A PRAGMATIC APPROACH TO EVALUATING A MULTIPURPOSE STREAM-GAGING NETWORK

by Kenneth L. Wahl and John R. Crippen

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ABSTRACT

A method for evaluating the relative worth of individual gaging stations in a multipurpose network is presented. Each individual station in the network is evaluated on the basis of selected rating factors. The factors relate to the need for information at the station, accuracy of data, economic aspects of operation, and usefulness of data as a basis for estimates at ungaged sites. The total score for the various factors provides a convenient basis for comparing relative importance of individual stations. The rating-factor method is both flexible and definitive, but the point values that are assigned for each rating factor are somewhat subjective. A table of the point values and guidelines for assigning those values is presented.

INTRODUCTION

The gaging-station networks that exist today have evolved over approximately the last hundred years as a result of many different needs. The U.S. Geological Survey is the Federal agency primarily responsible for the collection of streamflow data. The gaging station networks operated, however, are seldom complete enough to provide all the data desired at every location where needs arise. The networks, therefore, need to be evaluated as a sampling process from which information can be extrapolated with respect to both time and location. While the collection of stations usually is referred to as a network, the collection of gaging stations is not a network in the purest sense because data collected at individual stations or groups of stations in the network are intended to answer entirely different questions than data collected at other stations. In reality, the network is an amalgam of many individual networks with different objectives and sources of funding. Fortunately, many stations provide data that are useful for purposes other than that for which the station was originally installed.

Sometimes data are needed at sites that are not considered to be optimum for defining the hydrologic system. For example, financial or legal requirements and operating schedules of reservoirs or of waste-disposal facilities depend on timely streamflow data at specific sites. Stations established at such sites are operated primarily to provide data for a specific water-management purpose, but the data also are useful for hydrologic purposes. For example, stream-systems models cannot be calibrated and verified without data for diversions and reservoir operations. From a purely hydrologic viewpoint, the stations constitute a sampling system to describe streamflow characteristics, such as mean annual flow, average flow during certain seasons or months, instantaneous peak flows, or the ranges of probability distributions of such characteristics. The majority of stations, however, are not operated exclusively for hydrologic purposes; the desire for data arises from numerous needs. The need for these stations needs to be considered in any system of analysis, and the value of their data needs to be weighed against the value of data from other stations that might be deleted if they serve no unique purpose.

The funds to support most streamflow-data collection are provided by public agencies, either Federal, State, county, or municipalities. Budgetary restrictions on these agencies combined with the effects of inflation during the past several decades have caused the number of stream-gaging stations to remain nearly static or to decline. The number of stations operated in Nebraska from 1894 to 1983 are shown in figure 1 (Engel, Wahl, and Boohar, 1984); the pattern shown in figure 1 is representative of the history of gaging-station operations in most western States. Using each station in the network to satisfy as many joint needs as possible becomes increasingly important as budgetary restatictions increase.

The purpose of this report is to present a method that can be used in evaluating the relative usefulness of the information provided by individual gaging stations in a multipurpose network. The method differs from most available methods because it can be used where the network is made up of stations with different purposes and sources of funding. The method also can be used to evaluate stations in a network that is jointly funded by several agencies with differing data needs.

This report is directed principally at the evaluation of a network based on quantitative measures of surface flow, but similar principles and concepts may be applicable for networks designed to measure water quality, sediment movement, or ground-water levels. Specific problems commonly arise that require data collection for one purpose at points that do not coincide with needs for other purposes. Careful study of the interrelation of data needs and of possible modification of requirements is necessary if duplication of data-collection efforts is to be avoided.

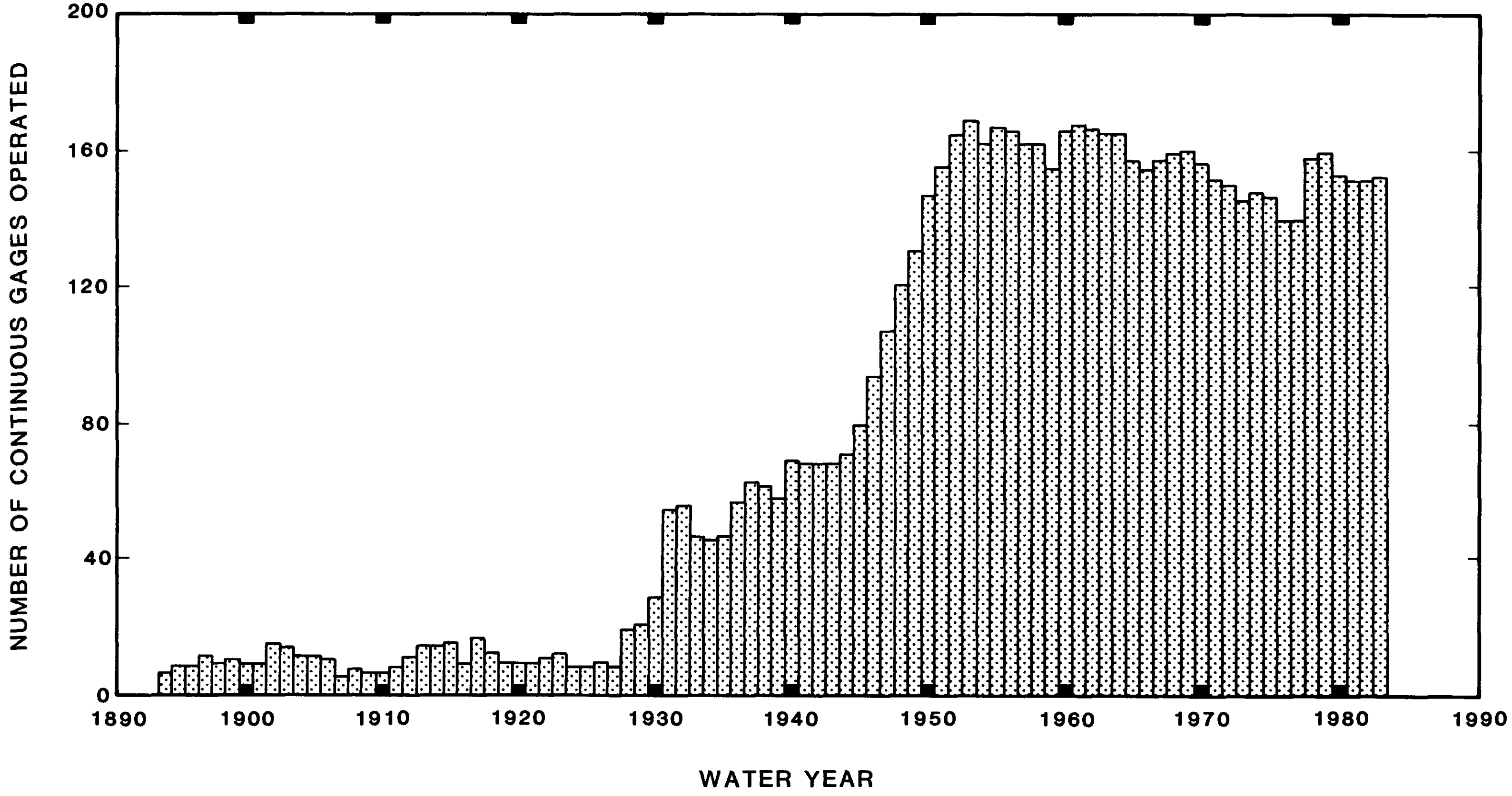

Figure 1.--History of continuous stream gaging in Nebraska.

EXISTING METHODS FOR EVALUATION METHODS

Moss (1982) notes that problems commonly arise in the design of networks because stations operated to satisfy many data uses are considered to comprise a single network. He points out that because of the many intended data uses, the data provided by this network will be used in many types of decisions, each with its own requirements for data and accuracy.

Moss (1982) gives an overview of techniques that have been used in network design. Some of these techniques have been used on all or parts of the U.S. Geological Survey gaging station network in the United States. However, none of these techniques are intended to address all the diverse needs for data. Most deal with the design of that part of the network that is operated primarily to define regional hydrology (Benson and Carter, 1973, Moss and Karlinger, 1974). As such, the techniques address only a part of the overall network.

In a national study of the streamflow-data program of the U.S. Geological Survey reported by Benson and Carter (1973), streamflow data were separated into four categories based on uses to be made of the data. The four categories were data for current use, planning and design, definition of long term trends, and defining the stream environment. Because the objectives for each data type were different, the four categories were treated as four separate but overlapping networks and were evaluated separately.

The technique of regression simulation was developed and discussed by Moss and Karlinger (1974). This method, however, is intended to be used to evaluate those stations in the network that are operated to define regional hydrology. The method is not readily applicable to those parts of the network needed for reservoir operations or to supply current information.

The evaluation method described by Maddock (1974) differs from most other evaluation methods in that it makes no provision for expanding the network; it is intended only for reducing a network in response to budgetary constraints. Maddock's method optimizes information yielded by the reduced network, subject to the budgetary constraints. However, the measure of information is the cross correlation coefficient. Therefore, the method is intended to be applied to the gaging stations operated to define regional hydrology. As such, Maddock's method cannot be used to simultaneously evaluate all stations in a multipurpose network.

The U.S. Geological Survey is currently (1984) involved in a re-evaluation of the Nationwide streamflow-information program. This evaluation has three major phases: phase one requires that data uses and funding be summarized for all continuous-record gaging stations; in phase two, stations are examined to see if there are alternative ways of providing the required data (in lieu of operating a station); and phase three is an in-depth evaluation of the operating efficiency of each station in the network. A pilot study was completed for Maine (Fontaine and others, 1984), and W. O. Thomas, Jr., and M. E. Moss (U.S. Geological Survey, written commun., 1984), have summarized the work completed under that study. Phase one of the Nationwide study is similar to the method proposed in this report except that in the Nationwide study stations are only proposed for discontinuance if no valid uses are found for the data.

PROPOSED METHOD FOR NETWORK EVALUATION

The preceding methods suggest that there is presently (1984) no completely objective method for simultaneously evaluating all gaging stations in a network in which the stations are operated for different purposes. Therefore, a somewhat formalized method of determining relative station worth by compositing subjective evaluations is proposed.

A set of criteria has been developed jointly by the California Department of Water Resources and the U.S. Geological Survey for assessing the relative merits of gaging stations in a multipurpose network. The criteria include a number of factors relating to need for information at the site, accuracy of data, economic aspects of operation, and usefulness of data as a base for estimates at ungaged sites. A summary of the station factors and the range of point values that were found to be useful in California are shown in table 1. The flexibility of this method is one of its advantages. Both the factors and the individual weights can be readily modified to make the method applicable in other areas. The need for modification probably will become apparent early in a given analysis, and the format of a more suitable categorization will evolve.

Evaluation Process

The evaluation process can be described as a three-phase activity. The first phase is a review and systematic summary of all gaging stations that have been and are now being operated. In the second phase, point values are assigned to individual stations for each factor in table 1. If the evaluation is being done only to select stations for discontinuance, only active stations will be included in the second phase. However, prospective stations also could be rated during this phase and thus be compared to existing stations. The third phase is the identification of stations that can be discontinued (or of sites where stations should be installed, if ungaged sites were included in phase 2).

Table 1.--*Summary of gaging-station factors and points*

Station-evaluation factor	Possible Point Range
1. Characteristics of site	
A. Quantity of water (not measured elsewhere)	1- 7
B. Areal coverage	1- 6
C. Data accuracy	1- 4
D. Length of record	2- 6
E. Correlation efficiency	0- 4
F. Unimpaired flow	0- 4
2. Existing and potential beneficial uses of water	0-15
3. Magnitude of water-resource problems	0-15
4. Data uses for planning	0-15
5. Data uses for management	0-15
6. Economic considerations	
A. Value of water	0- 6
B. Cost of station, operation, and maintenance	1- 3

The phase-one summary needs to note lengths of record, purpose of the data-collection activities, assessments of the quality of recorded data as related to purpose, and the relative difficulty (accessibility, cost, and so forth) of collecting the data at the sites. This summary is needed in phase two to define point values for the factors dealing with site characteristics.

The second phase involves developing a table that gives relative rankings for each gaging station (or potential station) included in the analysis. The factors evaluated and the guidelines used in assigning point values for each factor are given in table 2. The result of this phase is a table listing the point totals for each gaging station. Those stations with the greatest potential value have the largest total point scores.

The third phase is identification of current gaging stations that can be eliminated, based primarily on the rating points derived from the second phase, but also with consideration of the summary prepared in the first phase. Stations with the smallest total-point scores are candidates for discontinuance if budget constraints require a reduction in the network. Changes also may be indicated in the mode of operation at certain stations; for example, data may need be obtained only at times of high flow, or low flow, or during certain seasons. However, this is a decision that needs to be made based on the known needs for data. The rating criteria are not structured to make distinctions between needs for different flow characteristics.

The preceding discussion presumes that this procedure will be used to select stations for discontinuance. The procedure also could be used to prioritize potential gaging-station locations and would permit comparing potential sites to existing sites. However, the items under "Characteristics of site" that deal with quantity of water and data accuracy would have to be estimated.

There is a possibility that the summary evolving from phase 1 will reveal for some localities a pattern of multiple gaging stations, some of them providing data that can be combined to increase the information at one index station. In some cases the existence of many short-term stations at relatively nearby locations may reveal a history of groping to obtain data where conditions are difficult or problems are not well defined. For example, on the Santa Ana River in southern California records have been obtained at five stations with drainage areas ranging from 810 to 1,010 mi^2 and from seven stations with drainage areas ranging from 1,490 to 1,701 mi^2. A history of this nature indicates a need for careful study of station siting and of the overall data needs in the area.

Table 2.--*Guidelines for assigning point ratings*

Station factors	Points
1. Characteristics of site	
A. Quantity of flow, not measured at another gage, that reaches the site	
Mean annual unmeasured flow, in cubic feet per second	
3,000 - or more	7
1,000 - 3,000	6
300 - 1,000	5
50 - 300	4
10 - 50	3
2 - 10	2
0 - 2	1
B. Areal coverage (based on hydrologic unit maps, by State, prepared by the U.S. Geological Survey)	
Outflow from hydrologic region	6
Outflow from hydrologic subregion	5
Outflow from hydrologic accounting unit	4
Outflow from hydrologic cataloging unit	3
Outflow from major part of cataloging unit	2
Outflow from small area	1
C. Data accuracy	
Excellent (data accurate under all flow conditions)	4
Good (data less accurate under some flow conditions)	3
Fair (accuracy limited by site conditions)	2
Poor	1
D. Length of record, in years	
0 - 5	6
5 - 10	4
10 - 25	2
25 - 40	4
40 - or more	6
E. Correlation efficiency	
Excellent	4
Fair	2
Poor	0

Table 2.--*Guidelines for assigning point ratings*--Continued

Station factors	Points
F. Unimpaired flow (direct measurement of or the ability to compute unimpaired flow)	
Excellent (85-100 percent)	4
Fair (70-85 percent)	2
Poor (less than 70 percent)	0
2. Existing and potential beneficial uses of water	
Numerous beneficial uses, of regional importance	10-15
Numerous beneficial uses, of local importance	5-10
Few beneficial uses, of regional importance	8-12
Few beneficial uses, of local importance	0- 5
3. Magnitude of water-resource problems	
Major known problems of regional importance exist	15
Lesser problems of more than local importance exist	10-15
Only local problems exist	8-12
Potential problems may exist or arise	5- 8
No problems or very minor problems anticipated	0- 5
4. Data uses for planning (flood control, water rights, water-quality control, water conservation, power, monitoring, fishery, recreation, and others)	
Important to both regional and local planning	10-15
Important to regional planning	8-13
Important to local planning	5-10
No importance or of slight use to local or regional planning	0- 4
5. Data uses for management (flood control, water rights, water-quality control, water conservation, power, monitoring, fishery, recreation, and others)	
Important to several management needs	15
Important to one management need and useful for others	10-15
Useful for several management needs	5-10
Useful for a single management need	0- 5

Table 2.--*Guidelines for assigning point ratings*--Continued

Station factors	Points
6. Economic considerations	
A. Value of water	
High value (for municipal, industrial, power, and required irrigation of crops)	5- 6
Moderate value (supplemental irrigation of crops)	2- 4
Low value (for small seasonal uses and little or no irrigation of crops)	0- 2
B. Cost of station and operation and maintenance	
Inexpensive	3
Average	2
Expensive	1

The values shown in table 2 under "Length of record" require some explanation. The standard error of estimate of a particular streamflow characteristic is inversely related to number of years of record (Benson and Carter, 1973); after 20 to 30 years of record are obtained, however, the rate of decrease in standard error slows appreciably. Therefore, this factor was decreased as record length increased until record length reached 25 years. However, records longer than 25 years were believed to be increasingly important as indicators of trends, so the factor was increased with increasing record length after 25 years.

Use of Evaluation Table

In using these criteria the sum of the number of points assigned to factors can range from 6 to 100, with the larger number applying to the most important, most accurate, and least expensive site. The sums of points for a given group of gaging stations provide a quick measure of the relative merits of the stations.

An evaluation could be approached in several ways. One possibility would be for all agencies who are involved in the network to assign point values to all gaging stations for all categories. Perhaps a more practical approach would be for the operating agency to rate those factors dealing with the operational aspects--accuracy of data, and so forth--and for agencies concerned only with the use of data to prepare the ratings for factors dealing with need for data. The various contributions could then be compiled into a single table.

It is unlikely that two individuals would rate many gaging stations with identical values. In a situation where operation of a station is dependent on agreement among two or more parties, each party could determine their own rating. Items of substantial disagreement would need to be reconciled, and an average rating assigned. This set of criteria can be modified or expanded to accommodate specific situations. For example, certain stations may be operated to obtain very specialized information that is vital to a flood-warning program, although the stations may be expensive to operate, and of limited use except at times of very high flow. The sum of factors accumulated on the basis of the criteria outlined here would be small. Nevertheless, the station needs to be continued if no alternative site with superior characteristics is available. The importance of the station in question needs to be indicated in some manner.

The criteria outlined here are based in large part on the value of the record of streamflow only. Some gaging stations may be of substantial importance in obtaining water-temperature data or some aspect of chemical quality rather than streamflow. Because of these differing needs, two or more sets of criteria may be needed.

Perhaps the weakest point of the criteria, and an important one, is the measure of ability to obtain data at other sites by means of correlation, that is, the value of the gaging station as a base for estimates. A matrix of correlation coefficients for daily discharges can be produced for selected stations using readily available computer programs. However, correlation coefficient and length of record need to be combined in some manner. For example, a correlation factor (CF) might be computed thus:

$$CF = L/25 + 25(C-0.7) \qquad (1)$$

with L the length of record, in years; and C the average of the three largest correlation coefficients between the subject station and all others in the study. The weighting used here was arbitrarily selected to provide a reasonable relation between length of record and closeness of correlation.

SUMMARY

Selection of sites for a multipurpose network of stream-gaging stations cannot be accomplished by purely objective means. However, a method of rating the relative worth of individual stations has been devised. This method is definitive, but is somewhat subjective. Point values are assigned to each gaging station for factors relating to the need for information at the site, accuracy of the data, economic aspects of operation, and usefulness of the data as a basis for estimates at ungaged sites.

The evaluation is done in three phases. In phase one, a systematic summary is prepared for all gaging stations in operation. Point values are assigned for the various factors in phase two, and relative rankings are determined. Current stations that can be eliminated are determined in the third phase; this determination primarily is based on the relative rankings from the rating points, but can be modified if management considerations dictate that a low-ranked station be maintained.

A table of factors and guidelines for use in assigning point values is presented. The factors and point values are intended only as example; the concepts of this method are widely applicable, but the factors and point values required may differ between networks and regions. The method is flexible, however, in that both the factors used and the point-value ranges assigned to individual factors can be readily modified if the need arises.

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