6	-3	-13
7	+4	-6
8	+6	-4
9	+4	-2

The ability to examine a snowbound tributary with apparently identical pack conditions from one year to the next, and effectively integrate the subsequent soil moisture, temperature, evaporation, and precipitation regimes which truly define how much will run off and when, can only be obtained with such a system. If we are to advance in hydrologic forecasting, such systems are imperative.

To those who share the vision of meeting the purpose of this forum's existence, we appeal for a collective reexamination of our rather parochial standard "Snow Conference". It is time for a redefinition based upon a comprehensive time dependent analysis of the hydrologic cycle. If progress is to be made we should no longer think of a "snow conference" forum. The resolution needed to provide more effective water management information should take place under a title which demonstrates the broader water balance concepts which are required for progress in meeting the forecasting demands imposed by water management.

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