

Errata.—The following corrections should be made to the original paper:

- Page 38, line 22: Should read "which shows" instead of "which slows"
 Page 38, lines 29 and 30: Should read " W_2 = the water content after wetting and W_1 = water content before wetting in the soil profile" instead of " W_2 = the water content before wetting in the soil profile"
 Page 45, Table 1, Col. 3: Should read " h_T , in inches" instead of " h_T , in minutes"
 Page 45, last line: Should read 5% instead of 25%

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 REVIEW OF SMALL BASIN RUNOFF PREDICTION METHODS¹

Discussions by Asit K. Biswas and Kenneth G. Renard

ASIT K. BISWAS,¹¹ M. ASCE.—Allison's attempt to review the methodologies available for flood estimation from small drainage areas is of considerable interest to all hydrologists, and is laudable as well as timely. There is one unfortunate omission in the paper, however. Nowhere does the author define how small is a "small" basin. Obviously, the term "small" is extremely relative. For example, in a recent (1967) discussion of one of the writer's papers, Kaul stated¹² that catchment sizes on the order of about 700 sq miles are small; but to the writer, they are fair size drainage areas. Although, admittedly, a limitation on the size of a small basin is bound to be purely arbitrary, it would at least have the merit of creating no misunderstanding.

There is no sharp distinction between the various methods available for estimating floods from small and large basins. Table 1 shows the methodologies suggested by the ASCE *Hydrology Handbook*¹³ for the estimation of design flood from different sizes of catchment areas.

Because the Handbook was published in 1949, the absence of regional analysis is not surprising, but the omission of the probable maximum precipitation method is.

In a recent study (1966) by Biswas and Fleming^{14, 15} on previous flow records of Scottish rivers, the regional analysis method was found to be quite satisfactory for drainage area as small as 2 sq miles. Biswas and Fleming

¹March, 1967, by Stephen V. Allison (Proc. Paper 5119).

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¹²Kaul, A. K., discussion of "Hydropower Developments in India," by Asit K. Biswas, *Journal of the Power Division, ASCE*, Vol. 93, No. PO1, Proc. Paper 5140, Mar., 1967, pp. 145-146.

¹³"Hydrology Handbook," ASCE, Manual of Engineering Practice No. 28, 1949, p. 90.

¹⁴Biswas, Asit K., and Fleming G., "Regional Flood Frequency Analysis for Scotland," *Proceedings, Institution of Civil Engineers*, London, Vol. 35, Paper No. 6974, Oct., 1966, pp. 313-315.

¹⁵Biswas, Asit K., and Fleming G., "Floods in Scotland: Magnitude and Frequency," *Water and Water Engineering*, London, Vol. 70, No. 844, June, 1966, pp. 246-252.

also attempted to correlate runoff with physiographic and meteorologic factors other than catchment area, but these factors proved to be extremely difficult to define, as well as to measure, and were somewhat interdependent. When the factors were approximated or averaged some accuracy had to be sacrificed, and the correlation finally obtained was rather complex and did not give significantly better results.

The problem of statistical significance, as pointed out by Allison is tricky when runoff is estimated from rainfall, although it is not so complex when actual flow data of the river under consideration is analyzed. However, the problem, in such cases, especially for small basins, is a lack of streamflow records. It is often difficult to obtain 50-yr flow records for major rivers; and it is even more difficult to obtain such records for minor rivers, as it was probably considered to be neither worth the expense nor the time to gage them. The surprising fact, however, is the reluctance of some present-day river authorities to initiate new stream gaging programs.

It is possible to transpose an observed storm (within an hydrologically homogeneous area and without maximization) over a small basin and demon-

TABLE 1.—METHODOLOGIES¹⁵ FOR FLOOD ESTIMATION

Catchment areas, in square miles (1)	Methods used (2)
1	Overland flow hydrograph; rational method
1 to 100	Rational method; unit hydrograph; flood peaks versus drainage areas
100 to 2000	Unit hydrograph; flood frequencies; flood peaks versus drainage areas
2000	Flood routing; flood frequencies; flood peaks versus drainage areas

strate that, if the storm was centered over the catchment, the resulting flood would be many times greater than those observed.¹⁶ However, this is not very helpful as the probability of this occurrence cannot be determined, and this is a significant factor for minor structures like culverts. Unfortunately, current knowledge (1967) does not permit determination of the probability of a standard project storm centering over a specified small basin.

KENNETH G. RENARD,¹⁷ M. ASCE.—The author has directed attention to an important area in the field of hydrology, where many questions remain. The problems of runoff synthesis are generally complicated. Because of inadequate input information, sophisticated models requiring elaborate data are often of little more value than simple models considering only a few parameters.

The efforts a design hydrologist must make to ensure an adequate design are largely dictated by the economics of the project. If failure of the project might involve loss of life, or large inconveniences to society, elaborate design

¹⁶ Biswas, Asit K., "Risk Criteria and Flood Estimation." Lecture Notes on Hydrology, No. 1, Queen's University, Kingston, Ontario, Canada, 1967.

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efforts are necessary. In such cases, comparison of the results of more than one design procedure can be used, and reasonable answers can thus be obtained.

Elaborate design efforts can also be pursued in instances where substantial construction savings may be realized if the refinement reduces the design discharge. A greater degree of confidence associated with a design allows a smaller risk, and thus a smaller safety factor can be used in the project. In some design situations, reducing the peak discharge does not particularly reduce the construction cost. In such instances, long periods of design time for the hydrologist are not generally warranted.

Because the scope of the investigations can differ significantly, the writer believes that design problems involving only peak rates should be discussed separately from design problems involving hydrograph synthesis. Less refinement is generally necessary to determine peak rates than to determine a complete hydrograph. These two design problems are treated in the paper as one topic; and in several instances, the reader may be misled regarding the objective of the author.

The author lists generally two types of available methods for determining basin runoff: (1) Methods based on runoff records, and (2) methods based on rainfall records. A method based on rainfall and runoff records should be added to this grouping. Examples of such an approach are the two-parameter gamma distribution as used by Nash,¹⁸ Minshall's¹⁹ graphical approach, and the multiple regression approach as used by Wu, et al.²⁰

The design methods used presently, and those described by Allison, are primarily of a deterministic nature. Recent advances in stochastic models have opened still another new field of synthetic hydrology. This subject of stochastic models is certainly too lengthy to discuss here. Beard²¹ has examined such a stochastic model. The Committee on Surface Water Hydrology of ASCE reported their recommendations for standardizing the definition of terms in stochastic hydrology as well as in parametric hydrology.²² A review of this report is most valuable prior to reading articles on "synthetic" hydrology.

As stated in the paper, the problems of runoff hydrograph synthesis are especially acute; this is particularly true in the western United States. Most runoff studies in the United States have been made in the humid climates, and relationships determined from the humid watersheds are not generally applicable in arid and semiarid watersheds in the Southwest. Difficulties in measurement in these semiarid areas are largely responsible for the lack of understanding of hydrologic processes in such areas. The effect of the extreme

¹⁸Nash, J. E., "Systematic Determination of Unit Hydrograph Parameters," *Journal of Geophysical Research*, Vol. 64, No. 1, Jan., 1959, pp. 111-115.

¹⁹Minshall, Neal E., "Predicting Storm Runoff on Small Experimental Watersheds," *Journal of the Hydraulics Division, ASCE*, Vol. 86, No. HY8, Proc. Paper 2577, Aug., 1960, pp. 17-38.

²⁰Wu, J. P., Delleur, J. W., and Diskin, M. H., "Determination of Peak Discharge and Design Hydrographs for Small Watersheds in Indiana," *Hydromechanics Laboratory, Purdue University, Lafayette, Ind.*, Oct., 1964.

²¹Beard, Leo R., "Hydrologic Simulation in Water-Yield Analysis," *Journal of the Irrigation and Drainage Division, ASCE*, Vol. 93, No. IR1, Proc. Paper 5134, Mar., 1967, pp. 33-42.

²²"Parametric Hydrology and Stochastic Hydrology," Committee on Surface Water Hydrology, Walter Hofmann, Chmn., *Journal of the Hydraulics Division, ASCE*, Vol. 91, No. HY6, Proc. Paper 4539, November, 1965, pp. 119-122.

variability in precipitation resulting from the intense convective storms, which are common in the Southwest during the summer months, are well recognized but only partly documented. The work of Osborn^{23,24} has helped tremendously in describing precipitation variability, but more needs to be done, particularly on depth-area-frequency of the convective storms.

Published rainfall records in the mountainous western United States are generally not truly indicative of the patterns over the entire area. Most of the gages are located in the more populated areas, which are generally found in valleys. In design problems dealing with variations in elevation, the orographic influences of rainfall must generally be decided from the experiences of the design hydrologist, which in itself is a most perplexing problem.

Hydraulic transit phenomena in general, and transmission losses in particular, are also exceedingly important in semiarid watersheds with the influent streambeds. The transmission losses not only affect the runoff volumes, but also greatly affect the hydrograph shape.^{25,26} Much work remains to be done on development of hydrologic design methods for such areas, particularly for predicting the frequency of peak flows. Short records have, until now, limited the usefulness of hydrologic records for frequency analyses.

The principal problems of extending either the runoff- or rainfall-oriented methods into the four categories appear to be well delineated by the author. He states that ". . . even within a relatively limited geographical area, the number of possible interactions between different basin characteristics is infinite." This statement implies that the basin characteristics and the climatological characteristics are uniform primarily in their heterogeneity. Thus, one might justifiably expect that a model developed for one climatic and physiographic province may not truly represent conditions in another area with different climatic and physiographic conditions.

Problems of statistical significance in hydrology are becoming more common, as noted by the author. Perhaps the main problem for the hydrologist in projecting his short-term time series into a 50-yr or 100-yr return period prediction is deciding what type of statistical distribution to use. For instance, the normal, log normal, and gamma distributions, or the Gumbel extreme value distributions give 50-yr floods of greatly varying magnitude when the standard deviation of the time series is large. What is needed is information on what types of distributions best describe runoff volumes and peak discharges for the various types of watersheds (i.e., various sizes and climatic types) that might be encountered.

The author's statement that "confidence limits of predicted runoff values tend to be difficult to define" is quite misleading. Most statistical textbooks

²³ Osborn, H. B., and Reynolds, W. N., "Convective Storm Patterns in the Southwestern United States," *Bulletin, International Association of Scientific Hydrology*, Vol. 8, No. 3, 1963, pp. 71-83.

²⁴ Osborn, H. B., "Effect of Storm Duration on Runoff from Rangeland Watersheds in the Semiarid Southwestern United States," *Bulletin, International Association of Scientific Hydrology*, Vol. 9, No. 4, 1964, pp. 40-47.

²⁵ Keppel, R. V., and Renard, K. G., "Transmission Losses in Ephemeral Stream Beds," *Journal of the Hydraulics Division, ASCE*, Vol. 88, No. HY3, Proc. Paper 3116, May, 1962, pp. 59-68.

²⁶ Renard, K. G., and Keppel, R. V., "Hydrographs of Ephemeral Streams in the Southwest," *Journal of the Hydraulics Division, ASCE*, Vol. 93, No. HY2, Proc. Paper 4710, Mar., 1966, pp. 33-52.

such as Snedecor²⁷ describe procedures for computing confidence limits based on the standard deviation. Perhaps what the author intended to say was that because of large standard deviations, the range of values from high to low in the confidence limits may drastically change the hydrologic design for the location.

LAND MODIFICATION FOR EFFICIENT USE OF WATER²⁸

Discussion by Paul F. Keim

PAUL F. KEIM,²⁹ F. ASCE.—The writer was in complete agreement with the author's conclusions. Water management is the key to successful irrigation, but efficient management is not possible if the surface of the land is not properly prepared for the function it is expected to perform. The writer has just prepared a memorandum concerning possible legislation for irrigation water societies and for irrigation systems in one of the Latin American countries. It was stated in this memo that "Effective Land Management is only possible when surface modification, adequate soil preparation, proper cultivation practices and selected cropping patterns are factors of consideration and when the quantity of the available water to be delivered and the time of delivery to any user shall be predicated solely upon the basis of soil-water-plant relationships."

In this same country, which has large but seasonal rainfall, there are many readily irrigable areas which require little modification. A large proportion of the country, however, is covered by very shallow residual soils over limestone and is combined with undulating topography. In this case, the designer planner is not only not allowed "much freedom," he has no latitude at all.

The writer's Pennsylvania Dutch ancestors, on coming to Nebraska more than 100 yr ago, immediately recognized the problems of land management in relation to drainage and conservation of the natural water, even though they were in the part of Nebraska which was not, nor is now, irrigated. That land is still producing, which might not have been the case had management not been practiced in those early years.

Not all of the section headings of the paper (i.e. "Land Grading for Drainage," etc.) are applicable in any one case, but all must be considered when the efficient use of water is the subject.

One note of amusement to the writer was the reference to "areas of higher

²⁷Snedecor, G. W., Statistical Methods, 5th ed., The Iowa State College Press, Ames, Iowa, 1956.

²⁸March, 1967, by Tyler H. Quackenbush (Proc. Paper 5124).

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