COST EFFECTIVENESS OF THE U.S. GEOLOGICAL SURVEY'S STREAM-GAGING PROGRAM IN ILLINOIS

By Dean M. Mades and Kevin A. Oberg

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Multiply inch-pound units	by	To obtain SI units
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

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ABSTRACT

Data uses and funding sources were identified for the 138 stream-gaging stations operated in Illinois during the 1983 water year. Streamflow data collected at five gaging stations are used only for regional hydrologic studies. As an alternative to stream gaging, a statistical model was evaluated as a means of providing streamflow data for each of those five gaging stations. Estimated discharges calculated with the statistical model did not compare accurately enough with observed discharges to warrant deactivating stream gaging at those gaging stations. Streamflow records for a sixth gaging station were simulated within 10 percent of observed streamflow for 88 percent of the days studied with a flow-routing model, and for 81 percent of the days studied with a statistical model.

The annual budget, in 1983 dollars, for operating the 138-station stream-gaging program in Illinois is $768,000. The current average standard error of instantaneous discharge for all gaging stations is 36.5 percent. This overall level of accuracy could be maintained with a budget of $717,500 if stream-gaging resources were redistributed among the gaging stations.

A minimum budget of $706,600 is required to operate the program; a budget less than this does not permit proper service and maintenance of the gaging stations. At this minimum budget, the average standard error of instantaneous discharge is 38.5 percent. The maximum budget analyzed was $1,075,000 and resulted in an average standard error of instantaneous discharge of 19.7 percent.

INTRODUCTION

The U.S. Geological Survey is the principal Federal agency collecting surface-water data in the Nation. The collection of these data is a major activity of the Water Resources Division of the U.S. Geological Survey. The data are collected in cooperation with State and local governments and other Federal agencies. The U.S. Geological Survey is presently (1983) operating approximately 8,000 continuous-record streamflow stations throughout the Nation. Some of these records extend back to the turn of the century. Any activity of long standing, such as the collection of surface-water data, should be reexamined at intervals, if not continuously, because of changes in objectives, technology, or external constraints.

The last systematic nationwide evaluation of the streamflow information program was completed in 1970 and is documented by Benson and Carter (1973). A study by Sieber (1970) described the development of Illinois' surface-water program and proposed a program to meet the future needs of water-data users.

The U.S. Geological Survey is presently (1983) undertaking a nationwide evaluation of the stream-gaging program that will be completed over a 5-year period with 20 percent of the program being analyzed each year. Stream gaging is the process of measuring the depths, areas, velocities, and rates of flow in natural or artificial channels (Langbein and Iseri, 1960, p. 19). The objective of this evaluation is to define and document the most cost-effective means of furnishing streamflow information.

This report documents the results of an evaluation of the 1983 Illinois stream-gaging program. The first step of the evaluation identifies the principal uses of streamflow data and funding sources for every continuous-record streamflow station (hereafter, "gaging station"). Gaging stations for which data are no longer needed are identified. In addition, gaging stations are categorized as to whether the data are available to users in a real-time sense, on a provisional basis, or at the end of the water year.

The second step of the evaluation is to examine less costly alternative methods for furnishing the needed information; among these are flow-routing and statistical techniques. The stream-gaging activity no longer is considered a network of observation points, but rather an integrated information system in which data are provided both by observation and synthesis.

The final step of the evaluation involves the use of Kalman-filtering and mathematical-programing techniques to define strategies for operating the gaging stations that minimize the uncertainty in the streamflow records for given operating budgets. Kalman-filtering techniques are used to compute an uncertainty function for each gaging station in the stream-gaging network. The uncertainty function relates the standard errors of computed or estimated streamflow records to the frequency of visits to a gaging station. A steepest descent optimization program uses these uncertainty functions, information on practical routes to the gaging stations, the various costs associated with stream gaging, and the total operating budget to calculate the frequency of visits to each gaging station that minimizes the overall uncertainty in the streamflow records. The stream-gaging program that results from this final step of the evaluation will meet the expressed water-data needs in the most cost-effective manner.

This report is organized into five sections; the first being an introduction to the study itself and a discussion of the Illinois stream-gaging program. The middle three sections each contain discussions of an individual step of the evaluation. Because of the sequential nature of the steps and the dependence of subsequent steps on the previous results, summaries of conclusions are given at the end of each middle section. The complete study is summarized in the final section.

History of the Stream-Gaging Program in Illinois

The U.S. Geological Survey began collecting surface-water data for Illinois streams in water year 1903 when six gaging stations were established; Rock River at Rockton (05437500), Des Plaines River near Channahon (05539660), Illinois River at Minooka (05541510), Illinois River at Ottawa (05553500), Illinois River near La Salle (05556000), and Illinois River at Peoria (05560000). The stream-gaging program gradually expanded to 47 stations in 1939. Severe flooding in 1937 and 1943 increased public interest in the hydrology of the State's streams; by 1955, the U.S. Geological Survey was maintaining 157 gaging stations. Since 1955, the network of gaging stations has varied in size from a minimum of 138 stations in 1983 to a maximum of 171 stations in 1971. The number of gaging stations operated by the U.S. Geological Survey in Illinois is shown in figure 1.

A statewide network of crest-stage partial-record stations was established in 1955 to define flood-frequency characteristics of Illinois streams in rural and urban areas. The program increased from 48 partial-record stations in 1956 to 209 partial-record stations in 1972 and has since decreased to its present (1983) number of 28 stations. Data obtained from the partial-record and stream-gaging programs have been used to develop equations for estimating flood magnitudes on rural streams (Curtis, 1977a and 1977b) and on urban streams in northeastern Illinois (Allen and Bejcek, 1979).

A statewide network of low-flow partial-record stations was established in 1960. By 1970, measurements of low-flow had been made at about 100 stations. The low-flow network is no longer maintained. Twenty-two low-flow partial-record stations were operated during 1981 and 1982 as part of a study of the low-flow characteristics of streams in the Kishwaukee River basin in north-central Illinois (H. E. Allen, U.S. Geological Survey, oral commun., 1983). Lara (1970) and Singh and Stall (1973) performed studies to determine the low-flow characteristics of streams in Illinois. These studies were based mostly on streamflow data collected at stations in the stream-gaging program.

Current Illinois Stream-Gaging Program

The current (1983) stream-gaging program in Illinois consists of 138 gaging stations located throughout the State on streams draining watersheds with different physiography (fig. 2). The physiography of Illinois is classified into four major divisions, the Central Lowland, Ozark Plateaus, Interior Low Plateaus, and Coastal Plain physiographic provinces (Leighton and others, 1948). More than nine-tenths of the State lies within the Central Lowland and that province is subdivided into the Great Lake, Till Plains, Dissected Till Plains, and Wisconsin Driftless sections. All of the Central Lowland province except the Wisconsin Driftless section has been glaciated. Most of the Ozark Plateaus, Interior Low Plateaus, and Coastal Plain provinces lie outside the glacial boundary in southern and southwestern Illinois.

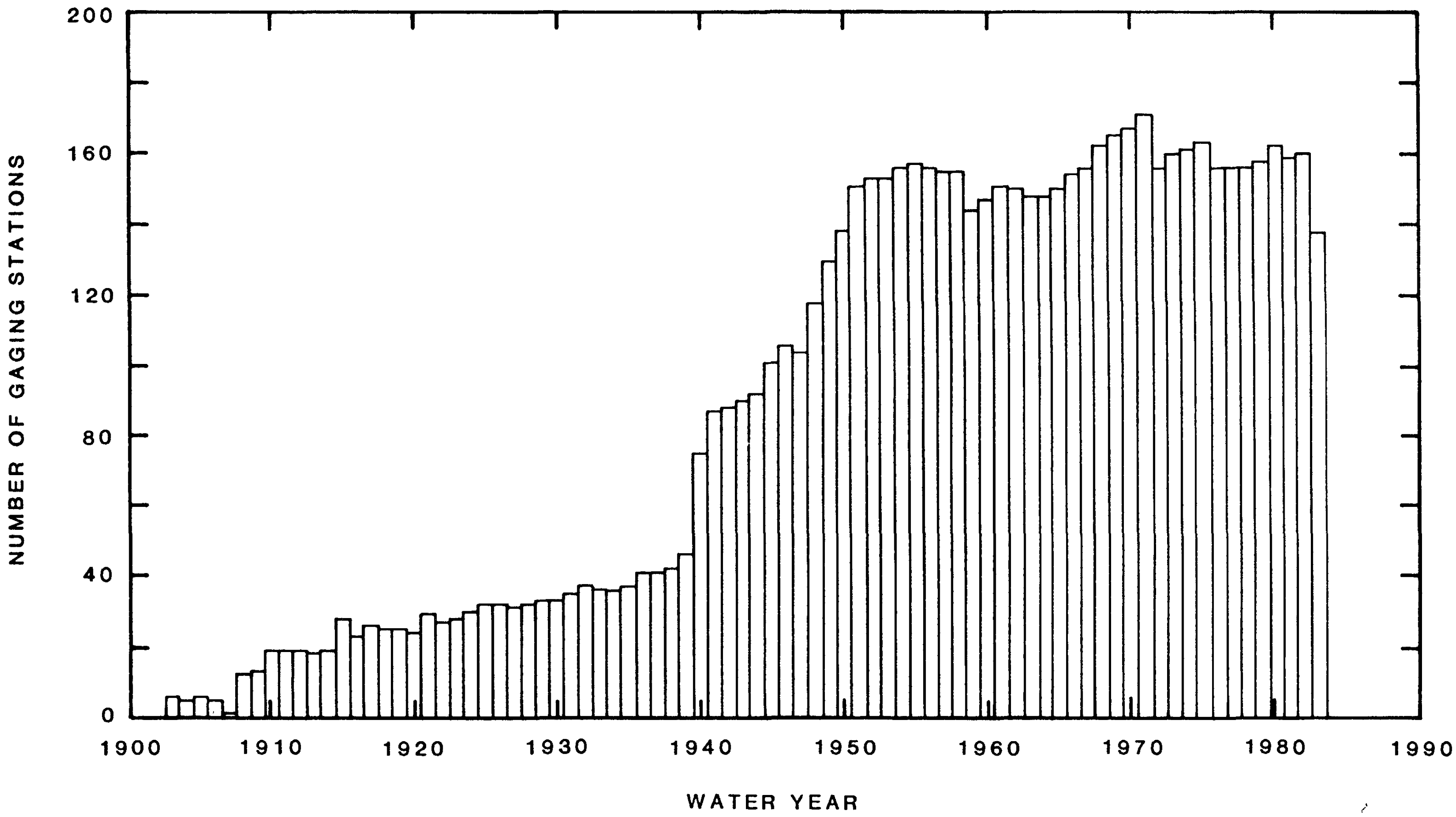


Figure 1.--Number of continuous-record streamflow stations that have been operated in Illinois.

Ninety-seven gaging stations are located in the Till Plains section, 34 are located in the Great Lake section, and 2 are located in the Wisconsin Driftless section. Three gaging stations are located in the Ozark Plateaus and two are located in the Interior Low Plateaus. No stations are operated in the Coastal Plains province or the Dissected Till Plains section of the Central Lowland province.

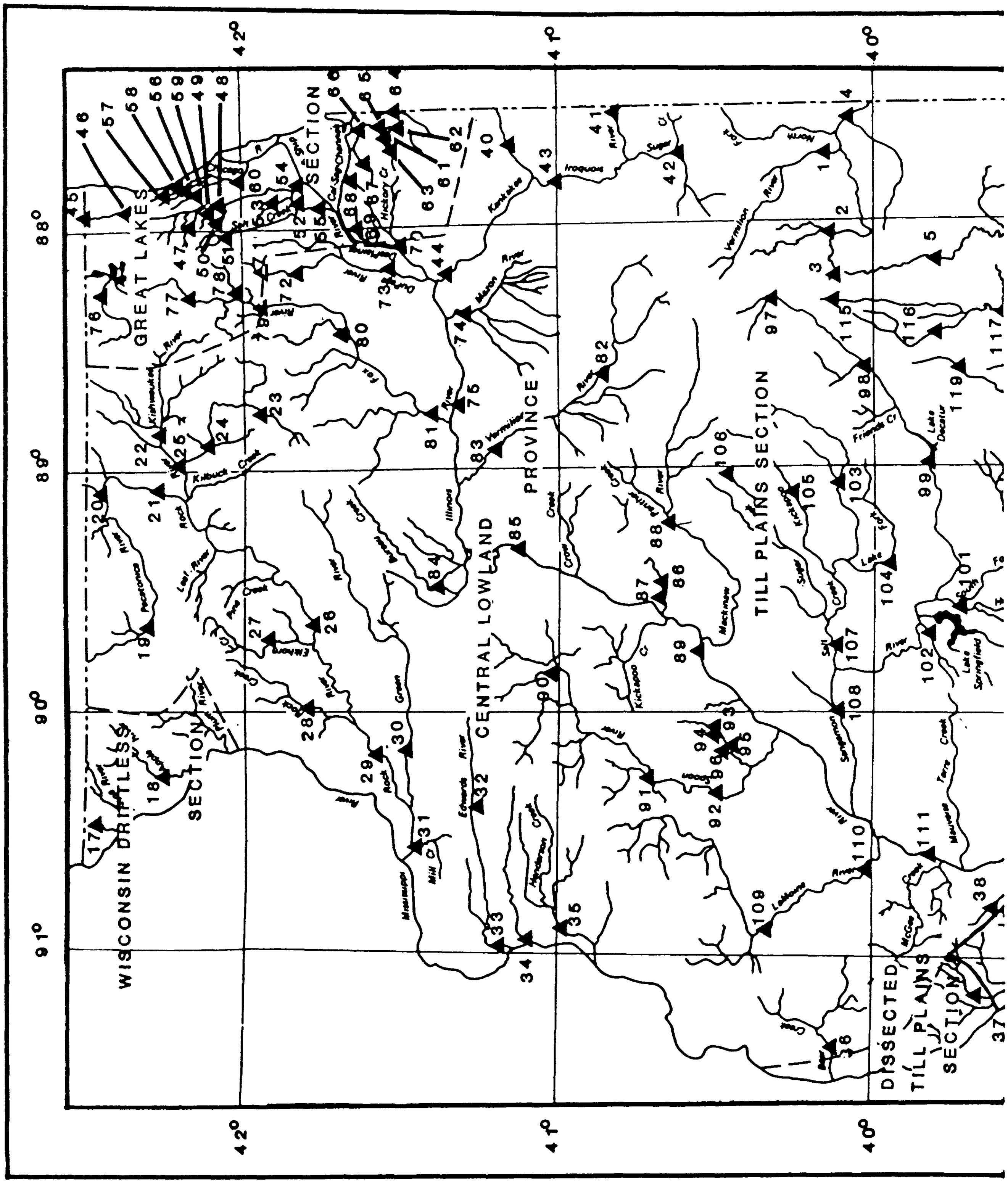
Map index numbers in figure 2 are referenced to U.S. Geological Survey eight-digit downstream-order station-identification numbers given in table 1. Table 1 also shows the name and selected hydrologic data, including drainage area, period of record, and average discharge for each gaging station.

Acknowledgments

The authors acknowledge the following agencies for their cooperation in identifying the uses of data collected at the gaging stations in the Illinois stream-gaging program:

U.S. Army, Corps of Engineers, Chicago District,
U.S. Army, Corps of Engineers, Louisville District,
U.S. Army, Corps of Engineers, Rock Island District,
U.S. Army, Corps of Engineers, St. Louis District,
U.S. Department of Agriculture, Soil Conservation Service,
U.S. Environmental Protection Agency, Region V,
U.S. Fish and Wildlife Service, Carbondale office,
U.S. Fish and Wildlife Service, Rock Island office,
Federal Emergency Management Agency, Region V,
National Weather Service, Chicago Forecast Center,
National Weather Service, Ohio River Forecast Center,
Water Resources Center, University of Illinois,
Illinois Department of Transportation, Division of Water Resources,
Illinois Environmental Protection Agency,
Illinois Natural History Survey,
Illinois State Water Survey, Champaign office,
Illinois State Water Survey, Peoria office,
Metropolitan Sanitary District of Greater Chicago, and
Northeastern Illinois Planning Commission.

The authors also acknowledge several colleagues in Madison, Wisconsin, who performed a hydrologic, flow-routing model study and determined autocovariance parameters for 29 of the gaging stations considered in the stream-gaging network evaluation. These colleagues are Peter E. Hughes, William R. Krug, and John F. Walker. Their contributions are noted in later sections of this report.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GREAT LAKES SECTION
CENTRAL LOWLAND PROVINCE
TILL PLAINS SECTION
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90°
89°
88°
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Pecatonica River
Kishwaukee River
Kilbuck Creek
Green River
Edwards River
Spoon River
Illinois River
Fox River
Vermilion River
Kankakee River
Iroquois River
Mackinaw River
Sangamon River
Salt Creek
Lake Decatur
Lake Springfield
Kickapoo Cr.
Crow Creek
Henderson Creek
Mill Cr.
Mississippi
LaMoine River
Vermilion River
Sugar Cr.
Friends Cr.
Hickory Cr.
Des Plaines River
DuPage River
Mazon River

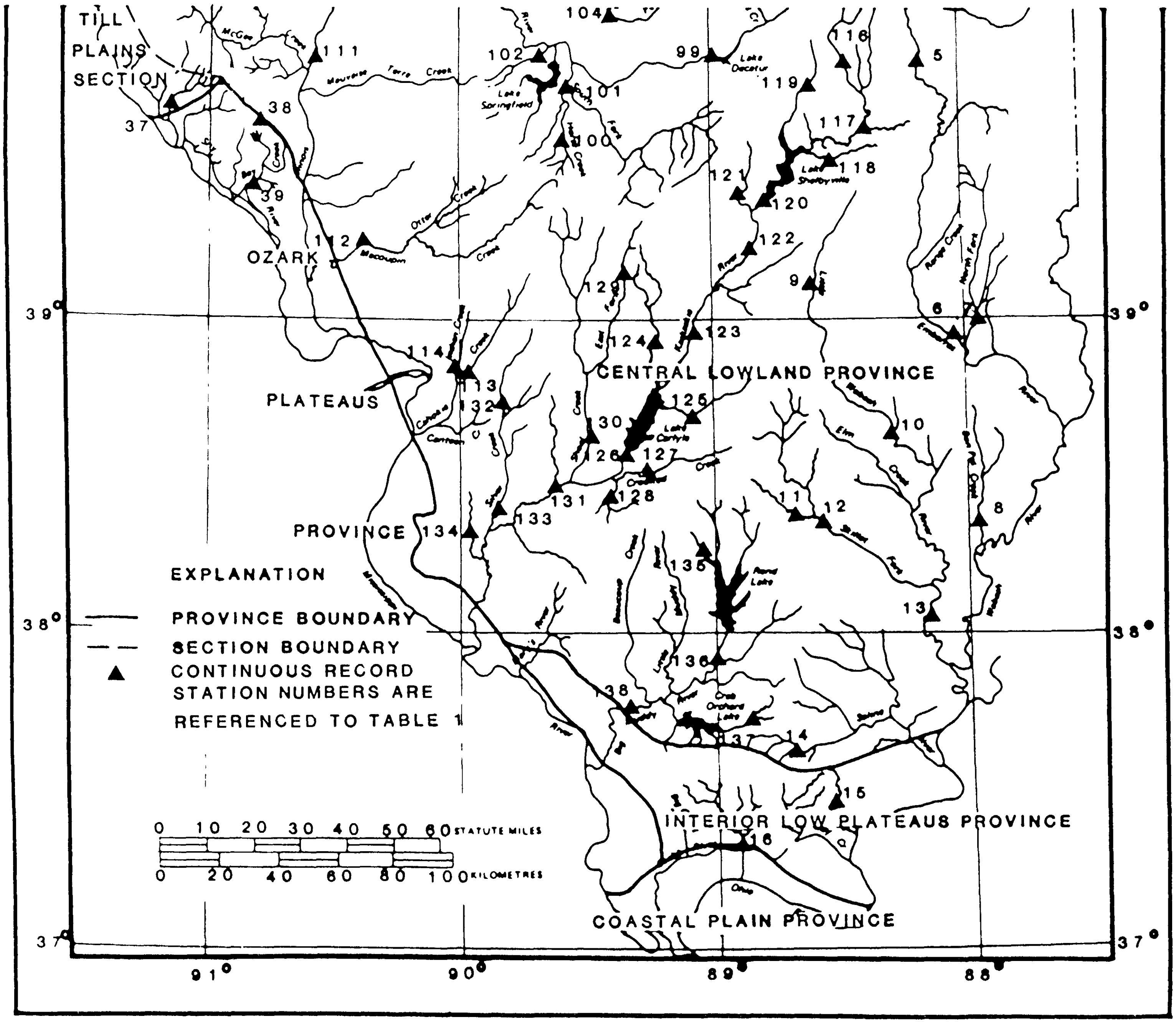


Figure 2.--Location of continuous-record streamflow stations operated in Illinois during 1983.

USES, FUNDING, AND AVAILABILITY OF CONTINUOUS STREAMFLOW DATA

The relevance of a gaging station is defined by the uses that are made of the data that are produced from the station. The uses of the data from each gaging station in the Illinois stream-gaging program were identified by a survey of known data users. The survey documented the importance of each gaging station and identified gaging stations that may be considered for discontinuation.

Data uses identified by the survey were categorized into eight classes, defined below. The sources of funding for each gaging station and the frequency at which data are provided to the users were also compiled.

Data-Use Classes

The following definitions were used to categorize each known use of streamflow data for each gaging station.

Regional Hydrology

For data to be useful in defining regional hydrology, the streamflow at a gaging station must be largely unaffected by manmade storage or diversion. In this class of uses, the effects of man on streamflow are not necessarily small, but the effects are limited to those caused primarily by land-use and climate changes. Large amounts of manmade storage may exist in the basin providing the outflow is uncontrolled. These gaging stations are useful in developing regionally transferable information about the relation between basin characteristics and streamflow.

Eighty-eight gaging stations (fig. 3) in the Illinois stream-gaging program are classified in the regional hydrology data-use category. Three of the gaging stations are index stations. The index stations, Skillet Fork at Wayne City (03380500), Pecatonica River at Freeport (05435500), and Sangamon River at Monticello (05572000), are used to indicate current hydrologic conditions.

Hydrologic Systems

Gaging stations that can be used for accounting--that is, to define current hydrologic conditions and the sources, sinks, and fluxes of water through hydrologic systems, including regulated systems--are designated as hydrologic-systems stations. Hydrologic-systems stations are useful for defining the interaction of water systems and measuring diversions and return flows. The index stations are included in the hydrologic-systems category because they are accounting for current conditions of the hydrologic systems that they gage.

Illinois presently maintains 87 gaging stations where streamflow data are used for accounting purposes. All but one of these gaging stations are used to monitor high streamflows resulting from excessive amounts of precipitation and snowmelt.

Legal Obligations

Some gaging stations provide records of flows for the verification or enforcement of existing treaties, compacts, and decrees. The legal obligation category contains only those gaging stations that the U.S. Geological Survey must operate to satisfy a legal responsibility.

There are no gaging stations operated in the Illinois stream-gaging program to fulfill a legal responsibility, although one is planned for 1984.

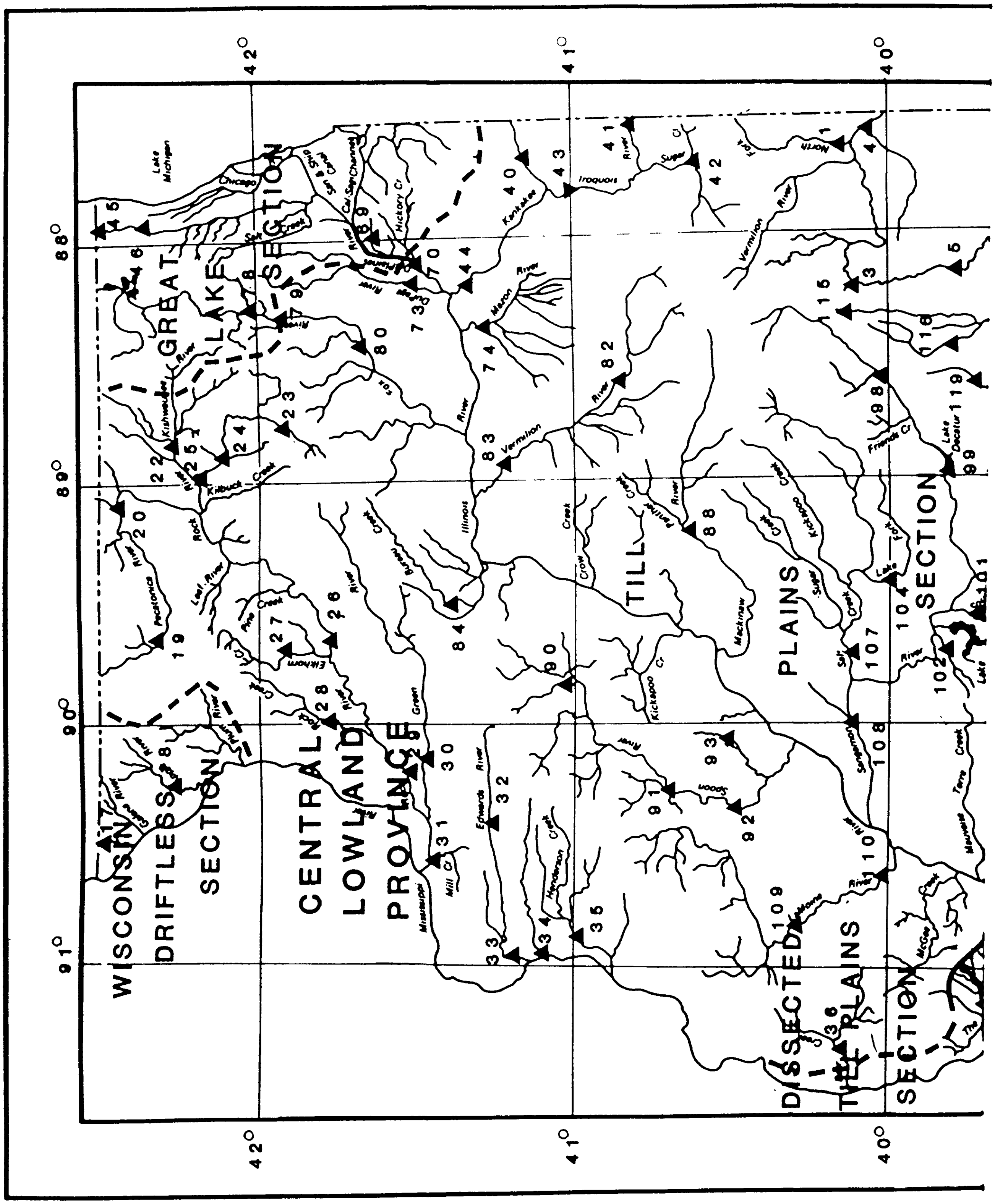
Planning and Design

Gaging stations in this category are used for the planning and design of a specific project (for example, a dam, levee, floodwall, navigation system, water-supply diversion, hydropower plant, or waste-treatment facility) or group of structures. The planning and design category is limited to those stations that were instituted for such purposes and where this purpose is still valid.

Three stations are maintained to provide data for the planning and design of a project. The Rock Island District of the Corps (U.S. Army, Corps of Engineers) is using data from a gaging station on Keith Creek (05437695) and a gaging station on Sugar Creek (05580950) to evaluate alternatives for mitigating flooding in those respective basins. Streamflow data obtained at the gaging station on Horse Creek (05575800) is being used in a water-supply study. The Northeastern Illinois Planning Commission uses streamflow data from 34 gaging stations in water-resources planning studies for six counties in northeastern Illinois.

Project Operation

Gaging stations in this category are used to assist water managers in making operational decisions such as reservoir releases, hydropower operations, or diversions. "Project operation" generally implies that the data are routinely available to the operators on a rapid-reporting basis. For projects on large streams having less variable streamflow, data may be reported at less frequent intervals. Streamflow data are transmitted via telemetry or reported by observers who periodically visit the gaging stations.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Vermilion
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Kishwaukee
Kilbuck Creek
Mackinaw
Sangamon
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Mississippi
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Elkhorn
Fox
Mazon River
Hickory Cr
Salt Creek
Kickapoo Cr
Crow Creek
Lake Decatur

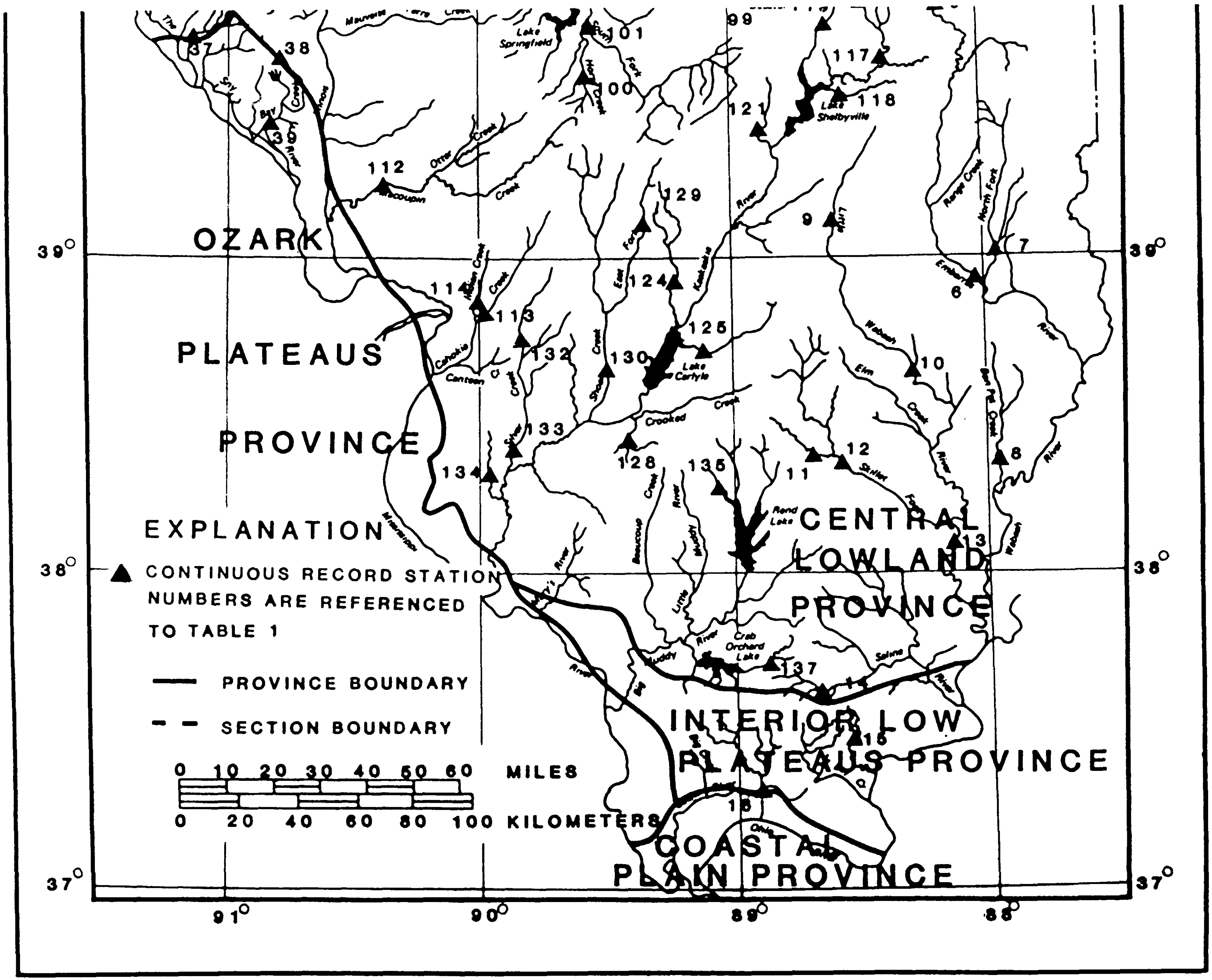

Figure 3.--Location of continuous-record streamflow stations that provide information about regional hydrology.

The Corps uses data from 17 gaging stations to decide when and how much water should be released at dams it maintains on the Mississippi, Ohio, and Illinois Rivers. The primary purpose for regulation is to provide adequate depths of water for navigation on those rivers.

Hydrologic Forecasts

Gaging stations in this category are regularly used to provide information for hydrologic forecasting; forecasts of floods for a specific river reach, or periodic (daily, weekly, monthly, or seasonal) flow-volume forecasts for a specific site or region. The hydrologic-forecast use generally implies that the data are routinely available to the forecasters on a rapid-reporting basis. On large streams having less variable streamflow, data may be reported at less frequent intervals. Streamflow data may be transmitted via telemetry or reported by observers who periodically visit the gaging stations.

The 52 gaging stations in the Illinois program included in the hydrologic forecast data-use category are used for flood forecasting. Streamflow data are used by the NWS (U.S. National Weather Service) to predict floodflows at downstream sites. Additionally, NWS uses the streamflow data from some gaging stations to make long-range predictions of floods caused by snowmelt.

Water-Quality Monitoring

Gaging stations where regular monitoring of water-quality or sediment-transport is being conducted and where the availability of streamflow data contributes to the utility, or is essential to the interpretation, of such data are designated as water-quality monitoring stations.

Five gaging stations in Illinois are designated NASQAN (National Stream Quality Accounting Network) stations. NASQAN stations are part of a nationwide network used to assess water-quality trends of significant streams. Streamflow data from 77 gaging stations are used by the Illinois Environmental Protection Agency to interpret water-quality data collected at its ambient water-quality network stations. Several other State, local, and Federal agencies use streamflow data from another 16 gaging stations to interpret water-quality or sediment data.

Research

Streamflow data from gaging stations in this category are used in particular research and water-investigations studies. Gaging stations operated solely for research needs usually are operated for a few years.

Streamflow data collected at 90 gaging stations are being used in research-type activities. Rainfall-runoff modeling studies rely on streamflow data from 79 of these gaging stations. All 60 of the gaging stations maintained in cooperation with the Illinois Department of Transportation, Division of Water Resources (IDOT) are used by IDOT to monitor long-term trends in streamflow.

Funding

The four possible sources of funding for the streamflow-data program are:

1. Federal program.--Funds that have been directly allocated to the U.S. Geological Survey.

2. Other Federal Agency (OFA) program.--Funds that have been transferred to the U.S. Geological Survey by OFA's.

3. Coop program.--Funds that come jointly from U.S. Geological Survey cooperative-designated funding and from a non-Federal cooperating agency.

4. Other non-Federal.--Funds that are provided entirely by a non-Federal agency or a private concern under the auspices of a Federal agency. Funds in this category are not matched by U.S. Geological Survey cooperative funds.

In all four categories, the identified sources of funding pertain only to the collection of streamflow data. Sources of funding for other activities, particularly collection of water-quality samples, that might be carried out at a gaging station may not necessarily be the same as those identified herein.

There are 11 sources of funds for the Illinois stream-gaging program. Four gaging stations are maintained solely or in part by Army Engineers Replacement (AER) funds directly allocated to the U.S. Geological Survey. The OFA program consists of three Corps Districts that fund 46 gaging stations. The Illinois Department of Transportation (Division of Water Resources) and the Illinois State Water Survey contribute funds to the Coop program for 60 and 23 gaging stations, respectively. Five local entities participate in the Coop program to support eight gaging stations. There are no "other non-Federal" sources of funds for the Illinois stream-gaging program.

Data Availability

Data availability refers to the method used to furnish streamflow data to the users. There are three distinct possibilities in this category. Data are furnished by direct-access telemetry for immediate use, by periodic release of provisional data, and by publication in the annual data report for

Illinois (Fitzgerald and others, 1984; Stahl and others, 1984). Streamflow data for all 138 stations are published in the annual report; data from 37 stations are available by telemetry on a real-time basis, and data from 25 stations are released on a provisional basis.

Presentation and Summary of Data Use

Information regarding data use, funding source, and data availability is shown in table 2 and in the accompanying footnotes. An asterisk or footnote in the "regional hydrology" column indicates the streamflow data can be used to define relations between watershed characteristics and streamflow. An asterisk in the "Federal program" column indicates AER funds.

Streamflow data collected at many gaging stations are used by several agencies for different purposes. An example is Salt Creek at Western Springs (05531500) which is funded by the U.S. Geological Survey and IDOT. Streamflow data collected at this gaging station is used by IDOT for monitoring high flow, rainfall-runoff modeling, and determining statistical characteristics of streamflow. Five other agencies use the streamflow data for planning and design, water-quality monitoring, and research activities.

The Corps and IDOT contribute funds for 107 of the 138 gaging stations. A review of the footnotes for table 2 indicates that these agencies are primarily interested in high streamflows. Few of the gaging stations in the 1983 stream-gaging program are funded for the primary purpose of measuring low flows.

Five gaging stations maintained in cooperation with the Illinois State Water Survey (03343400, 03380475, 05588000, 05590000, and 05593900) are maintained solely to provide regional hydrologic information. Concurrently with this study, the Network Analysis for Regional Information (NARI) procedure (Moss and others, 1982) is being used to study the statewide distribution of gaging stations that could be used in regional hydrologic studies. NARI is a procedure for determining the improvements in regional regression equations for various streamflow characteristics that may be obtained by lengthening the period of record at gaging stations, increasing the density of stations in the stream-gaging network, and modifying the regression equations.

Conclusions Pertaining to Data Uses

1. Surveys of gaging-station data use should be conducted at regular intervals of about 5 years. Results of the NARI will help to determine how regional information derived from long-term records of streamflow data can be improved. The following sections of this report provide information for assessing if the accuracy of instantaneous discharge at existing gaging stations is sufficient for the intended use of the data. Annual meetings between the U.S. Geological Survey and cooperators in the stream-gaging program and

other activities, such as collection of water-quality samples, serve to identify the immediate stream-gaging needs of a cooperator. Information from the NARI and present evaluation, coupled with the periodic documentation of the multiple uses of streamflow data collected at a gaging station, will ensure that funds from Federal and other sources are effectively distributed. This is particularly important if the availability of funds, reflected in the number of gaging stations maintained, continues to decline with time.

2. A long-range program for collecting low-flow data is desirable. The present emphasis for stream gaging is to collect high-flow data. In the southern two-thirds of Illinois, municipal and industrial water supplies generally are obtained from surface-water sources (U.S. Geological Survey, 1984, p. 120). Accurate, long-term records of low flow are needed to adequately address future municipal and industrial demands and minimum instream flow requirements for water quality, navigation, and fish and wildlife.

3. All gaging stations in the current stream-gaging program will be included for analysis in the following sections of this report. The continuing need for the five gaging stations providing streamflow data solely for regional information will be addressed in a forthcoming publication.

ALTERNATIVE METHODS OF DEVELOPING STREAMFLOW INFORMATION

The objective of the second step of the stream-gaging program evaluation is to identify gaging stations where alternative techniques, such as flow-routing or statistical methods, can be used to accurately estimate daily mean streamflow in a more cost-effective manner than operating a gaging station. Those gaging stations for which flood hydrographs are required at time intervals less than a day, such as for hydrologic forecasts, water-quality monitoring, and project operation, generally are not candidates for the alternative methods. However, gaging stations on the same stream, separated by a small percentage of intervening drainage and gaging stations on similar watersheds having the same physiographic and climatic characteristics also may have potential for alternative methods. The accuracy of estimated streamflow at those gaging stations may be suitable because of the high correlation of streamflow at the gaging stations.

Desirable attributes of an alternative method are: (1) The method should be computer oriented and easy to apply, (2) the method should have an available interface with the U.S. Geological Survey WATSTORE Daily Values File (Hutchinson, 1975), (3) the method should be technically sound and generally acceptable to the hydrologic community, and (4) the method should permit easy evaluation of the accuracy of the estimated streamflow. Because of time limitations, only two methods were considered--a flow-routing model and a statistical model.

Description of Flow-Routing Model

Hydrologic flow-routing models use the law of conservation of mass and the relation between the storage in a stream reach and the outflow from the reach. The hydraulics of the system are not considered. The model usually requires only a few parameters and treats the reach in a lumped sense without subdivision. The input to the model is usually a discharge hydrograph at the upstream end of the reach and the output is a discharge hydrograph at the downstream end. Several different types of hydrologic routing models are available such as Muskingum, Modified Puls, Kinematic Wave, and the unit-response.

The unit-response model was selected because it fulfilled the criteria noted above. Computer programs for the unit-response model can be used to route streamflow from one or more upstream locations to a downstream location. Downstream hydrographs are produced by the convolution of upstream hydrographs with their appropriate unit-response functions. This model can only be applied at a downstream station where there is an upstream station on the same stream. An advantage of this model is that it can be used for regulated stream systems. Reservoir-routing techniques are included in the model so streamflow can be routed through reservoirs if the operating rules are known. Calibration and verification of the model are achieved using observed upstream and downstream hydrographs and estimates of tributary inflows.

The convolution procedure treats a stream reach as a linear, one-dimensional system in which the downstream hydrograph is computed by multiplying the ordinates of the upstream hydrograph by the unit-response function and lagging them appropriately. The model can combine hydrographs, multiply a hydrograph by a ratio, and change the timing of a hydrograph. In this analysis, the model is only used to route an upstream hydrograph to a downstream location. Routing can be accomplished using any equal-interval streamflow data; only daily streamflow data were used in this analysis.

Two options are available for determining the unit (system) response function; single linearization and multiple linearization. Selection of the appropriate option depends primarily upon the variability of wave celerity (traveltime) and dispersion (channel storage) throughout the range of streamflows to be routed. Adequate routing of daily streamflows can usually be accomplished using a single unit-response function (linearization about a single streamflow) to represent the system response. However, if the routing coefficients vary drastically with streamflow, linearization about a low-range streamflow results in overestimated high streamflows that arrive late at the downstream location; whereas, linearization about a high-range streamflow results in low-range streamflows that are underestimated and arrive too soon. A single unit-response function may not provide acceptable results in such cases. Therefore, the option of multiple linearization (Keefer and McQuivey, 1974), which uses a family of unit-response functions to represent the system response, is available.

Determination of a system's response to input at the upstream end of a reach is not the total solution for most flow-routing problems. The convolution procedure makes no accounting of flow from the intervening area between the upstream and downstream locations. Such flows may be totally unknown and must be estimated by some combination of gaged and ungaged flows. An estimating technique that proves satisfactory in many instances is the multiplication of known streamflows at an index gaging station by a factor (for example, a drainage-area ratio).

The objective in calibrating the storage-continuity and diffusion-analogy flow-routing models is to determine two parameters that describe the storage-discharge relation in a given reach and the traveltime of streamflow passing through the reach. In the storage-continuity model (Sauer, 1973), a response function is derived by modifying a translation-hydrograph technique developed by Mitchell (1962) to apply to open channels. A triangular pulse (Sauer, 1973) is routed through reservoir-type storage and then transformed by a summation curve technique to a unit response of desired duration. The two parameters that describe the routing reach are K_s, a storage coefficient which is the slope of the storage-discharge relation, and W_s, the translation hydrograph time base. These two parameters determine the shape of the resulting unit-response function.

In the diffusion-analogy model (Keefer, 1974), the two parameters are K_o, a wave dispersion or damping coefficient, and C_o, the floodwave celerity. K_o controls the spreading of the wave (analogous to K_s in the storage-continuity model) and C_o controls the traveltime of the flood wave. In the single linearization model, only one K_o and C_o value are used. In the multiple linearization model, C_o and K_o are varied with streamflow so that tables of wave celerity (C_o) versus streamflow (Q) and dispersion coefficient (K_o) versus streamflow (Q) are used.

In both the storage-continuity and diffusion-analogy models, the two parameters are determined by trial and error. The analyst must decide if suitable parameters have been derived by comparing the calculated streamflow to the observed streamflow.

The diffusion-analogy, single unit-response function model was applied to one watershed in Illinois. The application is described in a subsequent section of the report.

Description of Statistical Model

Hirsch (1982) presented a method for developing time series of streamflow at a gaging station based on correlation with streamflow at a nearby long-term base gaging station. The method, termed MOVE.1, preserves the mean and variance of the historic record at the gaging station which is being analyzed. The method is easy to apply and provides indices of accuracy.

The estimating equation used by the MOVE.1 method to estimate daily mean streamflow in this study has the following form:

$$\hat{y}_i = m(y_1) + \frac{S(y_1)}{S(x_1)} [x_i - m(x_1)] \qquad (1)$$

where

$\hat{y}_i$ = estimated daily mean streamflow at the gaging station for which records are being extended in time period i,

x_i = observed daily mean streamflow at a nearby gaging station in time period i,

$m(y_1)$ = mean of the historic daily mean streamflows (y_i) at the dependent gaging station,

$m(x_1)$ = mean of the historic daily mean streamflows at the independent gaging station for the same period of record as the dependent gaging station,

$S(y_1)$ = standard deviation of the historic daily mean streamflows at the dependent gaging station, and

$S(x_1)$ = standard deviation of the historic daily mean streamflows at the independent gaging station.

Observed daily mean streamflows (y_i and x_i) can be retrieved from the WATSTORE Daily Values File for a designated period of time with the Statistical Analysis System (SAS Institute, 1982).[1] The SAS may then be used to calculate means and standard deviations for the observations of y_i and x_i. These statistics are used in equation 1 to calculate $\hat{y}_i$ for all x_i. Comparisons of the estimated streamflow, $\hat{y}_i$, to the observed streamflow, y_i, are made to determine the adequacy of the estimating equation.

The adequacy of the estimating equation is tested by (1) plotting the differences between $\hat{y}_i$ and y_i (estimated and observed streamflow) against the dependent variable (y_i) and independent variable (x_i), and (2) plotting the estimated and observed streamflow versus time. These tests are intended to identify (1) if the linear model (equation 1) is appropriate or whether some transformation of the discharges is needed, and (2) if there is any bias in the equation such as overestimating low flows.

The MOVE.1 model was applied to five watersheds in Illinois. Tests of equation 1 indicated that an untransformed model (y_i and x_i in cubic feet per second) was appropriate. The application of the MOVE.1 model is described in a subsequent section of the report.

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[1] Use of SAS in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Identification of Gaging Stations Suitable for Evaluating Alternative Methods

An analysis of the data uses presented in table 2 identified six gaging stations at which alternative methods for determining daily mean streamflows could be applied. The flow-routing model was used to calculate daily mean streamflows for Rock River at Joslin (05446500). Streamflow data collected at the gaging station supplement chemical and biological data collected within the NASQAN program and cooperative program with the Illinois Environmental Protection Agency. The gaging station is also used by the Corps for monitoring high streamflows. The MOVE.1 model was used to calculate daily mean streamflows for the five gaging stations operated solely to provide regional information (03343400, 03380475, 05588000, 05590000, and 05593900) and the Joslin station.

Results of Flow-Routing Modeling

The unit-response flow-routing model was used to simulate daily mean streamflows for Rock River near Joslin (05446500) for the entire range of streamflows observed at the gaging station. A diagram of the Rock River study area is presented in figure 4. Selected information about the four gaging stations used in the analysis (05443500, 05444000, 05446000, and 05446500) is presented in table 1.

The gaging station near Joslin (05446500) is located 42.3 miles downstream from the gaging station at Como (05443500). The intervening drainage area between the Como and Joslin gaging stations is 796 mi^2 (square miles), 8.3 percent of the drainage area at the Joslin gaging station. Flow from 310 mi^2, or 39 percent of the intervening area, is gaged at Elkhorn Creek near Penrose (05444000) and Rock Creek at Morrison (05446000).

Daily mean streamflow at Como and a portion of flow from the intervening area were routed to Joslin using the diffusion analogy, single unit-response model. The "best fit" total discharge at Joslin was computed as the sum of the routed streamflow from Como and adjusted streamflows at the Como, Penrose, and Morrison gaging stations, which were used to compute runoff from the intervening area as follows.

The ratio of intervening area to drainage area at Como is 0.0909 and the ratio of intervening area to the total gaged intervening area is 2.568. Runoff from the intervening area was partly simulated by multiplying the daily mean streamflow at Como by a factor equal to one-half the ratio of the intervening area to the Como drainage area or 0.0455. This quantity was added to the Como streamflow and the sum was routed to Joslin. The rest of the runoff from the intervening area was simulated by multiplying the sum of the daily mean streamflows at Penrose and Morrison by a factor equal to one-half of the ratio of the total intervening area to gaged intervening area or 1.284. These streamflows were added to the routed flow at Joslin, with one-half of the streamflows lagged one day, to obtain the total simulated streamflow at Joslin.

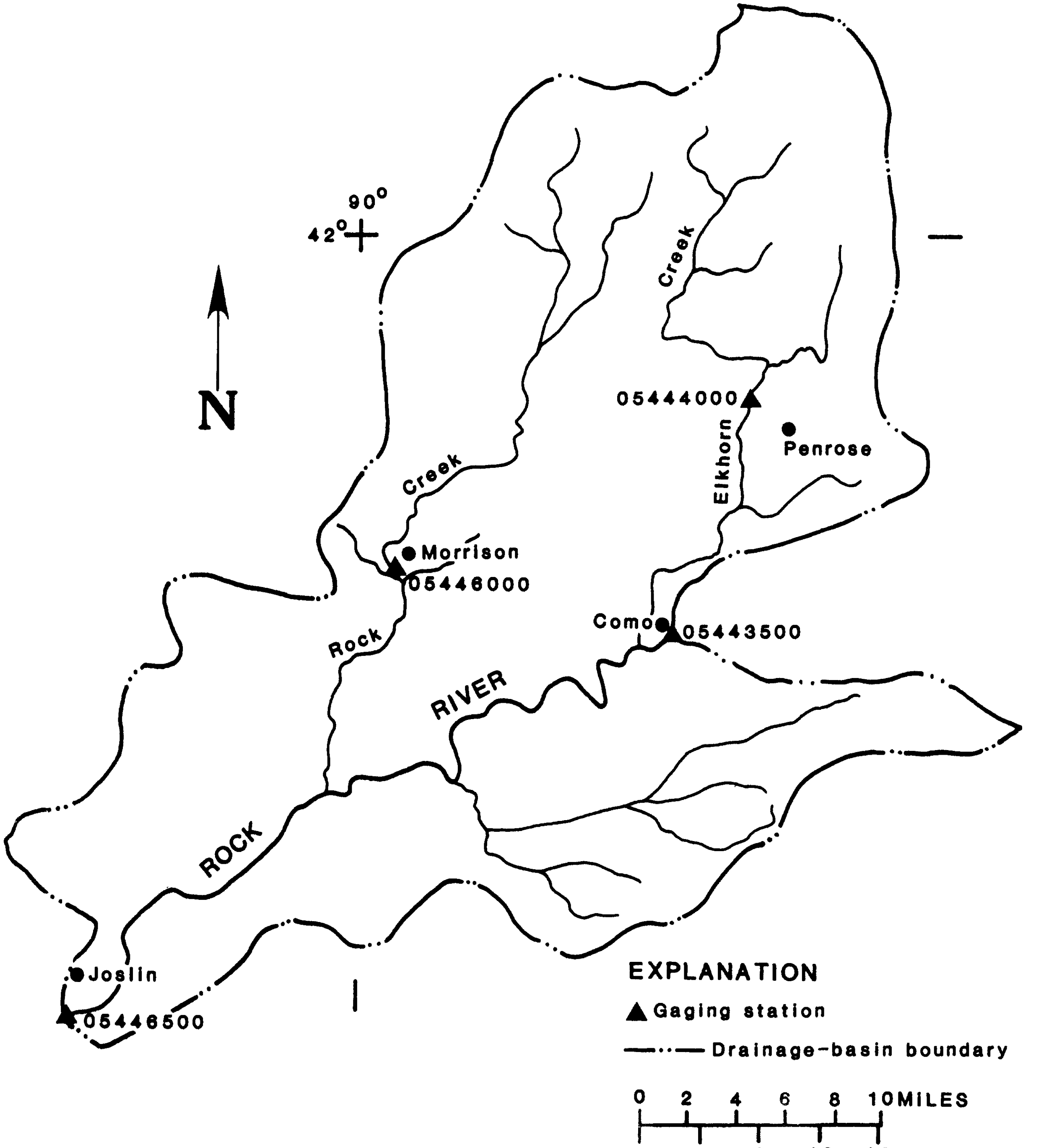

Figure 4.--Rock River basin flow-routing modeling study area.

The routing model is more clearly represented by the following equation:

$$Q_j(i) = 1.0455\ Q_c(i)\ \text{routed} + 0.642\ Q_t(i) + 0.642\ Q_t(i-1) \qquad (2)$$

where

$Q_j(i)$ = estimated daily mean streamflow at Joslin in time period i,

$Q_c(i)$ = observed daily mean streamflow at Como in time period i,

$Q_t(i)$, $Q_t(i-1)$ = sum of the observed daily mean streamflows at Penrose and Morrison in time periods i and i-1, respectively.

Daily mean discharges for water years 1978-82 were used to calibrate the flow-routing model.

To route the streamflow from Como to Joslin, it was necessary to determine the model parameters C_o (floodwave celerity) and K_o (wave dispersion coefficient). The coefficients C_o and K_o are functions of channel width (W_o), in feet; channel slope (S_o), in feet per foot (ft/ft); the slope of the stage-discharge relation (dQ_o/dY_o), in square feet per second (ft^2/s); and the discharge (Q_o), in cubic feet per second. The parameters are determined as follows:

$$C_o = \frac{1}{W_o} \frac{dQ_o}{dY_o} \qquad (3)$$

$$K_o = \frac{Q_o}{2\ S_o\ W_o} . \qquad (4)$$

The streamflow, Q_o, for which initial values of C_o and K_o were linearized was the average discharges for the Como and Joslin gaging stations (table 1). The channel width, W_o, is the average width in the 42.3-mile reach between Como and Joslin and was determined from topographic maps and discharge measurements. Channel slope, S_o, was determined by converting the gage heights corresponding to the initial streamflows, Q_o, at both gaging stations to a common datum. The difference between the values was then divided by the channel length between the gaging stations to obtain a slope. The slope of the stage-discharge relations, dQ_o/dY_o, was determined from the rating curves at each gaging station and represents the change in discharge for a 1-foot change in gage height that brackets the initial streamflow, Q_o. Flow-routing model parameters for the Rock River between Como and Joslin are listed in table 3.

Using the 1978-82 water-year data from Joslin as a calibration data set, several trials were made adjusting both the values of C_o, K_o, and the drainage-area adjustment factors. The "best fit" single linearization model was determined to be that with C_o = 3.64, K_o = 25,400, and the previously mentioned drainage-area adjustment ratios.

A summary of the apparent error in the simulation of daily mean streamflow at Joslin for water years 1978-82 is given in table 4. This summary includes both periods of winter backwater and days of low flow.

Figure 5 is a comparison of the observed and simulated streamflows for the Joslin gaging station during a spring flood in 1982. The comparison is very good, even during the period March 14-21 when the peak simulated streamflow was at most 15 ft^3/s (0.1 percent) lower than observed streamflow.

Flow-routing model parameters determined from calibrating the model to data from water years 1978-82 were used to simulate streamflow at Joslin for water years 1940-42. The simulation was performed as a means of testing or verifying the validity of the calibration results. Water years 1940-42 were selected because the range in streamflow observed at Joslin during this period was similar to the range of streamflow observed during the period of record used to calibrate the model. In addition, the 35-year interval between the periods of record used to calibrate and verify the model provides for a critical evaluation of how well the model can be used to simulate streamflows over a long period of time.

The simulated streamflows for 1940-42 were persistently lower than observed streamflows because of small changes in channel geometry and stage-discharge relations at the Como and Joslin gaging stations. The mean absolute error for the 910-day verification period was 5.73 percent. Fifty-eight percent of the simulated streamflows were within 5 percent of observed streamflows, 88 percent of the simulated streamflows were within 10 percent, and 94 percent of the simulated streamflows were within 15 percent of observed streamflows.

Results of Statistical Modeling

The MOVE.1 statistical model was applied to the five gaging stations shown in table 5. The mean and standard deviation of daily mean streamflows for the calibration period were calculated for the dependent gaging station (Q_d) where streamflow is to be estimated and the base gaging station (Q_b) where streamflow would be used to extend the record at the dependent gaging station. These statistical parameters are shown in table 5 in the column labeled "model." Discharges (Q_d) for the dependent gaging station were calculated for another period of analysis, the verification period, using the statistical parameters and observed streamflows at the base gaging station. Comparisons of estimated and observed daily mean streamflow at the dependent gaging station, during the verification period, are shown in the two rightmost columns of table 5.

Streamflow records for Embarras River near Camargo (03343400), Horse Creek near Keenes (03380475), Indian Creek at Wanda (05588000), and East Fork Shoal Creek near Coffeen (05593900) were not satisfactorily simulated with an acceptable degree of accuracy by using the MOVE.1 model. Streamflows at the

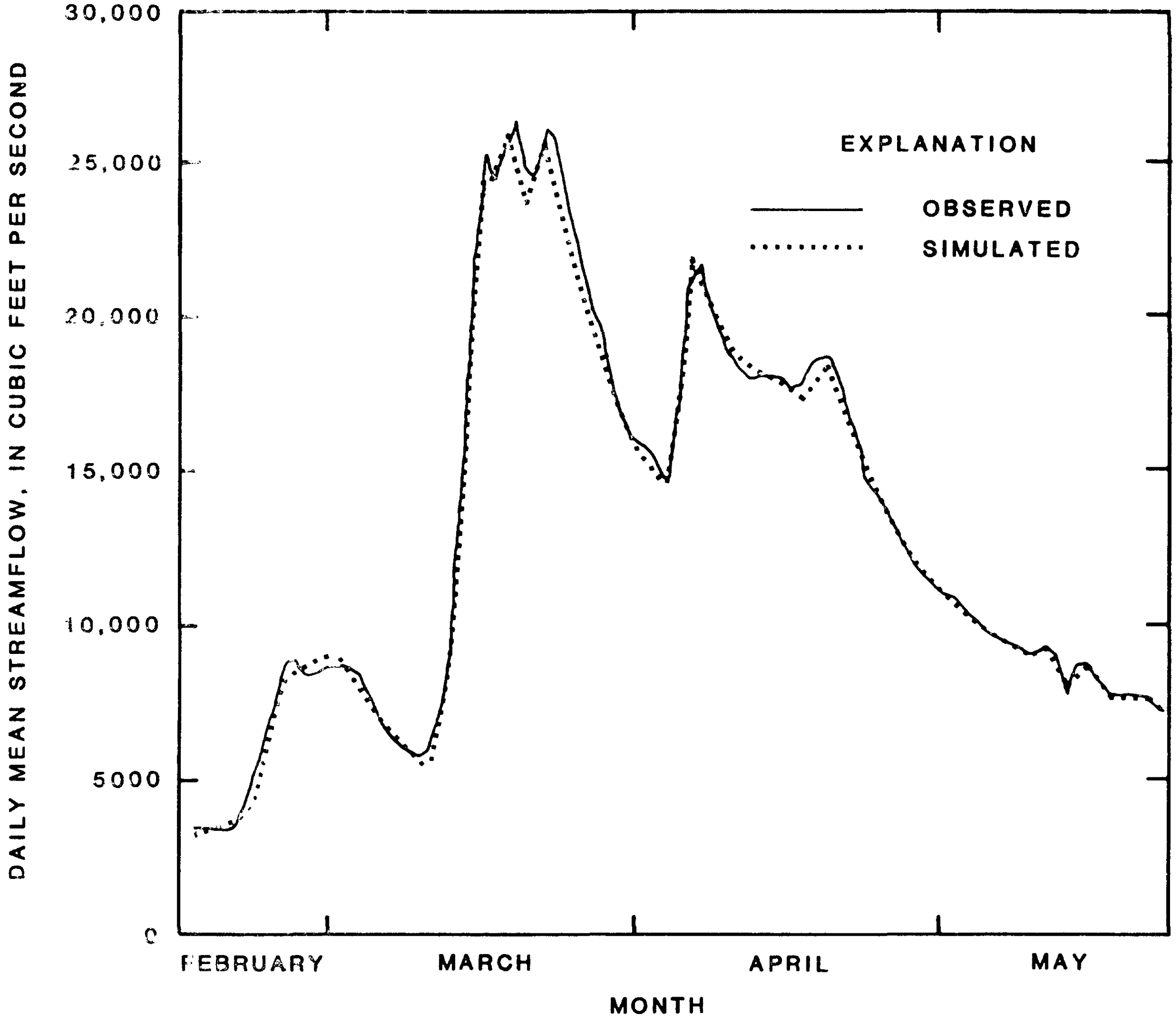

Figure 5.--Daily mean streamflow hydrograph for Rock River near Joslin (05466500), spring 1982.

gaging stations are quite variable and no flow is recorded for many days in a year. Differences in basin characteristics and precipitation patterns in watersheds in which the dependent and independent gaging stations are located are too great to ensure accurate results.

No attempt was made to simulate streamflow records for Kaskaskia Ditch at Bondville (05590000). The drainage area at the gaging station, 12.4 mi^2, is less than the drainage areas for the other five gaging stations for which the MOVE.1 model was tested. In addition, the nearest base gaging station that could be used as an independent source of streamflow records is located 16 miles away on a different watershed.

Streamflow records for Rock River near Joslin (05446500) were more accurately simulated because of the high correlation of its streamflow records with the records for Rock River near Como (05443500). The apparent errors in the simulation of daily mean streamflows at Joslin for water years 1940-42 were similar for the MOVE.1 model and the flow-routing model. Streamflow records calculated by the MOVE.1 model were within 10 percent of the observed daily mean streamflow for 81 percent of the days, compared to 88 percent of the days for the flow-routing model.

Conclusions Pertaining to Alternative Methods of Data Generation

1. The gaging stations Embarras River near Camargo (03343400), Horse Creek near Keenes (03380475), Indian Creek at Wanda (05588000), Kaskaskia Ditch at Bondville (05590000), and East Fork Shoal Creek near Coffeen (05593900) should remain in operation. The MOVE.1 model cannot simulate streamflow records accurately enough to justify deactivating the gaging stations.

2. The gaging station Rock River near Joslin (05446500) should remain in operation. It is the most downstream gaging station on the Rock River, a major tributary of the Mississippi River. The Corps uses streamflow data from the gaging station with other information on a real-time basis to regulate Mississippi River streamflow. The gaging station Rock River at Como (05443500) has been operated since 1915, except for a 6-year period from 1972-77 when it was operated as a crest-stage partial-record station. The Como gaging station is operated to provide the Corps accurate, long-term records of Rock River streamflow. The Corps is aware that streamflow records from the Joslin and Como gaging stations are highly correlated. However, the Corps feels that its needs for accurate, project-operation data at the Joslin gaging station and accurate, long-term hydrologic information for the Como gaging station justify operating the two gaging stations.

3. All six gaging stations considered in this step of the evaluation are included in the next step. At present, there is no basis for deactivating any gaging stations in lieu of using an alternative method for determining daily mean streamflow. However, the U.S. Geological Survey and the agencies that

cooperate in the stream-gaging program should periodically review the streamflow records of the network gaging stations to ensure that highly redundant (correlated) streamflow records are not being determined by stream gaging unless absolutely necessary. The time constraints of this project precluded application of the flow-routing or MOVE.1 models to all of the "best candidate" gaging stations based solely on hydrologic factors and regardless of how the gaging stations' data are used.

COST-EFFECTIVE RESOURCE ALLOCATION

The final step of the evaluation is to determine the cost effectiveness of the current schedule for visiting gaging stations (operating strategies) in the Illinois stream-gaging program. Current operating strategies are compared to optimal strategies determined by a steepest-descent optimization procedure. Optimal strategies are least-cost strategies that minimize the average uncertainty of instantaneous streamflow records for all of the gaging stations.

Introduction to Kalman-Filtering for Cost-Effective Resource Allocation (K-CERA)

In a study of the cost effectiveness of a network of gaging stations operated to determine water consumption in the Lower Colorado River basin, a set of techniques called K-CERA (Kalman-Filtering for Cost-Effective Resource Allocation) was developed (Moss and Gilroy, 1980). Because of the water-balance nature of that study, the measure of effectiveness of the network was chosen to be the minimization of the sum of variances of errors for estimating annual mean discharges at each gaging station in the network. This measure of effectiveness tends to concentrate stream-gaging resources on the larger, less stable streams where potential errors are greatest. Although such a tendency is appropriate for a water-balance network, in the broader context of the multitude of uses of the streamflow data collected in the U.S. Geological Survey's streamflow-information program, this tendency causes undue concentration on larger streams.

The original version of K-CERA was extended to include, as optional measures of effectiveness, the sums of the variances of errors (uncertainties) for estimating the following streamflow variables: Average discharge (mean annual flow), in cubic feet per second; average discharge, in percent; average instantaneous discharge, in cubic feet per second; or average instantaneous discharge, in percent. The use of percentage errors does not unduly weight activities at large streams to the detriment of records on small streams. In addition, the instantaneous discharge is the basic variable from which all other streamflow data are derived. For these reasons, the measure of effectiveness used in this study is the sums of the variances of the percentage errors for instantaneous discharges at all gaging stations.

The original version of K-CERA also did not account for errors caused by missing stage record or other correlative data used to compute streamflow data. The probabilities of missing correlative data increase as the period between service visits to a gaging station increases. A procedure for dealing with the missing stage record was developed and has been incorporated into this study.

Brief descriptions of the optimization procedure used to determine optimal strategies and of the application of Kalman filtering (Gelb, 1974) for determining the accuracy of instantaneous streamflow records are presented below. Details concerning the theory and the applications of K-CERA are discussed by Moss and Gilroy (1980), Gilroy and Moss (1981), and Fontaine and others (1984).

Description of Mathematical Program

The optimization procedure, called the "Traveling Hydrographer Program," attempts to allocate a predefined budget for collecting streamflow data among gaging stations in such a manner that the field operation is the most cost-effective possible. The measure of effectiveness is discussed above. The set of decisions, strategies, available to the manager is the frequency (number of times per year) that each of a number of routes be used to service the gaging stations and to make discharge measurements. Frequencies ranging from zero usage to daily usage are considered for each route. A route is defined as a set of one or more gaging stations and the least cost travel that takes the hydrographer from his base of operations to each of the gaging stations and back to base. Associated with a route is an average cost of travel and average cost of servicing each gaging station visited along the way.

The first step in applying K-CERA is to define the set of practical routes. This set of routes frequently will contain single-station routes, which are paths to one gaging station, so that the individual needs of a gaging station can be considered separate from other gaging stations.

Special requirements for visits to each gaging station for activities, such as necessary periodic maintenance and rejuvenation of recording equipment, must be determined. Such special requirements are considered to be inviolable constraints in terms of the minimum number of visits to each gaging station.

A computer program is used to determine the frequency that the i^{th} route, N_i (for i = 1, 2, ..., NR, where NR is the number of practical routes), is used such that (1) the budget for the network is not exceeded, (2) the minimum number of visits to each gaging station is made, and (3) the total uncertainty in the network is minimized. Figure 6 shows the mathematical form of the problem that must be solved.

Figure 7 shows a tabular layout of the problem. Each of the NR routes is represented by a row of the table and each of the gaging stations is represented by a column. The matrix, ω_{ij}, defines the routes in terms of the gaging stations that comprise it. A value of one in row i and column j indicates that

$$\underset{\underline{N}}{\text{Minimize}}\ V = \sum_{j=1}^{MG} \phi_j\ (M_j)$$

V ≡ total uncertainty in the network

$\underline{N}$ ≡ vector of annual number times each route was used

MG ≡ number of gages in the network

M_j ≡ annual number of visits to station j

ϕ_j ≡ function relating number of visits to uncertainty at station j

Such that

Budget $\geq T_c$ ≡total cost of operating the network

$$T_c = F_c + \sum_{j=1}^{MG} \alpha_j M_j + \sum_{i=1}^{NR} \beta_i N_i$$

F_c ≡ fixed cost

α_j ≡ unit cost of visit to station j

NR ≡ number of practical routes chosen

β_i ≡ travel cost for route i

N_i ≡ annual number times route i is used (an element of $\underline{N}$)

and such that

$$M_j \geq \lambda_j$$

λ_j ≡ minimum number of annual visits to station j

Figure 6.--Mathematical formulation for the optimization of the routing of hydrographers.

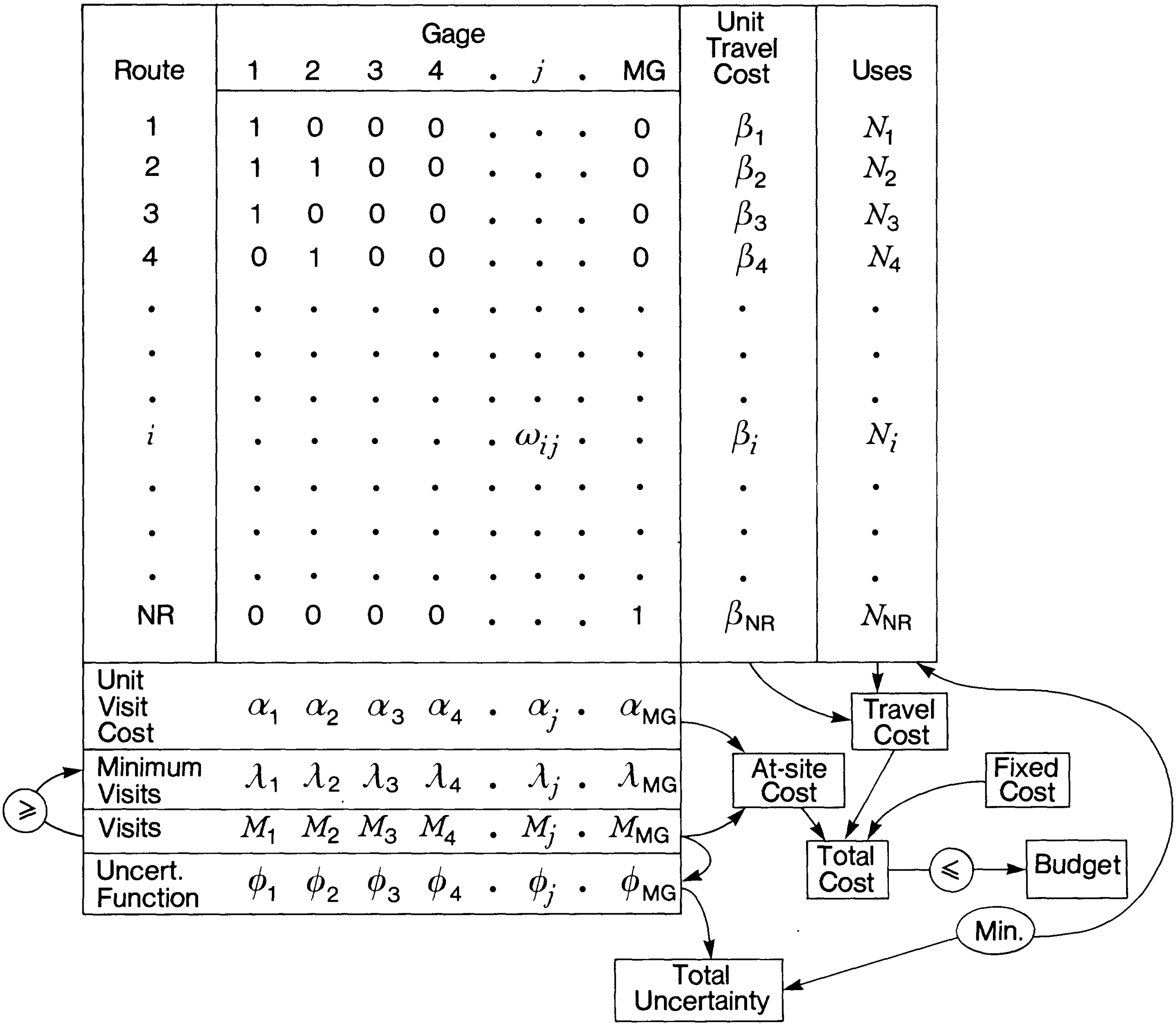

Figure 7.--Schematic of the mathematical formulation for the optimization of the routing of hydrographers.

gaging station j will be visited on route i; a value of zero indicates that it will not. The unit-travel costs, β_i, are the per-trip costs of the hydrographer's travel time and any related per diem and operation, maintenance, and rental costs of vehicles. The sum of the products of β_i and N_i for i = 1, 2, ..., NR is the total travel cost associated with the set of decisions $\underline{N} = (N_1, N_2 \ldots, N_{NR})$.

The unit-visit cost, α_j is comprised of the average service and maintenance costs incurred on a visit to the gaging station plus the average cost of making a discharge measurement. The set of minimum-visit constraints is denoted by the row λ_j, j = 1, 2, ..., MG, where MG is the number of gaging stations. The row of integers M_j, j = 1, 2, ..., MG specifies the number of visits to each gaging station. M_j is the sum of the products of ω_{ij} and N_i for all i and must equal or exceed λ_j for all j if $\underline{N}$ is to be a feasible solution to the problem.

The total cost expended at the gaging stations is equal to the sum of the products of α_j and M_j for all j. The cost of record computation, documentation, and publication is assumed to be influenced negligibly by the number of visits to the gaging station and is included along with overhead in the fixed cost of operating the network. The total cost of operating the network equals the sum of the travel costs, the at-site costs, and the fixed cost, and must be less than or equal to the available budget.

The total uncertainty in the estimates of discharges at the MG number of stations is determined by summing the uncertainty functions, ϕ_j, evaluated at the value of M_j from the row above it, for j = 1, 2, ..., MG. A description of the uncertainty function is given in the next section of the report.

As pointed out in Moss and Gilroy (1980), the steepest-descent search used to solve this problem does not guarantee a true optimum solution. However, the locally optimum set of values for $\underline{N}$ obtained with this technique specify an efficient strategy for operating the network, which may be the true optimum strategy. The true optimum cannot be guaranteed without testing all undominated, feasible strategies.

Description of Uncertainty Functions

As noted earlier, uncertainty in streamflow records is measured in this study as the variance of the percentage errors of estimation of instantaneous discharges. The accuracy of a streamflow estimate depends on how that estimate was obtained. Three situations are considered in this study: (1) Streamflow is estimated from a stage-discharge relation (rating curve) developed from measured discharge and primary correlative data such as stage, (2) the streamflow record is reconstructed using secondary data at nearby gaging stations because primary correlative data are missing, and (3) primary and secondary data are unavailable for estimating streamflow. The variances of the errors associated with these situations are weighted by the fraction of time each situation is expected to occur and combined to estimate the expected total error variance. Thus, the expected total error variance would be

$$V_T = \varepsilon_f V_f + \varepsilon_r V_r + \varepsilon_e V_e \tag{5}$$

with

$$1 = \varepsilon_f + \varepsilon_r + \varepsilon_e$$

where

V_T is the expected total error variance of the percentage errors of estimation of streamflow estimates,

ε_f is the fraction of time that the primary recorders are functioning,

V_f is the variance of the errors of streamflow records estimated from primary recorders and rating curves,

ε_r is the fraction of time that secondary data are available to reconstruct streamflow records given that the primary data are missing,

V_r is the variance of the errors of streamflow records reconstructed from secondary data,

ε_e is the fraction of time that primary and secondary data are not available to compute streamflow records, and

V_e is the variance of errors during periods of no concurrent data at nearby gaging stations.

The fractions of time that each source of error is relevant are functions of the frequencies at which the recording equipment is serviced. The time since the last service visit until failure of the recorder or recorders at the primary gaging station, τ, is assumed to have a negative-exponential probability distribution truncated at the next service time. The distribution's probability density function is

$$f(\tau) = ke^{-k\tau}/(1-e^{-ks}) \tag{6}$$

where

k is the failure rate in units of $(\text{day})^{-1}$,

e is the base of natural logarithms, and

s is the interval between visits to the gaging station in days.

It is assumed that, if a recorder fails, it continues to malfunction until the next service visit. As a result,

$$\varepsilon_f = (1-e^{-ks})/(ks) \tag{7}$$

(Fontaine and others, 1984, eq. 21).

The fraction of time that no records exist at either the primary or secondary gaging stations, ε_e, can also be derived by assuming that the times between failures at both sites are independent and have negative exponential distributions with the same rate constant. It then follows that

$$\varepsilon_e = 1 - [2(1-e^{-ks}) + 0.5(1-e^{-2ks})]/(ks) \qquad (8)$$

(Fontaine and others, 1984, eqs. 23 and 25).

Finally, the fraction of time that records are reconstructed based on data from a secondary gaging station, ε_r, is determined by the equation

$$\begin{aligned}\varepsilon_r &= 1 - \varepsilon_f - \varepsilon_e \\ &= [(1-e^{-ks}) + 0.5(1-e^{-2ks})]/(ks).\end{aligned} \qquad (9)$$

The variance, V_f, of the error derived from primary record computation is determined by analyzing a time series of residuals that are the differences between the common logarithms of measured discharge and the rating curve discharge. The rating curve discharge is determined from a relation between discharge and some correlative data, such as water-surface elevation (stage) at the gaging station. The measured discharge, $q_m(t)$, is the discharge determined by field observations of depths, widths, and velocities. Let $q_T(t)$ be the true instantaneous discharge at time t and let $q_R(t)$ be the discharge estimated using the rating curve. Then

$$x(t) = \log q_T(t) - \log q_R(t) = \log [q_T(t)/q_R(t)] \qquad (10)$$

is the instantaneous difference between the common logarithms of the true discharge and the rating curve discharge.

In computing estimates of streamflow, the rating curve may be continually adjusted on the basis of periodic measurements of discharge. This adjustment process results in an estimate, $q_c(t)$, that is a better estimate of the stream's discharge at time t. The difference between the variable $\hat{x}(t)$, which is defined

$$\hat{x}(t) = \log q_c(t) - \log q_R(t) \qquad (11)$$

and x(t) is the error in the streamflow record at time t. The variance of this difference over time is the desired estimate of V_f.

Unfortunately, the true instantaneous discharge, $q_T(t)$, cannot be determined and thus x(t) and the difference, $\hat{x}(t) - x(t)$, cannot be determined as well. However, the statistical properties of $\hat{x}(t) - x(t)$, particularly its variance, can be inferred from the available discharge measurements. Let the observed residuals (differences between the common logarithms of measured discharge and rating curve discharge) be z(t), so that

$$z(t) = x(t) + v(t) = \log q_m(t) - \log q_R(t) \qquad (12)$$

where

$v(t)$ is the measurement error, and

$\log q_m(t)$ is the common logarithm of the measured discharge, equal to $\log q_T(t)$ plus $v(t)$.

The time series of residuals, $z(t)$, was analyzed by using a Kalman filter to determine three site-specific parameters.

The Kalman filter used in this study assumes that the residuals, $x(t)$, arise from a continuous, first-order Markovian process that has a Gaussian (normal) probability distribution with zero mean and variance (subsequently referred to as process variance) equal to p. A second important parameter is β, the reciprocal of the correlation time of the Markovian process giving rise to $x(t)$; the correlation between $x(t_1)$ and $x(t_2)$ is $\exp[-\beta|t_1-t_2|]$. Fontaine and others (1984) also define q, the constant value of the spectral density function of the white noise which drives the Gauss-Markov x-process. The parameters, p, q, and β are related by

$$\mathrm{Var}[x(t)] = p = q(2\beta). \tag{13}$$

The variance of the observed residuals $z(t)$ is

$$\mathrm{Var}[z(t)] = p + r \tag{14}$$

where r is the variance of the measurement error $v(t)$. The three parameters, p, β, and r, are computed by analyzing the statistical properties of the $z(t)$ time series. These three site-specific parameters are needed to define this component of the uncertainty relationship. The Kalman filter utilizes these three parameters to determine the variance of the errors of streamflow records estimated from a rating curve and primary recorder, V_f, as a function of the number of discharge measurements made at a gaging station each year (Moss and Gilroy, 1980).

If the recorder at the gaging station (primary station) fails and there are no concurrent data at other gaging stations that can be used to reconstruct the missing record at the primary station, there are at least two ways of estimating discharges at the primary station. The stage hydrograph could be extended as a recession curve from the time of recorder stoppage until the recorder was once again functioning, or the expected value of discharge for the period of missing data could be used as an estimate. The expected-value approach is used in this study to estimate V_e, the relative variance of errors during periods of no concurrent data at nearby gaging stations. The expected value used should be the expected value of discharge at the time of year when the missing record occurred because of the seasonality of streamflow. The variance of streamflow also varies seasonally and is an estimate of the error variance that results from using the expected value as an estimate of discharge. Thus, the coefficient of variation, C_v, squared is an estimate of the error variance V_e. Because C_v varies seasonally and the times of failures cannot be anticipated, a seasonally averaged C_v is used:

$$\bar{C}_v = 100 \left(\frac{1}{365} \sum_{i=1}^{365} \left(\frac{\sigma_i}{\mu_i} \right)^2 \right)^{1/2} \tag{15}$$

where

$\bar{C}_v$ is the seasonally averaged coefficient of variation (in percent),

σ_i is the standard deviation of daily discharges for the i^{th} day of the year,

μ_i is the expected value of discharge on the i^{th} day of the year, and

$(\bar{C}_v)^2$ is used as an estimate of V_e.

The variance of the error during periods of reconstructed streamflow records, V_r, is estimated on the basis of correlation between records at the primary station and records from other nearby gaging stations. The cross-correlation coefficient, ρ_c, between the streamflows with seasonal trends removed (detrended) at the primary stations and detrended streamflows at the other gaging stations is a measure of the goodness of their linear relation. The fraction of the variance of streamflow at the primary station that is explained by data from the other gaging stations is equal to $\rho_c{}^2$. The fraction of unexplained variance, that is the error in reconstructed records at the primary station is $(1 - \rho_c{}^2)$. The relative variance of the errors of streamflow records reconstructed from secondary data is

$$V_r = (1 - \rho_c{}^2)\bar{C}_v{}^2. \tag{16}$$

Sometimes the record for a gaging station can be reconstructed by correlation with more than one nearby gaging station. For the fraction of time when no secondary data are available from the gaging station typically used (secondary station) for record reconstruction (ε_e), data from another (tertiary) gaging station can be used. The correlation of data from the tertiary station with data from the station of interest is denoted R_2. The value of R_2 is always less than or equal to ρ_c. The error variance of records estimated from a tertiary source of information is

$$(1 - R_2^2)\ (\bar{C}_v)^2 = (1 - R_2^2)\ V_e. \tag{17}$$

Because errors in streamflow estimates arise from three different sources with widely varying precisions, the resultant distribution of those errors may differ significantly from a normal or log-normal distribution. This lack of normality causes difficulty in interpreting the expected total error variance. When data are unavailable, the error variance V_e may be very large. This could yield correspondingly large values of V_T in equation 5 even if the probability that auxiliary correlative data are not available, ε_e, is quite small.

A new statistic, the equivalent Gaussian spread (EGS), is introduced here to assist in interpreting the results of the analyses. If it is assumed that the various errors arising from the three situations represented in equation 5 are log-normally distributed, the value of EGS is determined by the probability statement that

$$\text{Probability } [10^{-EGS} \leq (q_c(t) \,/\, q_T(t)) \leq 10^{+EGS}] = 0.683. \qquad (18)$$

Thus, if the residuals, $\log q_c(t) - \log q_T(t)$, were normally distributed, $(EGS)^2$ would be their variance. The EGS is reported in units of percent because EGS is defined so that nearly two-thirds of the errors in instantaneous streamflow data will be within plus or minus EGS percent of the reported values.

Application of K-CERA

As a result of the first two steps of the stream-gaging program evaluation, it was determined that all of the gaging stations in the Illinois stream-gaging program should continue to be operated. These gaging stations were studied using the K-CERA techniques, with results that are described below.

Probability of Missing Record

As was described earlier, the statistical characteristics of missing stage records or other correlative data for computing streamflow records can be defined by a single parameter, the value of k in the truncated, negative-exponential probability distribution of times to failure for the equipment at a gaging station. In the representation of $f(\tau)$ as given in equation 6, the average time to failure is $1/k$. The value of $1/k$ varies from station to station depending upon the type of equipment at the station and upon its exposure to natural elements and vandalism. The value of $1/k$ can be changed by advances in the technology of data collection and recording. A 10-year period of actual data collection during which little change in technology occurred was used to estimate $1/k$ in Illinois.

During this 10-year period, the equipment at gaging stations could be expected to malfunction 7.5 percent of the time when stations were visited on a monthly frequency. The corresponding value for $1/k$ of 193 days was used to determine ε_f, ε_e, and ε_r for each gaging station as a function of the frequency of visiting the station.

The most common causes of missing stage record were malfunctioning water-stage recorders and timing devices; and undercharged batteries. These causes were responsible for 53 percent of the missing record during the 10-year period analyzed. Water-stage sensing equipment malfunctions caused 12 percent of the missing record--3.3 percent associated with floats in stilling wells and 8.7 percent associated with manometers. Twelve percent of the missing record was attributable to orifice lines and intakes that were plugged by sand and silt. Frozen orifice lines, intakes, and stilling wells typically caused 7 percent of the missing record. However, during the severe winters of 1977, 1978, and 1979, these conditions caused 41, 34, and 17 percent of the missing record, respectively. Equipment failure due to frozen conditions was not considered in the calculation of the probability of missing record for reasons given in a subsequent section of the report on Kalman-filter definition of variance.

Cross-Correlation Coefficients and Coefficients of Variation

Daily streamflow records for 132 stations having 3 or more years of data were analyzed to compute the values of V_e and V_r. As many as 30 years of daily streamflow records for each gaging station, back to water year 1952, were retrieved from WATSTORE (Hutchinson, 1975) and used to compute the seasonally-averaged coefficient of variation ($\overline{C_v}$) for each station. Various options, based on combinations of other gaging stations, were explored to determine the maximum ρ_c. The next largest value of ρ_c for a different combination of gaging stations, if available, was assigned to R_2. Values of $\overline{C_v}$ and ρ_c were estimated subjectively for the six gaging stations that had less than 3 water years of data.

There are several other ways of reconstructing streamflow record when the primary recorder malfunctions. Telemetry systems that operate independent of the primary recorder may be queried. A local resident, called an observer, may be hired to read and record stage data at a specified frequency. Fontaine and others (1984) determined that the cross-correlation coefficient, ρ_c, for daily discharges and daily observer or telemetry readings was 0.96 in Maine. The same value was used in this study.

Parameters for each gaging station and the auxiliary sources of hydrographic records that gave the highest cross-correlation coefficients are listed in table 6. The seasonally-averaged coefficient of variation varied from 62.0 percent for Kankakee River at Momence (05520500) to 300 percent for Crab Orchard Creek near Marion (05597500). Thirty-one gaging stations have a $\overline{C_v}$ greater than 200 percent, and 20 gaging stations have a $\overline{C_v}$ less than 100 percent.

Missing streamflow records at 100 gaging stations are reconstructed from hydrographic records at nearby gaging stations. The cross-correlation coefficient for daily mean streamflows at those stations ranges from 0.54 for Boneyard Creek at Urbana (03337000) to 0.97 at four other gaging stations. Twenty-six of these gaging stations have a ρ_c greater than 0.90.

Telemetry systems that operate independently of the recorder at a gaging station and observers provide auxiliary hydrographic records at 14 and 24 of the gaging stations, respectively. The ρ_c for these auxiliary sources of information is 0.96.

Kalman-Filter Definition of Variance

The error variance V_f for each gaging station was determined from a 3-step procedure: (1) Long-term rating analysis and computation of residuals of measured discharges from the long-term rating, (2) time-series analysis of the residuals to determine the input parameters of the Kalman-filter streamflow records, and (3) computation of the relative variance V_f as a function of the time-series parameters, the discharge-measurement error variance, and the frequency of measuring discharge.

The rating functions determined for 137 of the 138 gaging stations have the form:

$$LQM = B1 + B3 \times \log(GHT-B2) \qquad (19)$$

where

LQM is the common logarithm of measured discharge,

GHT is the gage height observed during the discharge measurement,

B1 is the logarithm of discharge for an effective flow depth of 1 foot (when GHT-B2 = 1.0),

B2 is the effective gage height of zero flow,

B3 is the slope of the discharge versus gage-height relation plotted on logarithmic paper, and

log is the common logarithm function.

Between 13 and 128 pairs of discharge and corresponding gage height from recent discharge measurements at a gaging station were analyzed using a nonlinear optimization algorithm (PROC NLIN) available on the SAS (Statistical Analysis System, SAS Institute, 1982).[1] The measurements are representative of present (1983) stream-channel conditions. Measurements significantly affected by ice cover were omitted from analysis. PROC NLIN computes values for B1, B2, and B3 that minimize the sum of the squared difference between the estimated LQM's and common logarithms of observed discharges.

At many gaging stations, the stage-discharge rating function is segmented; it can be plotted as a number of straight-line segments on logarithmic paper for different values of B2. All rating functions were segmented to remove any inter-dependency between residuals and gage height. Many of the rating functions consist of two or three sets of B1, B2, and B3 that are appropriate within prescribed ranges of gage height.

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[1] Use of SAS in this report is for identification purposes only and does not constitute endorsement by the U.S. Geological Survey.

Discharges at several gaging stations were adjusted to account for rapidly changing stage or backwater conditions. Methods for adjusting discharges to account for such conditions are presented by Rantz and others (1982). Adjusted discharge and observed gage height were used to calculate B1, B2, and B3.

The U.S. Geological Survey also maintains a gaging station, Illinois River near Henry (05558900), where an electromagnetic velocity meter is operated. The meter senses stream velocity at a fixed location in the river. Discharge measurements are made to determine a stage-flow area rating function and a point velocity (measured by the meter)-mean channel velocity rating function. Measured discharge is a function of stage and point velocity. The general form of the function used in this study is:

$$LQM = B1 + B3 \times \log(GHT - B2) + B4 \times LPV \qquad (20)$$

where

LPV is the common logarithm of the measured point velocity, and

B4 is similar to the slope of the discharge-point velocity relation plotted on logarithmic paper.

All other variables and parameters are essentially the same as defined for equation 19. PROC NLIN was used to compute B1, B2, B3, B4, and a set of residuals.

The relation for the residual calculated for each measurement as a function of time, in days, is referred to as a time series of residuals. This time series was used to compute sample estimates of q and β (equation 13), two of the three parameters required to compute V_f. This was accomplished by determining a best-fit autocovariance function to the time series of residuals. Measurement error variance, the third parameter, is assumed to be a constant 3.5 percent standard error.

The process variance of the residuals is a function of q and β and the 1-day autocorrelation coefficient (RHO) is a function of β. Table 7 presents a summary of the autocorrelation analyses expressed in terms of process variance and 1-day autocorrelation. The right-most column in table 7 refers to the duration of the open-water period typically experienced at a gaging station. Autocovariance analyses were strictly limited to periods when backwater effects due to ice were minimal.

The autocovariance parameters, summarized in table 7, and statistics for reconstructing missing record, summarized in table 6, are used jointly to define uncertainty functions for each gaging station. The uncertainty functions give the relation of expected total error variance to the number of visits and discharge measurements. Three uncertainty functions are shown in figure 8. The functions are based on the assumption that a measurement was made during each visit to the gaging station.

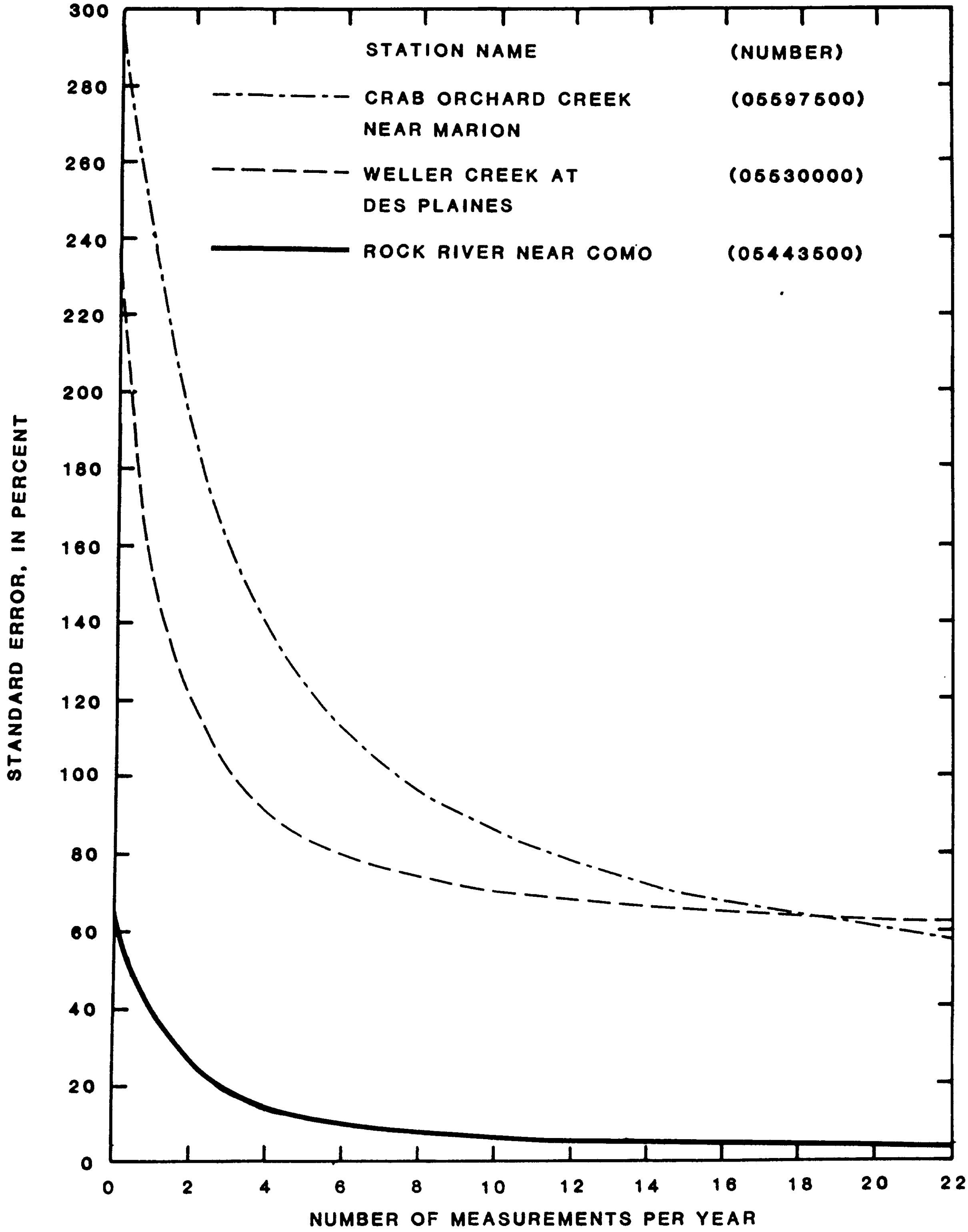


Figure 8.--Uncertainty functions for three gaging stations in Illinois.

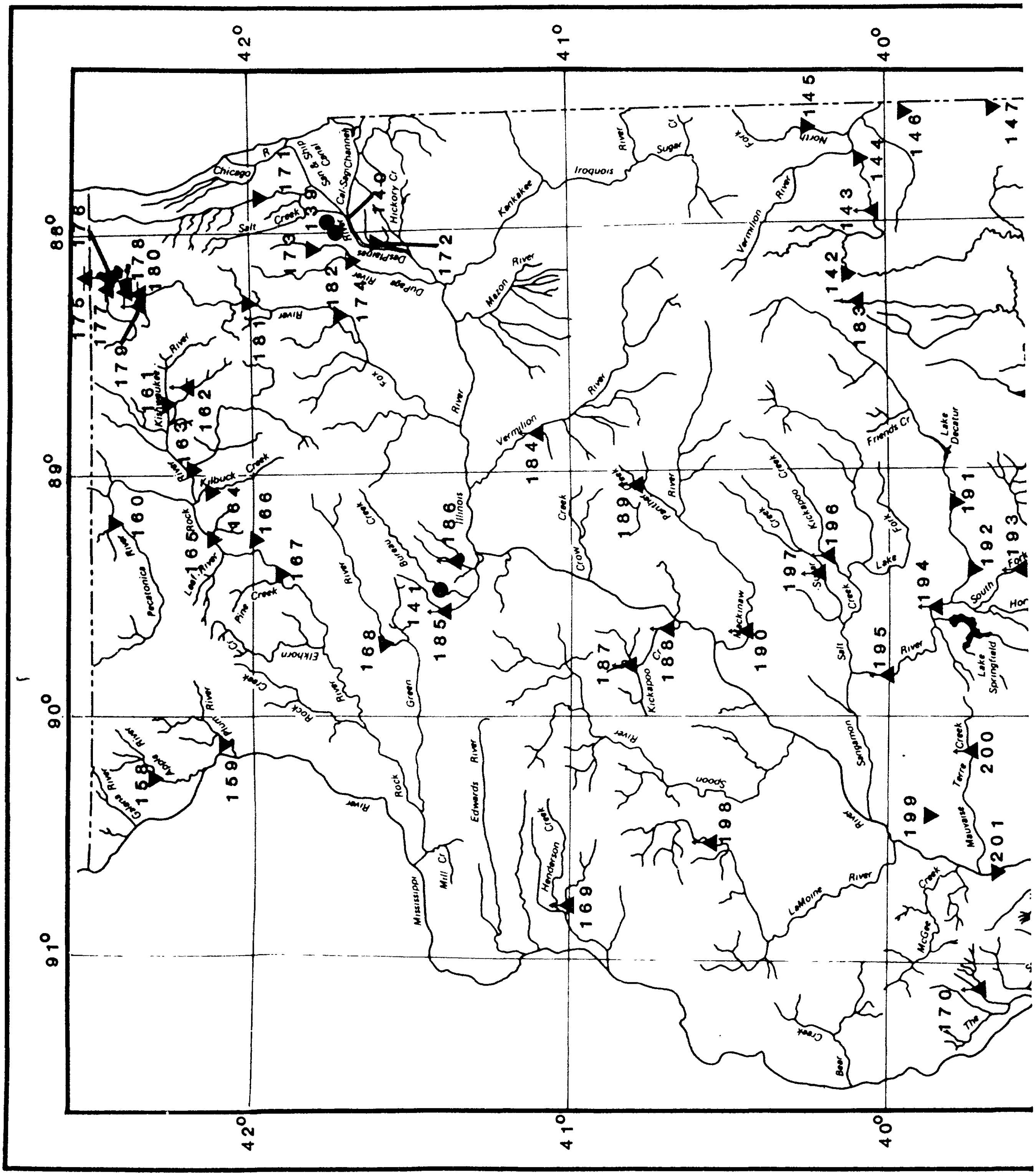
Stream-Gaging Routes and Costs

In Illinois, feasible routes to service the 138 gaging stations were determined after consulting with U.S. Geological Survey personnel located in field offices in De Kalb, Mt. Vernon, and Urbana and after reviewing the uncertainty functions. A total of 141 routes were selected to service all of the gaging stations in Illinois. These routes included all possible combinations that describe the current operating practice, alternatives that were under consideration as future possibilities, routes that visited certain individual gaging stations, and combinations that grouped proximate stations where the levels of uncertainty indicated more frequent visits might be useful. These routes and the stations visited on each route are summarized in table 8. A negative station number identifies a "dummy" station. Dummy stations, such as crest-stage partial-record stations and stations where ratings are maintained for water-quality sampling, are routinely visited but do not have uncertainty functions. Station names and numbers, and principal uses of data collected for the 81 dummy stations included in this study are listed in table 9. Station locations are shown in figure 9.

The costs, in 1983 dollars, associated with stream gaging were then determined. The costs are categorized as annual fixed, visit, and route costs. Annual fixed costs to operate a gage typically include equipment rental, batteries, electricity, data processing and storage, computer charges, maintenance and miscellaneous supplies, and analysis and supervisory charges. At stations where ice measurements are routinely made, $100 per ice measurement was added to the fixed cost. No more than two ice measurements are routinely made at any gaging station. Costs of analysis and supervision are a large percentage of the fixed cost of a gaging station and ranged from $600 to $2,200 per station. These costs were determined by estimating, on a station-by-station basis from past experience, the time spent performing such activities. That time was then multiplied by the average hourly salary of hydrographers in each field office and added to all other fixed station costs.

Visit costs are associated with the salary of the hydrographer for the time actually spent at a gaging station servicing the equipment and making a discharge measurement during a visit. These costs differ from station to station and are a function of the difficulty and time required to make the discharge measurement. Average visit times were estimated for each station based on the field-office personnels' past experience. This time was then multiplied by the average hourly salary of hydrographers in each field office to determine total visit costs. Costs ranged from $10 to $100 per visit.

Route costs include the vehicle cost associated with driving the route, the cost of the hydrographer's time while in transit, and any per diem cost associated with the time it takes to complete the trip. Vehicle costs were determined by calculating total route mileage from maps and multiplying by a rate of 46 cents per mile. Per diem cost and transit time were estimated from past experience. Transit time was multiplied by the average hourly salary of hydrographers in each field office and added to a per diem cost of $50 and vehicle costs to determine total route costs.


42°
41°
40°
88°
89°
90°
91°
Chicago
Salt Creek
San & Ship Canal
Cal.Sag Channel
Hickory Cr
DesPlaines River
DuPage River
Kankakee
Iroquois
Sugar Cr
North Fork
Vermilion River
Mazon River
Fox River
Illinois River
Kishwaukee River
Kilbuck Creek
Rock River
Pecatonica River
Leaf River
Pine Creek
Elkhorn Creek
Green River
Bureau Creek
Crow Creek
Kickapoo Cr
Mackinaw River
Salt Creek
Sangamon River
Friends Cr
Lake Decatur
Lake Fork
South Fork
Lake Springfield
Spoon River
Edwards River
Henderson Creek
Mill Cr
Mississippi River
LaMoine River
Mauvaise Terre Creek
McGee Creek
Bear Creek
Apple River
Galena River
Plum River

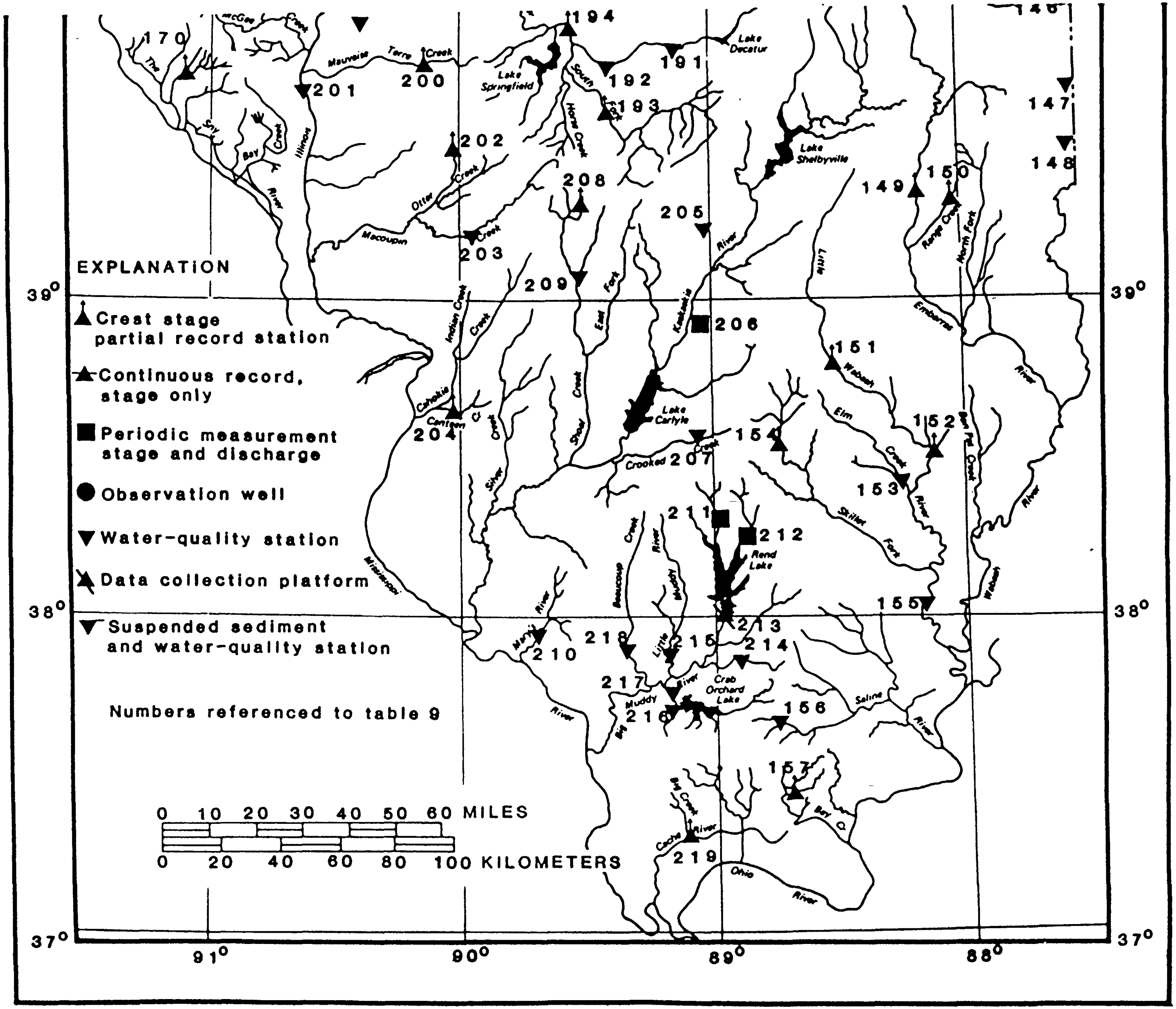


Figure 9.--Location of additional stations included in routes used to visit continuous-record streamflow stations in Illinois.

Results of K-CERA

The "Traveling Hydrographer Program" uses the uncertainty functions along with the appropriate cost data and route definitions to compute the most cost-effective way of operating the stream-gaging program. First, the current practice for operating the stream-gaging program was simulated to determine the total uncertainty associated with it. This is accomplished by fixing the number of visits made to each gaging station and selecting only the specific routes presently used to make these visits. The simulation of the current practice is strictly an accounting of all fixed, visit, and route costs; no optimization is performed. Most of the gaging stations in Illinois are routinely visited nine times per year. The resulting average standard error per station for the current method of operation in Illinois is plotted as a point labeled "current practice" in figure 10.

The solid curve in figure 10 labeled "optimal practice (with missing record)" represents the minimum level of average uncertainty that can be obtained for a given budget with the existing instrumentation and technology. The curve was defined by executing the "Traveling Hydrographer Program" to determine optimal strategies for different budgets. Constraints on the operations other than budget were defined as described below.

Physical limitations of the method used to record data determine the minimum number of times each gaging station must be visited. The criteria used to assign a minimum-visit requirement to each gaging station are summarized in table 10. The effect of visitation frequency on the accuracy of the data and amount of lost record is taken into account in the uncertainty function.

No flow occurs at many gaging stations located on small watersheds. The hydrographer visiting a gaging station during such a period will only perform routine maintenance work and will not make a discharge measurement. The probability of making a discharge measurement during a visit was estimated by field-office personnel based on past experience and used as an input to the "Traveling Hydrographer Program." This constraint ensures that the more appropriate uncertainty related to the number of measurements, and not the number of visits, is used.

The current budget available for visiting all gaging stations considered in this analysis is $768,000. The average standard error (square root of average expected total error variances) for the stream-gaging program, resulting from the current practice for visiting the stations, is 36.5 percent (fig. 10). Site specific standard errors corresponding to the number of measurements made at each gaging station are presented in table 11. Standard errors range from 5.3 percent for Rock River at Como (05443500) to 80.4 percent for Crab Orchard Creek near Marion (05597500).

The standard error for the current practice is 5.7 percent greater than the 30.8 percent standard error associated with optimal practice, indicated by the solid curve at a budget of $768,000 (fig. 10 and table 11). The reduction in average standard error is achieved by visiting gaging stations having higher

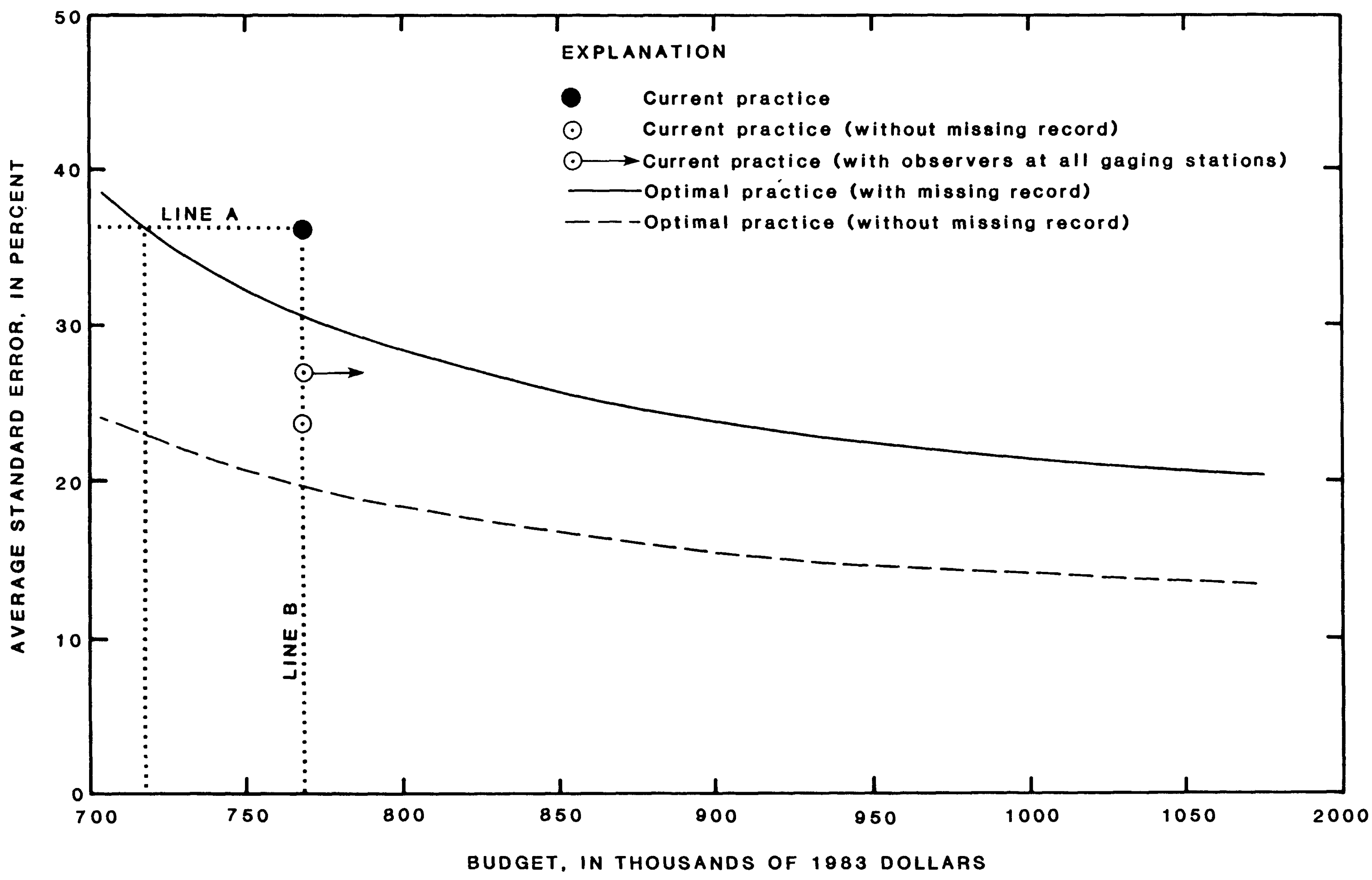


Figure 10.--Temporal-average standard error per station.

uncertainties more frequently and stations with lower uncertainties less frequently than the current practice (table 11). For example, although the standard error at Rock River near Como (05443500) would remain nearly the same (5.1 percent) by visiting 10 times rather than the present 9 times per year, the uncertainty at Crab Orchard Creek near Marion (05597500) would be reduced to 51.9 percent by increasing the annual number of visits to the station from 9 to 22. Route number 27 (table 8), which is currently used nine times per year, would never be used. Routes number 30 and 44 would be used 14 times and 8 times per year, respectively. The slopes of the uncertainty functions for Rock River near Como and Crab Orchard Creek near Marion (fig. 8) at nine measurements per year indicate that the decrease in standard error for an additional measurement at Crab Orchard Creek near Marion is much greater than the decrease expected for Rock River near Como. Therefore, the cost-effective solution is to redistribute resources from gaging stations with lesser-sloped uncertainty functions to Crab Orchard Creek near Marion.

Districtwide, 41 routes are currently used; however, this would be increased to 65 routes to reduce average standard error to a minimum-attainable level of 30.8 percent for a budget of $768,000.

The solid curve in figure 10 also indicates that the minimum budget needed to maintain the current average standard error of 36.5 percent is $717,500. This budget is determined by drawing line A through the "current practice" point parallel to the budget axis to the solid curve and dropping vertically to the budget axis.

The minimum-practicable budget (for optimal practice) is $706,600; 8 percent less than the current budget. Any budget less than this amount does not allow for a minimum number of visits to the gaging stations for maintenance activities. The average standard error for the minimum-practicable budget is 38.5 percent.

Visit frequencies and resulting standard errors for four budgets are presented in table 11. The two strategies presented in third and fourth columns of table 11 are for current operations (with and without the error associated with missing record) and a current budget of $768,000.

The other four strategies show minimum-attainable standard errors for budgets -8.0, 0.0, 10, and 20 percent different than $768,000. The table indicates the change in activity at a gaging station that could be expected as the budget changed. The average standard errors for the budgets define part of the solid curve shown in figure 10. The curve extends from a minimum-practicable budget of $706,600 to $1,075,000 (40 percent more than the current budget) for which the average standard error is 19.7 percent.

The dashed curve, labeled "optimal practice (without missing record)" on figure 10, shows the average standard errors that could be obtained if perfectly reliable systems were available to measure and record the correlative data. The impacts of less-than-perfect equipment are greatest for the minimum-practicable budget of $706,600 where the average standard error increases from 24.4 percent to 38.5 percent. For a budget of $921,600, gaging stations are visited more frequently and the average standard error would increase from

15.1 percent for ideal equipment performance to 23.4 percent for the present percentage of lost record. For the current practice of visiting gaging stations, stage record that is lost due to equipment malfunction and other causes increases average standard error from 23.8 percent to 36.5 percent [see fig. 10, point labeled "current practice (without missing record)" and third and fourth columns of table 11]. Thus, improved equipment and maintenance activities can have a very positive impact on streamflow uncertainties throughout the range of operational budgets that possibly could be anticipated for the stream-gaging program in Illinois.

Technological advances in recording equipment and telemetry systems should reduce the current percentage of missing stage record. The U.S. Geological Survey currently (1983) is developing a family of data-acquisition instruments to replace existing water-stage recorders and timing devices. This family of instruments, referred to as AHDAS (Adaptable Hydrologic Data Acquisition System), has solid-state memory and "intelligent" microprocessor-control features. Present carbon-zinc batteries will soon be replaced with rechargeable lead-acid batteries. Field tests have shown that the new batteries are very reliable and are expected to last from 3 to 5 years (W. P. Bartlett, Jr., W. B. Higgins, and K. V. Sharp, U.S. Geological Survey, written commun., 1983). The Corps will soon be operating a DCP (Data Collection Platform) at about 45 gaging stations in Illinois. A DCP records hydrographic data (primarily stage data) and transmits the recorded data at specified time intervals to a geostationary satellite. Signals from the DCP are relayed by the satellite to a receive site. Users may acquire the data at a receive site through a dial-up or real-time dedicated circuit. Hydrographers will be able to more efficiently monitor trends in stage records to determine if equipment at a gaging station is malfunctioning.

If all of the gaging stations had an observer or telemetry system that provided auxiliary hydrographic data, the average standard error for current operations would be 27.0 percent or 3.2 percent more than the average standard error when there is no missing record. This strategy (of maintaining observers or telemetry systems at all gaging stations) was simulated by recalculating the uncertainty function for each gaging station using an interstation correlation coefficient (ρ_c) of 0.96. The cost to implement such a strategy would vary depending on whether the U.S. Geological Survey or some other agency purchased and maintained the telemetry systems or paid observer salaries. Therefore, the point in figure 10 that is labeled "current practice (with observers at all gaging stations)" is plotted at the current budget with an arrow indicating the budget might have to be increased.

The "best possible" average standard error that can be attained for the current budget of $768,000 using the 141 routes shown in table 8 is 19.7 percent. This error is shown in figure 10 as the intersection of line B with the dashed curve. Stream-gaging resources must be optimally distributed among the gaging stations and all of the instrumentation at the gaging stations must provide accurate hydrographic record for the entire year (ice-free period) to attain this standard error. The only way to further reduce the average standard error is to define additional routes that have not been considered and(or) to reduce the relative variance of errors associated with the stage-discharge rating (V_f) at gaging stations having high standard errors of instantaneous discharge.

A majority of the discharge measurements considered in the Kalman-filter definition of variance for a gaging station were made during low- to medium-flow conditions. The low range of many stage-discharge ratings is subject to considerable shifting due to transient changes in streambed geometry, intermittent debris jams, or seasonal aquatic plant growth. The high end of a rating is often much more stable. The standard errors presented in table 11 are more representative of low to medium discharges. Kalman filtering can be used to determine the standard error associated with the high end of a rating; however, the long intervals of time (more than 80 days) between high-flow measurements would preclude an accurate determination of the 1-day autocorrelation coefficient (RHO) for a time series of high-flow rating residuals.

The stream-gaging network in Illinois is maintained by hydrographers based in De Kalb, Urbana, and Mt. Vernon. The field areas covered by the hydrographers encompass roughly the northern-, central-, and southern-thirds of the State, respectively. The average standard errors for the current practice of visiting gaging stations within the De Kalb, Urbana, and Mt. Vernon field areas are 28.8, 32.1, and 48.8 percent, respectively. Because all stations are visited at nearly the same frequency and have the same percentage of missing record, the higher standard error for the Mt. Vernon field area is probably a result of less stable controls, low inter-station correlation of hydrographic data, and more variable streamflow at gaging stations in the field area. Optimal strategies associated with the current budget and an average standard error of 30.8 percent, shown in figure 10 as the intersection of line B and the solid curve, reduce the average standard errors for the De Kalb, Urbana, and Mt. Vernon field areas to 26.8, 31.2, and 35.4 percent.

Ice-related backwater conditions were not included in the Kalman-filter definition of variance for stage-discharge ratings. Additional analyses would have to be performed to determine the standard errors for ice-affected instantaneous discharge.

Conclusions Pertaining to the K-CERA Analysis

1. The information presented in table 11, especially the standard error and EGS for instantaneous discharge that are associated with the current practice for visiting gaging stations, should be critically evaluated in terms of required accuracy for intended use. The accuracy of instantaneous discharge at gaging stations where the EGS is greater than 20 percent may not be sufficient for the intended use of the streamflow data. The long-term stage-discharge ratings for those gaging stations should be reviewed to determine the range in discharge that is sufficiently accurate for the intended data use.

2. No significant changes in the current practice for visiting gaging stations is warranted except, possibly, in the Mt. Vernon field area where the greatest number of "problem" stations exist. This may depend on actions resulting from the first conclusion.

3. The average annual percentage of missing hydrographic record attributable to equipment malfunctions at gaging stations is high. Technological advances in recording equipment and telemetry systems should reduce the current percentage of missing stage record. A reasonable goal for the current practice of visiting the gaging stations nine times per year is 5.0 percent, or 18 days, of missing record per year. Accurate records of the amounts and causes of missing record encountered in the future should be maintained to measure progress towards that goal.

4. An observer or telemetry system should be considered as an auxiliary source of hydrographic data at gaging stations where: Accurate records for the full range of discharge are needed, the seasonally-averaged coefficient of variation ($\overline{C}_V$) is greater than 150 percent, and the difference between the standard error with missing record and standard error without missing record for the current practice of visiting the stations (table 11) is greater than 20 percent.

5. The "Traveling Hydrographer Program" should be used as an operational tool to evaluate the sensitivity of route selection and gaging-station visit frequency to changes in budget and minimum-visit constraints and to determine if routes are economically and operationally feasible.

6. There is a need for a long-range program to collect accurate low-flow data (see conclusion number 2 on page 15). Table 11 indicates a high standard error and EGS for low flow at many gaging stations. This is of minimal concern if those gaging stations are primarily operated to provide flood data. However, low-flow data published and archived on WATSTORE (Hutchinson, 1975) may have limited usefulness in future investigations of low flows.

SUMMARY

The U.S. Geological Survey began collecting surface-water data for Illinois streams in 1903 when six gaging stations were established. The stream-gaging program gradually expanded to 47 gaging stations in 1939 and rapidly expanded to 157 gaging stations in 1955. From 1955 to 1982, the network of gaging stations varied in size from 144 gaging stations in 1959 to 171 gaging stations in 1971. The present (1983) stream-gaging program consists of 138 gaging stations, 23 stations less than were operated in the 1982 program.

The first formal evaluation of the Illinois stream-gaging program is described by Sieber (1970). This study, the second formal evaluation of the Illinois stream-gaging program, is part of a 5-year, nationwide effort by the U.S. Geological Survey to evaluate the operation of the gaging stations it maintains. This evaluation consists of three steps--identification of streamflow data use, funding, and availability; examination of less costly alternative methods for determining daily mean discharge in lieu of stream gaging; and determination of the cost effectiveness of the current stream-gaging program.

Current uses of streamflow data collected at each gaging station were determined by a survey of known data users, including agencies that do not participate in funding the stream-gaging program. Data uses were categorized into eight classes: Regional hydrology, hydrologic systems, legal obligations, planning and design, project operation, hydrologic forecasts, water-quality monitoring, and research.

Most of the 138 gaging stations in the current stream-gaging program are operated primarily to provide information on high streamflows to the agencies that participate in funding the stations. However, streamflow data at many gaging stations are used by several agencies for different purposes. Streamflow data at 88 gaging stations are useful for developing regionally transferable information about surface-water hydrology. Those stations are classified in the regional-hydrology data-use category. Eighty-seven gaging stations are used to monitor current hydrologic conditions, particularly high streamflows, and are classified in the hydrologic-systems category. The project-operation category includes 17 gaging stations used by the U.S. Army Corps of Engineers on a real-time basis to regulate the Mississippi, Ohio, and Illinois Rivers for navigation purposes. Streamflow data from 52 gaging stations in the hydrologic-forecasts category are used by the National Weather Service to predict floods. The Illinois Environmental Protection Agency uses streamflow data from 77 gaging stations to interpret water-quality data collected at its ambient water-quality network stations. The research category includes 90 gaging stations, 79 of which provide streamflow data for rainfall-runoff modeling and 60 of which provide information for determining long-term trends of streamflow.

Four gaging stations are maintained entirely or partially by Army Engineers Replacement funds which are directly allocated to the U.S. Geological Survey. The remaining funding for the Illinois stream-gaging program is derived from one other Federal agency and the U.S. Geological Survey's cooperative program with two State agencies and five local entities.

Streamflow data for all 138 gaging stations are published in the annual report for Illinois (Stahl and others, 1984; Fitzgerald and others, 1984). Telemetry systems provide streamflow data on a real-time basis at 37 gaging stations. Streamflow data are released on a provisional basis at 25 gaging stations.

Based on the data uses at each gaging station, six gaging stations were selected for the second step of the evaluation. A unit-response, hydrologic flow-routing model and(or) a statistical model were used to calculate estimates of daily mean streamflow at five of the gaging stations during two periods, each 3 to 5 years in duration. One period was used to calibrate a model and another to verify the calibrated model.

Streamflow records for Rock River near Joslin (05446500), which has a drainage area of 9,549 mi^2, were simulated with flow-routing and statistical models. Daily mean streamflows calculated by the flow-routing model were within 10 percent of observed streamflows for 88 percent of the days in the verification period 1940-42. The statistical model was somewhat less accurate, as calculated streamflows were within 10 percent of observed streamflow for 81 percent of the days for the same period.

Five other gaging stations located on rural watersheds and with drainage areas ranging from 12.4 to 186 mi^2 were considered for analysis by the statistical model only. Streamflow records at four of the gaging stations were not satisfactorily simulated with an acceptable degree of accuracy. Streamflow records at the gaging stations of interest did not correlate well with nearby gaging stations considered in the analysis. The gaging station with a 12.4 mi^2 drainage area was not analyzed for this reason.

The time constraints of this study precluded application of the alternative methods to all of the "best candidate" gaging stations based solely on hydrologic factors. However, results from applying the alternative methods to Rock River near Joslin (probably the best candidate station in the stream-gaging program) indicate that both the flow-routing and statistical models can be used to estimate daily mean discharge with a fair degree of accuracy at certain gaging stations.

Based on the evaluation of data use and the evaluation of alternative methods to stream gaging, no gaging stations in the 1983 stream-gaging program should be deactivated. All 138 gaging stations were included in the third step of the stream-gaging program evaluation.

The U.S. Geological Survey developed the Kalman-Filtering for Cost-Effective Resource Allocation (K-CERA) methodology to aid in evaluating its stream-gaging programs. The methodology identifies the uncertainty (error) of instantaneous discharge that results from (1) the variability of streamflow, (2) the methods used by the U.S. Geological Survey to determine discharge, and (3) realistic financial and operational constraints.

The standard errors presented in this report are more representative for low to medium discharges than for flood flows. The majority of discharges considered in the determination of uncertainty are for low- to medium-flow conditions. In addition, the effects of ice-related backwater conditions are not considered in this study.

The current practice for operating the stream-gaging program uses an annual budget of $768,000 (in 1983 dollars). The present (1983) average standard error of the instantaneous discharge for all gaging stations is 36.5 percent. This average could be maintained for a budget of $717,500, or 6.6 percent less than the present budget, if the current practice for visiting gaging stations is significantly modified. It may also be possible to decrease the average standard error by 5.7 percent if the present $768,000 budget is optimally redistributed to the gaging stations.

A budget of $706,600 is needed to optimally visit all gaging stations a minimum number of 2, 3, 5, or 17 times per year depending on the type of instrumentation at a gaging station. The resultant average standard error associated with this minimum-practicable budget is 2.0 percent more than the current level.

The loss of primary stage record and other correlative data at the gaging stations is a major component of error in streamflow records. Primary stage record is unavailable at gaging stations in Illinois an average of 27 days per year, 7.5 percent of the time, when gaging stations are visited on a monthly frequency. This percentage of lost record presently increases the average standard error associated with instantaneous discharge from 23.8 to 36.5 percent, or 12.7 percent, for the current practice of visiting gaging stations. The minimum possible average standard error that could be attained for the current budget of $768,000 is 19.7 percent. Stream-gaging resources must be optimally distributed among the gaging stations and all of the instrumentation at the gaging stations must provide accurate hydrographic record for the entire year to attain this level of accuracy.

As a result of the three-step evaluation of the Illinois stream-gaging program, the following conclusions are offered:

1. Formal surveys of gaging-station data use should be conducted at intervals of about 5 years or less.

2. The continuing need for five gaging stations providing streamflow data solely for regional information should be addressed in the results of the Network Analysis for Regional Information study that will be completed in the near future.

3. No gaging stations should be deactivated for the purpose of using alternative methods for estimating daily mean streamflow in lieu of stream gaging.

4. The U.S. Geological Survey and agencies that cooperate in the stream-gaging program should periodically review streamflow records of network gaging stations to ensure that highly correlated streamflows are not being measured without due cause.

5. Long-term stage-discharge ratings at gaging stations where the EGS (error) of instantaneous discharge is greater than 20 percent should be reviewed to determine the range in discharge that is sufficiently accurate for the intended data use.

6. No significant changes in the current practice for visiting gaging stations is warranted except, possibly, in the Mt. Vernon field area (southern third of Illinois) where the greatest number of "problem" stations exist.

7. The average annual percentage of missing hydrographic record attributable to equipment malfunctions at the gaging stations should be reduced to 5.0 percent for the current practice of visiting the gaging stations.

8. Observers or telemetry systems should be considered for gaging stations where: Accurate records for the full range of discharge are needed, streamflow is quite variable, and unstable controls for stage-discharge ratings exist.

9. The "Traveling Hydrographer Program" should be used to evaluate the feasibility of new routes and the impacts of changing budgets or operational constraints.

10. A program to obtain long-term, accurate, low-flow data for Illinois streams should be considered.

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TABLES 1 through 11

Table 1.--Selected information about continuous-record streamflow stations in the 1983 Illinois surface-water program

[Information from Fitzgerald and others (1984) and Stahl and others (1984)]

Period of record: Partial or complete water years during which stream-gaging station was operated.

Average discharge: Computed as the arithmetic mean of the water-year mean discharges for all water years, through water year 1983, that are complete either in annual or compilation reports. Not computed if less that 5 complete water years of record are available.

Map index No.	Station No.	Station name	Drainage area (mi^2)	Period of record	Average discharge (ft^3/s)
1	03 3366 45	Middle Fork Vermilion River above Oakwood, Ill.	432	1979-	473
2	03 3369 00	Salt Fork near St. Joseph, Ill.	134	1959-	114
3	03 3370 00	Boneyard Creek at Urbana, Ill.	4.46	1948-	4.45
4	03 3390 00	Vermilion River near Danville, Ill.	1,290	1915-21, 1928-	962
5	03 3434 00	Embarras River near Camargo, Ill.	186	1961-	155
6	03 3455 00	Embarras River at Ste. Marie, Ill.	1,516	1910-13, 1914-	1,224
7	03 3460 00	North Fork Embarras River near Oblong, Ill.	318	1941-	256
8	03 3780 00	Bonpas Creek at Browns, Ill.	228	1941-	226
9	03 3786 35	Little Wabash River near Effingham, Ill.	240	1967-	192
10	03 3795 00	Little Wabash River below Clay City, Ill.	1,131	[1]1914-	879
11	03 3804 75	Horse Creek near Keenes, Ill.	97.2	1959-	94.9
12	03 3805 00	Skillet Fork at Wayne City, Ill.	464	1908-21, 1928-	390
13	03 3815 00	Little Wabash River at Carmi, Ill.	3,102	[2]1909-13, 1940-	2,529
14	03 3821 00	South Fork Saline River near Carrier Mills, Ill.	147	1966-	162
15	03 3844 50	Lusk Creek near Eddyville, Ill.	42.9	1968-	61.1
16	03 6120 00	Cache River at Forman, Ill.	244	1923-	300
17	05 4148 20	Sinsinawa River near Menominee, Ill.	39.6	1968-	28.0
18	05 4190 00	Apple River near Hanover, Ill.	247	1935-	173
19	05 4355 00	Pecatonica River at Freeport, Ill.	1,326	1914-	900

20	05 4375 00	Rock River at Rockton, Ill.	6,363	[3] 1903-09, [4] 1914-19, 1940-	3,980
21	05 4376 95	Keith Creek at Eighth Street at Rockford, Ill.	13.4	1980-	-
22	05 4385 00	Kishwaukee River at Belvidere, Ill.	538	1940-	347
23	05 4390 00	South Branch Kishwaukee River at De Kalb, Ill.	77.7	1925-33, 1980-	60.8
24	05 4395 00	South Branch Kishwaukee River near Fairdale, Ill.	387	1940-	263
25	05 4400 00	Kishwaukee River near Perryville, Ill.	1,099	1940-	713
26	05 4435 00	Rock River at Como, Ill.	8,753	[5] 1905-06, [6] 1915-71, [7] 1972-77, 1978-	5,189
27	05 4440 00	Elkhorn Creek near Penrose, Ill.	146	1940-	97.4
28	05 4460 00	Rock Creek at Morrison, Ill.	164	[8] 1940-58, [7] 1959-71, 1978-	98.8
29	05 4465 00	Rock River near Joslin, Ill.	9,549	1940-	6,020
30	05 4475 00	Green River near Geneseo, Ill.	1,003	1936-	610
31	05 4480 00	Mill Creek at Milan, Ill.	62.4	1940-	43.0
32	05 4660 00	Edwards River near Orion, Ill.	155	1941-	107
33	05 4665 00	Edwards River near New Boston, Ill.	445	1935-	286
34	05 4670 00	Pope Creek near Keithsburg, Ill.	174	1935-	110
35	05 4690 00	Henderson Creek near Oquawka, Ill.	432	1935-	288
36	05 4955 00	Bear Creek near Marcelline, Ill.	349	1944-	206
37	05 5020 40	Hadley Creek at Kinderhook, Ill.	72.7	1940-	56.2
38	05 5125 00	Bay Creek at Pittsfield, Ill.	39.4	1940-	27.0
39	05 5130 00	Bay Creek at Nebo, Ill.	161	1940-	101
40	05 5205 00	Kankakee River at Momence, Ill.	2,294	1905-06, 1915-	1,970

[1] Prior to water year 1959, published as Little Wabash River at Wilcox, Ill.
[2] Operated as a stage-only continuous-record station.
[3] Published as Rock River below mouth of Pecatonia River at Rockton, Ill.
[4] Published as Rock River at Rockford, Ill.
[5] Published as Rock River at Sterling, Ill.
[6] Prior to water year 1934, published as Rock River at Lyndon, Ill.
[7] Operated as a crest-stage gage.
[8] Published as Rock Creek near Morrison, Ill.

Table 1.--Selected information about continuous-record streamflow stations in the 1983 Illinois surface-water program--Continued

Map index No.	Station No.	Station name	Drainage area (mi^2)	Period of record	Average discharge (ft^3/s)
41	05 5250 00	Iroquois River at Iroquois, Ill.	686	1945-	549
42	05 5255 00	Sugar Creek at Milford, Ill.	446	1948-	361
43	05 5260 00	Iroquois River near Chebanse, Ill.	2,091	1923-	1,645
44	05 5275 00	Kankakee River near Wilmington, Ill.	5,150	1934-	4,233
45	05 5278 00	Des Plaines River at Russell, Ill.	123	[9]1961-63, [7]1962-66, 1967-	97.5
46	05 5280 00	Des Plaines River near Gurnee, Ill.	232	1946-58, [7]1960-68, 1969-	175
47	05 5285 00	Buffalo Creek near Wheeling, Ill.	19.6	1952-	16.9
48	05 5290 00	Des Plaines River near Des Plaines, Ill.	360	1941-	258
49	05 5295 00	McDonald Creek near Mount Prospect, Ill.	7.93	1952-	5.91
50	05 5300 00	Weller Creek at Des Plaines, Ill.	13.2	1951-	10.8
51	05 5309 90	Salt Creek at Rolling Meadows, Ill.	30.5	1974-	28.9
52	05 5315 00	Salt Creek at Western Springs, Ill.	114	1946-	109
53	05 5320 00	Addison Creek at Bellwood, Ill.	17.9	1950-	14.8
54	05 5325 00	Des Plaines River at Riverside, Ill.	630	1944-	471
55	05 5330 00	Flag Creek near Willow Springs, Ill.	16.5	1951-	17.6
56	05 5345 00	North Branch Chicago River at Deerfield, Ill.	19.7	1952-	14.8
57	05 5350 00	Skokie River at Lake Forest, Ill.	13.0	1952-	12.1
58	05 5350 70	Skokie River near Highland Park, Ill.	21.1	1967-	22.0
59	05 5355 00	West Fork of North Branch Chicago River at Northbrook, Ill.	11.5	1952-	12.7
60	05 5360 00	North Branch Chicago River at Niles, Ill.	100	1951-	92.4
61	05 5362 15	Thorn Creek at Glenwood, Ill.	24.7	1949-	37.4
62	05 5362 35	Deer Creek near Chicago Heights, Ill.	23.1	1948-	17.5
63	05 5362 55	Butterfield Creek at Flossmoor, Ill.	23.5	1948-	17.8
64	05 5362 65	Lansing Ditch near Lansing, Ill.	8.84	1948-	8.03
65	05 5362 75	Thorn Creek at Thornton, Ill.	104	1948-	100
66	05 5362 90	Little Calumet River at South Holland, Ill.	208	1948-	184
67	05 5363 40	Midlothian Creek at Oak Forest, Ill.	12.6	1951-	11.3

68	05 5365 00	Tinley Creek near Palos Park, Ill.	11.2	1951-	9.69
69	05 5375 00	Long Run near Lemont, Ill.	20.9	1951-	16.7
70	05 5390 00	Hickory Creek at Joliet, Ill.	107	1945-	86.3
71	05 5399 00	West Branch Du Page River near West Chicago, Ill.	28.5	1961-	32.2
72	05 5400 95	West Branch Du Page River near Warrenville, Ill.	90.4	1969-	101
73	05 5405 00	Du Page River at Shorewood, Ill.	324	[10]1941-	260
74	05 5420 00	Mazon River near Coal City, Ill.	455	1940-	334
75	05 5435 00	Illinois River at Marseilles, Ill.	8,259	[11]1920-	10,760
76	05 5482 80	Nippersink Creek near Spring Grove, Ill.	192	1966-	156
77	05 5500 00	Fox River at Algonquin, Ill.	1,403	1916-	841
78	05 5505 00	Poplar Creek at Elgin, Ill.	35.2	1951-	23.9
79	05 5512 00	Ferson Creek near St. Charles, Ill.	51.7	1961-	40.5
80	05 5517 00	Blackberry Creek near Yorkville, Ill.	70.2	1961-	52.1
81	05 5525 00	Fox River at Dayton, Ill.	2,642	[12]1915-	1,703
82	05 5545 00	Vermilion River at Pontiac, Ill.	579	1943-	391
83	05 5553 00	Vermilion River near Leonore, Ill.	1,251	[13]1931-	822
84	05 5565 00	Big Bureau Creek at Princeton, Ill.	196	[14]1936-	135
85	05 5589 00	Illinois River at Henry, Ill.	13,543	1982-	-
86	05 5605 00	Farm Creek at Farmdale, Ill.	27.4	1949-	19.5
87	05 5615 00	Fondulac Creek near East Peoria, Ill.	5.54	1948-	4.36
88	05 5675 00	Mackinaw River near Congerville, Ill.	767	1945-	511
89	05 5685 00	Illinois River at Kingston Mines, Ill.	15,819	1940-	15,031
90	05 5688 00	Indian Creek near Wyoming, Ill.	62.7	1960-	47.2
91	05 5695 00	Spoon River at London Mills, Ill.	1,062	1943-	710
92	05 5700 00	Spoon River at Seville, Ill.	1,636	1914-	1,054
93	05 5703 50	Big Creek at St. David, Ill.	28.0	1972-	28.9
94	05 5703 60	Evelyn Branch near Bryant, Ill.	5.78	1972-	5.34
95	05 5703 70	Big Creek near Bryant, Ill.	41.2	1972-	41.7
96	05 5703 80	Slug Run near Bryant, Ill.	7.12	1975-	5.01
97	05 5709 10	Sangamon River at Fisher, Ill.	240	1979-	251
98	05 5720 00	Sangamon River at Monticello, Ill.	550	[15]1908-	405

[7] Operated as a crest-stage gage.
[9] Operated as a low-flow partial-record station.
[10] Prior to water year 1966, published as Du Page River at Troy, Ill.
[11] Prior to water year 1940, published as Illinois River at Morris, Ill.
[12] Prior to water year 1925, published as Fox River at Wedron, Ill.
[13] Prior to water year 1972, published as Vermilion River at Lowell, Ill.
[14] Prior to water year 1975, published as Bureau Creek at Princeton, Ill.
[15] Prior to water year 1913, published as Sangamon River near Monticello, Ill.

Table 1.--Selected information about continuous-record streamflow stations in the 1983 Illinois surface-water program--Continued

Map index No.	Station No.	Station name	Drainage area (mi^2)	Period of record	Average discharge (ft^3/s)
99	05 5735 40	Sangamon River at Route 48 at Decatur, Ill.	938	1982-	-
100	05 5758 00	Horse Creek at Pawnee, Ill.	52.2	1968-	43.3
101	05 5760 00	South Fork Sangamon River near Rochester, Ill.	867	1949-	588
102	05 5775 00	Spring Creek at Springfield, Ill.	107	1948-	66.9
103	05 5785 00	Salt Creek near Rowell, Ill.	335	1943-	[16]237
104	05 5795 00	Lake Fork near Cornland, Ill.	214	1948-	154
105	05 5800 00	Kickapoo Creek at Waynesville, Ill.	227	1948-	160
106	05 5809 50	Sugar Creek near Bloomington, Ill.	34.4	1975-	52.0
107	05 5820 00	Salt Creek near Greenview, Ill.	1,804	1942-	1,290
108	05 5830 00	Sangamon River near Oakford, Ill.	5,093	1910-12, 1914-19, 1921-22, 1929-34, 1940-	3,335
109	05 5845 00	La Moine River at Colmar, Ill.	655	1945-	445
110	05 5850 00	La Moine River at Ripley, Ill.	1,293	[17]1921-	802
111	05 5855 00	Illinois River at Meredosia, Ill.	26,028	1939-	21,976
112	05 5870 00	Macoupin Creek near Kane, Ill.	868	1921-34, 1940-	535
113	05 5879 00	Cahokia Creek at Edwardsville, Ill.	212	1969-	144
114	05 5880 00	Indian Creek at Wanda, Ill.	36.7	1940-	25.0
115	05 5900 00	Kaskaskia Ditch at Bondville, Ill.	12.4	[18]1949-	10.4
116	05 5908 00	Lake Fork at Atwood, Ill.	149	1973-	160
117	05 5912 00	Kaskaskia River at Cooks Mills, Ill.	473	1971-	467
118	05 5915 50	Whitley Creek near Allenville, Ill.	34.6	1980-	-
119	05 5917 00	West Okaw River near Lovington, Ill.	112	[9]1970-73, 1980-	-
120	05 5920 00	Kaskaskia River at Shelbyville, Ill.	1,054	1908-15, 1941-	[19]788
121	05 5920 50	Robinson Creek near Shelbyville, Ill.	93.1	1980-	-
122	05 5921 00	Kaskaskia River near Cowden, Ill.	1,330	1970-	1,241
123	05 5925 00	Kaskaskia River at Vandalia, Ill.	1,940	1908-	[20]1,412

124	05 5928 00	Hurricane Creek near Mulberry Grove, Ill.	152	1971-	138
125	05 5929 00	East Fork Kaskaskia River near Sandoval, Ill.	113	1980-	-
126	05 5930 00	Kaskaskia River at Carlyle, Ill.	2,719	1908-15, [7]1931-37, 1938-	[21]1,944
127	05 5935 20	Crooked Creek near Hoffman, Ill.	254	[2]1968-74, 1975-	181
128	05 5935 75	Little Crooked Creek near New Minden, Ill.	84.3	1968-	64.0
129	05 5939 00	East Fork Shoal Creek near Coffeen, Ill.	55.5	1964-	41.1
130	05 5940 00	Shoal Creek near Breese, Ill.	735	1910-15, 1946-	520
131	05 5941 00	Kaskaskia River near Venedy Station, Ill.	4,393	1970-	3,648
132	05 5944 50	Silver Creek near Troy, Ill.	154	1967-	114
133	05 5948 00	Silver Creek near Freeburg, Ill.	464	1971-	329
134	05 5952 00	Richland Creek near Hecker, Ill.	129	1970-	98.0
135	05 5957 30	Rayse Creek near Waltonville, Ill.	88.0	1980-	-
136	05 5970 00	Big Muddy River at Plumfield, Ill.	794	[22]1908-	[23]699
137	05 5975 00	Crab Orchard Creek near Marion, Ill.	31.7	1952-	25.2
138	05 5995 00	Big Muddy River at Murphysboro, Ill.	2,169	[24]1917-	[25]1,788

[2] Operated as a stage-only continuous-record station.
[7] Operated as a crest-stage gage.
[9] Operated as a low-flow partial-record station.
[16] Average discharge based on water years 1943-77, prior to construction of Clinton Reservoir. Average discharge based on water years 1978-83 is 274 ft^3/s.
[17] Prior to water year 1932, published as Crooked Creek at Ripley, Ill.
[18] Prior to water year 1971, published as Kaskaskia River at Bondville, Ill.
[19] Average discharge based on water years 1909-12 and 1941-69, prior to construction of Shelbyville Reservoir. Average discharge based on water years 1970-83 is 980 ft^3/s.
[20] Average discharge based on water years 1909-12 and 1915-69, prior to construction of Shelbyville Reservoir. Average discharge based on water years 1970-83 is 1,769 ft^3/s.
[21] Average discharge based on water years 1909-12, 1915, and 1939-66, prior to constuction of Carlyle Reservoir. Average discharge based on water years 1968-83 is 2,347 ft^3/s.
[22] Prior to water year 1914, published as Big Muddy River near Cambon.
[23] Average discharge based on water years 1909, 1912, 1915-70, prior to construction of Rend Lake. Average discharge based on water years 1971-83 is 674 ft^3/s.
[24] Fragmentary prior to water year 1931.
[25] Average discharge based on water years 1931-70, prior to construction of Rend Lake. Average discharge based on water years 1971-83 is 1,888 ft^3/s.

Table 2.--Data use, station funding, and data availability for gaging stations operated in the 1983 Illinois surface-water program

[Asterisk (*) indicates explanation of data use or funding is given in text; footnotes are at end of table]

Map index No.	Station No.	Data Use: Regional hydrology	Data Use: Hydrologic systems	Data Use: Legal obligations	Data Use: Planning and design	Data Use: Project operation	Data Use: Hydrologic forecasts	Data Use: Water-quality monitoring	Data Use: Research	Funding: Federal program	Funding: OFA program	Funding: Coop program	Funding: Other non-Federal	Data avail-ability
1	03 3366 45	*						2,3	1			4		A
2	03 3369 00	*						2,5				6		A
3	03 3370 00								7			6		A,P
4	03 3390 00	*					8	3,9,10				6		A
5	03 3434 00	*										6		A
6	03 3455 00	*					8	2,3,11				6		A
7	03 3460 00	*						3	1,12			4		A
8	03 3780 00	*						2,3	1			4		A
9	03 3786 35	*					8	2,3	1			4		A
10	03 3795 00	*						2,3,9				6		A
11	03 3804 75	*										6		A
12	03 3805 00	13	14				8	2			15			A,P,T
13	03 3815 00	*	14,16			14	8		1a			4		A
14	03 3821 00	*	14					3,10			15			A,P
15	03 3844 50	*						3,5,10	1a			4		A
16	03 6120 00	*	16					2	12		15			A,P
17	05 4148 20	*							1			4		A
18	05 4190 00	*	17						17		18			A
19	05 4355 00	13					8	2	1			6		A,P,T
20	05 4375 00	*	19			19		20		*	18			A,T

21	05 4376 95				21						18			A
22	05 4385 00	*	16				8		1			4		A
23	05 4390 00	*	19								18			A
24	05 4395 00	*	16				8	2,3	1			4		A
25	05 4400 00	*	16				8	2,3	1			4		A,T
26	05 4435 00	*	17			17		2,3	17		18			A,T
27	05 4440 00	*						2,3	1			4		A
28	05 4460 00	*	17						17		18			A
29	05 4465 00	*	17			17		3,10, 22	17		18			A,P,T
30	05 4475 00	*	17			17		3,10	17		18			A,T
31	05 4480 00	*	19						1		18			A
32	05 4660 00	*						11				6		A
33	05 4665 00	*	16					3	1a			4		A
34	05 4670 00	*	17						17		18			A
35	05 4690 00	*	17					2,3	17,23		18			A
36	05 4955 00	*	17					2,3	17		18			A
37	05 5020 40	*	17						17		18			A
38	05 5125 00	*	17						17,23	*	18			A
39	05 5130 00	*						2,3	24		18			A
40	05 5205 00	*					8	3,5, 10,20				6		A,T
41	05 5250 00	*	17					2	17		18			A
42	05 5255 00	*						2	24		18			A
43	05 5260 00	*	16				8	2,3	1			4		A,T
44	05 5275 00	*			25			3,5, 10,20				6		A,P,T
45	05 5278 00	*	16		25			2,3	1a			4		A
46	05 5280 00	*	16		25		8	2,3	1			4		A,T
47	05 5285 00		16		25				1,12			4		A
48	05 5290 00		16		25		8	2,3, 20	1			4		A
49	05 5295 00		16		25				1,12			4		A
50	05 5300 00		16		25		8		1			4		A

Table 2.--Data use, station funding, and data availability for gaging stations operated in the 1983 Illinois surface-water program--Continued

Map index No.	Station No.	Data Use: Regional hydrology	Hydrologic systems	Legal obligations	Planning and design	Project operation	Hydrologic forecasts	Water-quality monitoring	Research	Funding: Federal program	OFA program	Coop program	Other non-Federal	Data avail-ability
51	05 5309 90		16		25		8		1,12, 23			4		A,T
52	05 5315 00		16		25			3,10, 20	1,12, 23			4		A
53	05 5320 00		16		25			2,3	1,12, 23			4		A
54	05 5325 00				25		8	5,20	1			6		A,T
55	05 5330 00				25		8		1			4		A
56	05 5345 00		26		25		8	2,3	1a			4		A
57	05 5350 00				25		8		1			4		A
58	05 5350 70		27		25							28		A
59	05 5355 00				25		8		1,12, 23			4		A
60	05 5360 00				25			3,10, 20	1			4		A
61	05 5362 15				25		8		1,12, 23			4		A
62	05 5362 35		16		25		8		1,12, 23			4		A
63	05 5362 55		16		25		8		1,12, 23			4		A
64	05 5362 65		16		25				1,12, 23			4		A
65	05 5362 75		16		25		8	2,3	1,12, 23			4		A

66	05 5362 90		16		25		8		1,12, 23			4		A
67	05 5363 40		16		25		8		1,12, 23			4		A
68	05 5365 00		16		25				1,12, 23			4		A
69	05 5375 00	*	16		25				1a			4		A
70	05 5390 00	*	16,26		25			2,3	1a			4		A,T
71	05 5399 00		16		25			2,3	1a,29			4		A
72	05 5400 95		16		25			2,3	1			4		A
73	05 5405 00	*	16		25			2,3	1			4		A,T
74	05 5420 00	*	17			17	8	2	17		18			A,P
75	05 5435 00		19			19		3,20, 22		*				A,T
76	05 5482 80		16		25			2,3	1			4		A
77	05 5500 00				25		8	2,5				6		A,T
78	05 5505 00	*			25			2,3	1,12			4		A
79	05 5512 00	*			25			11				6		A
80	05 5517 00	*	16					2,3, 9	1a			4		A
81	05 5525 00		16				8	3,10	1			4		A,T
82	05 5545 00	*	16				8		1			4		A,T
83	05 5553 00	*					8	2,3, 5				6		A,T
84	05 5565 00	*	17				8	2	17	*	18			A
85	05 5589 00		17				8	20	17		18			A
86	05 5605 00		17						17		18			A
87	05 5615 00		17						17		18			A
88	05 5675 00	*	19				8	5				6		A,T
89	05 5685 00		19					20	1			4		A
90	05 5688 00	*						2,3, 5				6		A

Table 2.--Data use, station funding, and data availability for gaging stations operated in the 1983 Illinois surface-water program--Continued

Map index No.	Station No.	Data Use: Regional hydrology	Data Use: Hydrologic systems	Data Use: Legal obligations	Data Use: Planning and design	Data Use: Project operation	Data Use: Hydrologic forecasts	Data Use: Water-quality monitoring	Data Use: Research	Funding: Federal program	Funding: OFA program	Funding: Coop program	Funding: Other non-Federal	Data avail-ability
91	05 5695 00	*	17			17	8	2,3	17		18			A,T
92	05 5700 00	*	16				8	2,3	1a			4		A,T
93	05 5703 50	*						30				31		A
94	05 5703 60							30				31		A
95	05 5703 70							30				31		A
96	05 5703 80							30				31		A
97	05 5709 10							2,3, 32	1a, 12,24			4		A
98	05 5720 00	13					8	5,32				6		A,P,T
99	05 5735 40	*	33									34		A,P,T
100	05 5758 00	*			35							36		A
101	05 5760 00	*	17			17			17		18			A,T
102	05 5775 00	*	16					2,9	1a			4		A
103	05 5785 00		16					2,3	1			4		A
104	05 5795 00	*	16,17					2,3	1a,17			4		A
105	05 5800 00		17					2,3	17		18			A
106	05 5809 50				21			37				38		A
107	05 5820 00	*					8	2,3, 5				6		A,T
108	05 5830 00	*	17			17	8	3,10, 22	17		18			A,T
109	05 5845 00	*	17			17	8	2	17		18			A,T
110	05 5850 00	*					8	3,5, 10				6		A,T

111	05 5855 00		17				8	20	17		18			A
112	05 5870 00	*					8	2	1			4		A
113	05 5879 00	*						2,3	1			4		A
114	05 5880 00	*										6		A
115	05 5900 00	*										6		A
116	05 5908 00	*							1			4		A
117	05 5912 00	*	39					3,10, 20			40			A,P
118	05 5915 50	*	39					20			40			A,P
119	05 5917 00	*	39					2,3, 20			40			A,P
120	05 5920 00		39				8	2			40			A,P
121	05 5920 50	*	39			39					40			A,P,T
122	05 5921 00		39			39		2,3			40			A,P
123	05 5925 00		39			39	8	3,10			40			A,P,T
124	05 5928 00	*	39			39		2,3			40			A,P,T
125	05 5929 00	*	39					2,3			40			A,P,T
126	05 5930 00		39				8	2			40			A,P
127	05 5935 20							2,3	1			4		A
128	05 5935 75	*							1			4		A
129	05 5939 00	*										6		A
130	05 5940 00	*	16				8	2,3	1			4		A,T
131	05 5941 00		16				8	3,22	1			4		A,T
132	05 5944 50	*	16				8	2,3, 9	1			4		A
133	05 5948 00	*	39			39	8	2,3			40			A,P
134	05 5952 00	*						2,3	41		40			A,P
135	05 5957 30	*	39					2,3			40			A,P
136	05 5970 00		39				8	2,3			40			A,P
137	05 5975 00	*	16					2,3	1			4		A
138	05 5995 00		39			39	8	3,10, 22			40			A,P,T

Footnotes for Table 2

1. Determining statistical characteristics of streamflow from long period of record and rainfall-runoff modeling--Illinois Department of Transportation, Division of Water Resources.

1a. Determining statistical characteristics of streamflow from long period of record--Illinois Department of Transportation, Division of Water Resources.

2. Chemical sampling--Illinois Environmental Protection Agency.
3. Monitoring quality of water--U.S. Environmental Protection Agency.
4. Illinois Department of Transportation, Division of Water Resources.
5. Determining sediment load and water-quality relations--Illinois State Water Survey.
6. Illinois State Water Survey.
7. Rainfall-runoff modeling and monitoring effects of urbanization on streamflow--Illinois State Water Survey.
8. Flood forecasting--National Weather Service.
9. Determining water-quality relations--Illinois State Water Survey.
10. Biological and chemical sampling--Illinois Environmental Protection Agency.
11. Determining sediment load--Illinois State Water Survey.
12. Rainfall-runoff modeling--U.S. Department of Agriculture.
13. Long-term index gaging station.
14. Monitoring high streamflow--U.S. Army, Corps of Engineers, Louisville District.
15. U.S. Army Corps of Engineers, Louisville District.
16. Monitoring high streamflow--Illinois Department of Transportation, Division of Water Resources.
17. Rainfall-runoff modeling and monitoring high streamflow--U.S. Army, Corps of Engineers, Rock Island District.
18. U.S. Army, Corps of Engineers, Rock Island District.
19. Monitoring high streamflow--U.S. Army, Corps of Engineers, Rock Island District.
20. Monitoring quality of water--Illinois Natural History Survey.
21. Evaluating flood-control alternatives--U.S. Army, Corps of Engineers, Rock Island District.
22. NASQAN station.
23. Monitoring impacts of reservoir on streamflow--U.S. Department of Agriculture.
24. Rainfall-runoff modeling--U.S. Army, Corps of Engineers, Rock Island District.
25. Chemical, biological, and streamflow data used in water resources planning studies--Northern Illinois Planning Commission.

26. Monitoring high streamflow--U.S. Army, Corps of Engineers, Chicago District.
27. Monitoring high streamflow--Forest Preserve District of Cook County.
28. Forest Preserve District of Cook County.
29. Monitoring effects of urbanization on floods and low flow--Illinois State Water Survey.
30. Monitoring effects of sludge application for reclamation of strip-mined land on receiving water quality--Metropolitan Sanitary District of Greater Chicago.
31. Metropolitan Sanitary District of Greater Chicago.
32. Sediment delivery analysis--U.S. Department of Agriculture.
33. Monitoring streamflow just downstream from Lake Decatur--City of Decatur, Illinois.
34. City of Decatur, Illinois.
35. Water supply study--City of Springfield, Illinois.
36. City of Springfield, Illinois.
37. Periodic water-quality sampling--City of Bloomington, Illinois.
38. City of Bloomington, Illinois.
39. Monitoring high streamflow--U.S. Army, Corps of Engineers, St. Louis District.
40. U.S. Army, Corps of Engineers, St. Louis District.
41. Rainfall-runoff modeling--U.S. Army, Corps of Engineers, St. Louis District.

Table 3.--Selected reach characteristics used in the flow-routing model

[Information provided by W. R. Krug, USGS, Madison, Wisconsin]

Site	Q_o (ft^3/s)	W_o (ft)	S_o (ft/ft)	$\frac{dQ_o}{dY_o}$ (ft^2/s)	C_o (ft/s)	K_o (ft^2/s)
Como	5,189	600	1.804×10^{-4}	3,110	5.18	23,500
Joslin	6,020			1,680	2.80	27,200

Table 4.--Results of the flow-routing modeling

[Information provided by W. R. Krug, USGS, Madison, Wisconsin]

Mean absolute error for 1,823 days = 3.95 percent
Mean negative error (1,040 days) = -3.76 percent
Mean positive error (783 days) = 4.19 percent
Total volume error = -0.77 percent

74 percent of the total observations had errors $\leq$ 5 percent
94 percent of the total observations had errors $\leq$ 10 percent
97 percent of the total observations had errors $\leq$ 15 percent
98 percent of the total observations had errors $\leq$ 20 percent
99 percent of the total observations had errors $\leq$ 25 percent
1 percent of the total observations had errors > 25 percent

Table 5.--Summary of results of MOVE.1 statistical analysis of daily mean streamflows at selected gaging stations in Illinois

Station number[1] and name	Model[2] $\hat{Q}_d = m(Q_d) + \frac{S(Q_d)}{S(Q_b)}(Q_b - m(Q_b))$		Calibration period	Verification period	Apparent[3] error at 5 percent level	Apparent[3] error at 10 percent level
03343400 Embarras River near Camargo, Ill.	$m(Q_d)$ = 122	$m(Q_b)$ = 88.6	1961-65	1976-80	5.3	16.0
(03336900) Salt Fork near St. Joseph, Ill.	$S(Q_d)$ = 290	$S(Q_b)$ = 245				
03380475 Horse Creek near Keenes, Ill.	$m(Q_d)$ = 74.6	$m(Q_b)$ = 313	1961-65	1966-70	2.8	5.0
(03380500) Skillet Fork at Wayne City, Ill.	$S(Q_d)$ = 332	$S(Q_b)$ = 1,590				
05446500 Rock River near Joslin, Ill.	$m(Q_d)$ = 7,370	$m(Q_b)$ = 6,700	1978-82	1940-42	56.0	80.7
(05443500) Rock River at Como, Ill.	$S(Q_d)$ = 5,170	$S(Q_b)$ = 4,720				
05588000 Indian Creek at Wanda, Ill.	$m(Q_d)$ = 29.9	$m(Q_b)$ = 171	1971-75	1976-80	2.0	3.8
(05587900) Cahokia Creek at Edwardsville, Ill.	$S(Q_d)$ = 109	$S(Q_b)$ = 497				
05593900 East Fork Shoal Creek near Coffeen, Ill.	$m(Q_d)$ = 48.9	$m(Q_b)$ = 71.3	1969-73	1974-78	0.9	1.6
(05593575) Little Crooked Creek near New Minden, Ill.	$S(Q_d)$ = 196	$S(Q_b)$ = 239				

[1] Uppermost station is dependent gaging station. Station number enclosed by parentheses is base gaging station, used to extend record at dependent gaging station.

[2] Q_d is daily mean streamflow at dependent gaging station. Caret (^) indicates an estimated value.
Q_b is daily mean streamflow observed at base gaging station.
m ( ) denotes mean of observed streamflows.
S ( ) denotes standard deviation of observed streamflows.

[3] Denotes the number of observations, as percent of the total, that are within the given level of accuracy.

Table 6.--Statistics of record reconstruction at gaging stations in Illinois

Station No.	Station name	$\overline{C}_v$ [1] (percent)	Correlation coefficient [2] ρ_c	Correlation coefficient [2] R_2	Source for reconstructing record [3] secondary	Source for reconstructing record [3] tertiary
03 3366 45	Middle Fork Vermilion River above Oakwood	120	0.94	0.90	03339000	03336900
03 3369 00	Salt Fork near St. Joseph	167	.89	.75	03339000	03343400
03 3370 00	Boneyard Creek at Urbana	146	.54	.50	03336900	05590000
03 3390 00	Vermilion River near Danville	171	.96	.96	observer	observer
03 3434 00	Embarras River near Camargo	173	.79	.75	03339000	05572000
03 3455 00	Embarras River at Ste. Marie	167	.76	.52	03346000	03380500
03 3460 00	North Fork Embarras River near Oblong	234	.76	.56	03345500	03378000
03 3780 00	Bonpas Creek at Browns	246	.70	.56	03380500	03346000
03 3786 35	Little Wabash River near Effingham	189	.70	.00	03379500	--
03 3795 00	Little Wabash River below Clay City	210	.72	.70	03381500	03378635
03 3804 75	Horse Creek near Keenes	269	.79	.00	03380500	--
03 3805 00	Skillet Fork at Wayne City	248	.79	.57	03380475	03346000
03 3815 00	Little Wabash River at Carmi	157	.72	.00	03379500	--
03 3821 00	South Fork Saline River near Carrier Mills	170	.75	.68	03612000	03384450
03 3844 50	Lusk Creek near Eddyville	200	.68	.61	03382100	05597500
03 6120 00	Cache River at Forman	207	.75	.00	03382100	--
05 4148 20	Sinsinawa River near Menominee	111	.66	.62	05435500	05444000
05 4190 00	Apple River near Hanover	160	.75	.71	05435500	05444000
05 4355 00	Pecatonica River at Freeport	86.5	.88	.66	05437500	05444000
05 4375 00	Rock River at Rockton	71.3	.94	.88	05443500	05435500
05 4376 95	Keith Creek at Eighth St. at Rockford[4]	170	.65	.00	--	---
05 4385 00	Kishwaukee River at Belvidere	123	.97	.89	05440000	05548280
05 4390 00	South Branch Kishwaukee River at De Kalb	93.3	.93	.85	05439500	05440000

05 4395 00	South Branch Kishwaukee River near Fairdale	160	.94	.87	05440000	05438500
05 4400 00	Kishwaukee River near Perryville	126	.97	.96	05438500	telemetry
05 4435 00	Rock River at Como	70.8	.97	.96	05446500	telemetry
05 4440 00	Elkhorn Creek near Penrose	135	.72	.71	05447500	05419000
05 4460 00	Rock Creek at Morrison	68.6	.89	.75	05444000	05419000
05 4465 00	Rock River near Joslin	73.6	.97	.00	05443500	---
05 4475 00	Green River near Geneseo	124	.84	.78	05556500	05440000
05 4480 00	Mill Creek at Milan	197	.63	.56	05556500	05440000
05 4660 00	Edwards River near Orion	174	.87	.84	05466500	05467000
05 4665 00	Edwards River near New Boston	165	.96	.96	observer	observer
05 4670 00	Pope Creek near Keithsburg	174	.96	.96	observer	observer
05 4690 00	Henderson Creek near Oquawka	161	.96	.96	observer	observer
05 4955 00	Bear Creek near Marcelline	277	.96	.96	observer	observer
05 5020 40	Hadley Creek at Kinderhook	258	.96	.96	observer	observer
05 5125 00	Bay Creek at Pittsfield	278	.83	.81	05513000	05502040
05 5130 00	Bay Creek at Nebo	237	.96	.96	observer	observer
05 5205 00	Kankakee River at Momence	62.0	.87	.69	05527500	05526000
05 5250 00	Iroquois River at Iroquois	137	.93	.75	05526000	05525500
05 5255 00	Sugar Creek at Milford	196	.96	.96	observer	observer
05 5260 00	Iroquois River near Chebanse	153	.93	.87	05525000	05525500
05 5275 00	Kankakee River near Wilmington	92.1	.96	.96	telemetry	telemetry
05 5278 00	Des Plaines River at Russell	152	.94	.86	05528000	05529000
05 5280 00	Des Plaines River near Gurnee	143	.96	.96	telemetry	telemetry
05 5285 00	Buffalo Creek near Wheeling	177	.87	.79	05529500	05530990
05 5290 00	Des Plaines River near Des Plaines	146	.93	.92	05528000	05532500
05 5295 00	McDonald Creek near Mount Prospect	200	.87	.77	05528500	05530000
05 5300 00	Weller Creek at Des Plaines	233	.77	.66	05529500	05530990

1 Seasonally-averaged coefficient of variation.

2 ρ_c is the correlation between hydrographic records, with seasonal trends removed, at the station of interest and a secondary source used for hydrographic record reconstruction. R_2 is the correlation between the station of interest and a tertiary source that will be used if record from secondary source is unavailable.

3 Secondary and tertiary sources of records used to reconstruct hydrographic record at the primary station.

4 Less than 3 water years of data are available. Estimates of $\overline{C}_v$, ρ_c, and R_2 are subjective.

Table 6.--Statistics of record reconstruction at gaging stations in Illinois--Continued

Station No.	Station name	$\bar{C}_v$[1] (percent)	Correlation coefficient[2] ρ_c	R_2	Source for reconstructing record[3] secondary	tertiary
05 5309 90	Salt Creek at Rolling Meadows	133	0.79	0.77	05528500	05529500
05 5315 00	Salt Creek at Western Springs	129	.80	.76	05532000	05530990
05 5320 00	Addison Creek at Bellwood	148	.84	.80	05533000	05531500
05 5325 00	Des Plaines River at Riverside	130	.96	.96	telemetry	telemetry
05 5330 00	Flag Creek near Willow Springs	143	.84	.78	05532000	05536500
05 5345 00	North Branch Chicago River at Deerfield	209	.90	.87	05535000	05528500
05 5350 00	Skokie River at Lake Forest	147	.91	.90	05535070	05534500
05 5350 70	Skokie River near Highland Park	129	.91	.86	05535000	05534500
05 5355 00	West Fork of North Branch Chicago River at Northbrook	171	.86	.83	05535000	05534500
05 5360 00	North Branch Chicago River at Niles	140	.90	.88	05534500	05531500
05 5362 15	Thorn Creek at Glenwood	119	.96	.96	observer	observer
05 5362 35	Deer Creek near Chicago Heights	200	.88	.82	05536255	05536215
05 5362 55	Butterfield Creek at Flossmoor	211	.88	.87	05536235	05536215
05 5362 65	Lansing Ditch near Lansing	158	.84	.76	05536235	05536215
05 5362 75	Thorn Creek at Thornton	148	.92	.87	05536255	05536215
05 5362 90	Little Calumet River at South Holland	140	.94	.87	05536275	05536255
05 5363 40	Midlothian Creek at Oak Forest	204	.88	.84	05536500	05536255
05 5365 00	Tinley Creek near Palos Park	227	.88	.88	05536340	05537500
05 5375 00	Long Run near Lemont	216	.88	.88	05539000	05536500
05 5390 00	Hickory Creek at Joliet	196	.96	.96	telemetry	telemetry
05 5399 00	West Branch Du Page River near West Chicago	114	.92	.86	05540095	05551200
05 5400 95	West Branch Du Page River near Warrenville	104	.92	.89	05539900	05540500
05 5405 00	Du Page River at Shorewood	126	.96	.96	telemetry	telemetry
05 5420 00	Mazon River near Coal City	210	.80	.72	05554500	05567500
05 5435 00	Illinois River at Marseilles	64.3	.96	.96	telemetry	telemetry

05 5482 80	Nippersink Creek near Spring Grove	91.7	.96	.96	observer	observer
05 5500 00	Fox River at Algonquin	86.5	.96	.96	observer	observer
05 5505 00	Poplar Creek at Elgin	162	.86	.85	05551200	05539900
05 5512 00	Ferson Creek near St. Charles	140	.86	.86	05539900	05550500
05 5517 00	Blackberry Creek near Yorkville	113	.86	.85	05540500	05551200
05 5525 00	Fox River at Dayton	94.1	.86	.72	05550000	05543500
05 5545 00	Vermilion River at Pontiac	194	.96	.96	telemetry	telemetry
05 5553 00	Vermilion River near Leonore	147	.87	.78	05554500	05542000
05 5565 00	Big Bureau Creek at Princeton	180	.84	.77	05447500	05439500
05 5589 00	Illinois River at Henry[4]	85.0	.96	.96	observer	observer
05 5605 00	Farm Creek at Farmdale	197	.83	.63	05561500	05570350
05 5615 00	Fondulac Creek near East Peoria	273	.83	.59	05560500	05570350
05 5675 00	Mackinaw River near Congerville	181	.84	.79	05554500	05580000
05 5685 00	Illinois River at Kingston Mines	63.8	.96	.96	observer	observer
05 5688 00	Indian Creek near Wyoming	156	.81	.71	05466000	05556500
05 5695 00	Spoon River at London Mills	158	.95	.76	05570000	05466000
05 5700 00	Spoon River at Seville	151	.96	.96	observer	observer
05 5703 50	Big Creek at St. David	110	.96	.79	05570370	05570360
05 5703 60	Evelyn Branch near Bryant	92.0	.81	.79	05570370	05570350
05 5703 70	Big Creek near Bryant	103	.96	.96	observer	observer
05 5703 80	Slug Run near Bryant	91.4	.75	.73	05570370	05570350
05 5709 10	Sangamon River at Fisher	150	.90	.85	05572000	05580000
05 5720 00	Sangamon River at Monticello	128	.95	.90	05578500	05580000
05 5735 40	Sangamon River at Rt. 48 at Decatur[4]	100	.96	.96	telemetry	telemetry
05 5758 00	Horse Creek at Pawnee	211	.68	.60	05577500	05593900

1 Seasonally-averaged coefficient of variation.

2 ρ_c is the correlation between hydrographic records, with seasonal trends removed, at the station of interest and a secondary source used for hydrographic record reconstruction. R_2 is the correlation between the station of interest and a tertiary source that will be used if record from secondary source is unavailable.

3 Secondary and tertiary sources of records used to reconstruct hydrographic record at the primary station.

4 Less than 3 water years of data are available. Estimates of $\overline{C}_v$, ρ_c, and R_2 are subjective.

Table 6.--Statistics of record reconstruction at gaging stations in Illinois--Continued

Station No.	Station name	$\bar{C}_v$ [1] (percent)	Correlation coefficient[2] ρ_c	Correlation coefficient[2] R_2	Source for reconstructing record[3] secondary	Source for reconstructing record[3] tertiary
05 5760 00	South Fork Sangamon near Rochester	195	0.96	0.96	telemetry	telemetry
05 5775 00	Spring Creek at Springfield	210	.68	.64	05575800	05579500
05 5785 00	Salt Creek near Rowell	181	.89	.89	05572000	05582000
05 5795 00	Lake Fork near Cornland	184	.80	.80	05578500	05580000
05 5800 00	Kickapoo Creek at Waynesville	189	.84	.80	05578500	05572000
05 5809 50	Sugar Creek near Bloomington	90.4	.64	.60	05567500	05580000
05 5820 00	Salt Creek near Greenview	148	.92	.89	05583000	05578500
05 5830 00	Sangamon River near Oakford	133	.96	.96	observer	observer
05 5845 00	La Moine River at Colmar	207	.88	.75	05585000	05570000
05 5850 00	La Moine River at Ripley	189	.96	.96	observer	observer
05 5855 00	Illinois River at Meredosia	68.2	.96	.96	observer	observer
05 5870 00	Macoupin Creek near Kane	233	.96	.96	observer	observer
05 5879 00	Cahokia Creek at Edwardsville	190	.76	.70	05588000	05587000
05 5880 00	Indian Creek at Wanda	287	.76	.00	05587900	--
05 5900 00	Kaskaskia Ditch at Bondville	188	.82	.78	03336900	03343400
05 5908 00	Lake Fork at Atwood	140	.92	.81	05591200	03343400
05 5912 00	Kaskaskia River at Cooks Mills	137	.96	.96	observer	observer
05 5915 50	Whitley Creek near Allenville[4]	165	.96	.96	observer	observer
05 5917 00	West Okaw River near Lovington[4]	125	.96	.96	observer	observer
05 5920 00	Kaskaskia River at Shelbyville	103	.92	.75	05592100	05592500
05 5920 50	Robinson Creek near Shelbyville	122	.96	.96	telemetry	telemetry
05 5921 00	Kaskaskia River near Cowden	97.2	.92	.89	05592000	05592500
05 5925 00	Kaskaskia River at Vandalia	109	.96	.96	telemetry	telemetry
05 5928 00	Hurricane Creek near Mulberry Grove	184	.96	.96	telemetry	telemetry
05 5929 00	East Fork Kaskaskia River near Sandoval	114	.96	.96	telemetry	telemetry

05 5930 00	Kaskaskia River at Carlyle	97.6	.86	.72	05594100	05592500
05 5935 20	Crooked Creek near Hoffman	154	.61	.00	05593575	--
05 5935 75	Little Crooked Creek near New Minden	235	.61	.53	05593520	05594450
05 5939 00	East Fork Shoal Creek near Coffeen	244	.69	.68	05592800	05594000
05 5940 00	Shoal Creek near Breese	213	.96	.96	telemetry	telemetry
05 5941 00	Kaskaskia River near Venedy Station	101	.96	.96	observer	observer
05 5944 50	Silver Creek near Troy	215	.77	.76	05594800	05587900
05 5948 00	Silver Creek near Freeburg	178	.77	.67	05594450	05587900
05 5952 00	Richland Creek near Hecker	175	.60	.00	05594450	--
05 5957 30	Rayse Creek near Waltonville	130	.70	.66	03380475	05593575
05 5970 00	Big Muddy River at Plumfield	108	.86	.00	05599500	--
05 5975 00	Crab Orchard Creek near Marion	300	.64	.61	03382100	03384450
05 5995 00	Big Muddy River at Murphysboro	112	.96	.96	observer	observer

1 Seasonally-averaged coefficient of variation.

2 ρ_c is the correlation between hydrographic records, with seasonal trends removed, at the station of interest and a secondary source used for hydrographic record reconstruction. R_2 is the correlation between the station of interest and a tertiary source that will be used if record from secondary source is unavailable.

3 Secondary and tertiary sources of records used to reconstruct hydrographic record at the primary station.

4 Less than 3 water years of data are available. Estimates of $\overline{C}_v$, ρ_c, and R_2 are subjective.

Table 7.--Uncertainty function autocovariance parameters for gaging stations in Illinois

[Based in part on analyses performed by P. E. Hughes and J. Walker, USGS, Madison, Wis.]

Station No.	Station name	Number of measurements analyzed	RHO[1]	Process variance[2] (log base 10)[2]	Length of period[3] (days)
03 3366 45	Middle Fork Vermilion River above Oakwood	35	0.883	0.00995	323
03 3369 00	Salt Fork near St. Joseph	114	.989	.00694	323
03 3370 00	Boneyard Creek at Urbana	102	.966	.03010	365
03 3390 00	Vermilion River near Danville	128	.967	.00110	365
03 3434 00	Embarras River near Camargo	123	.985	.02120	323
03 3455 00	Embarras River at Ste. Marie	127	.972	.00194	323
03 3460 00	North Fork Embarras River near Oblong	113	.991	.03940	365
03 3780 00	Bonpas Creek at Browns	91	.936	.01860	365
03 3786 35	Little Wabash River near Effingham	51	.967	.03070	323
03 3795 00	Little Wabash River below Clay City	113	.971	.00366	323
03 3804 75	Horse Creek near Keenes	95	.975	.04910	323
03 3805 00	Skillet Fork at Wayne City	114	.968	.01600	365
03 3815 00	Little Wabash River at Carmi	119	.977	.00398	365
03 3821 00	South Fork Saline River near Carrier Mills	127	.975	.00297	365
03 3844 50	Lusk Creek near Eddyville	57	.935	.07380	365
03 6120 00	Cache River at Forman	105	.968	.06120	365
05 4148 20	Sinsinawa River near Menominee	74	.979	.00368	281
05 4190 00	Apple River near Hanover	100	.932	.00158	281
05 4355 00	Pecatonica River at Freeport	108	.962	.00051	281
05 4375 00	Rock River at Rockton	65	.982	.00026	323
05 4376 95	Keith Creek at Eighth St. at Rockford	33	.979	.01380	281
05 4385 00	Kishwaukee River at Belvidere	109	.984	.00124	323
05 4390 00	South Branch Kishwaukee River at De Kalb	51	.980	.00318	323
05 4395 00	South Branch Kishwaukee River near Fairdale	96	.985	.00226	281
05 4400 00	Kishwaukee River near Perryville	101	.982	.00186	281

05 4435 00	Rock River at Como	106	0.974	0.00021	281
05 4440 00	Elkhorn Creek near Penrose	100	.994	.00718	281
05 4460 00	Rock Creek at Morrison	66	.944	.00180	281
05 4465 00	Rock River near Joslin	77	.782	.00003	281
05 4475 00	Green River near Geneseo	71	.988	.00214	281
05 4480 00	Mill Creek at Milan	110	.995	.23800	281
05 4660 00	Edwards River near Orion	95	.985	.01250	281
05 4665 00	Edwards River near New Boston	82	.992	.01650	281
05 4670 00	Pope Creek near Keithsburg	86	.991	.03890	281
05 4690 00	Henderson Creek near Oquawka	90	.963	.00232	281
05 4955 00	Bear Creek near Marcelline	94	.978	.01960	281
05 5020 40	Hadley Creek at Kinderhook	102	.992	.38300	323
05 5125 00	Bay Creek at Pittsfield	109	.988	.24400	365
05 5130 00	Bay Creek at Nebo	116	.994	.17600	365
05 5205 00	Kankakee River at Momence	99	.943	.00030	323
05 5250 00	Iroquois River at Iroquois	89	.899	.00061	281
05 5255 00	Sugar Creek at Milford	110	.988	.06430	323
05 5260 00	Iroquois River near Chebanse	89	.964	.00070	281
05 5275 00	Kankakee River near Wilmington	113	.973	.00113	323
05 5278 00	Des Plaines River at Russell	82	.966	.00706	281
05 5280 00	Des Plaines River near Gurnee	99	.980	.00501	323
05 5285 00	Buffalo Creek near Wheeling	97	.974	.03800	281
05 5290 00	Des Plaines River near Des Plaines	101	.960	.00547	323
05 5295 00	McDonald Creek near Mount Prospect	81	.963	.01640	281
05 5300 00	Weller Creek at Des Plaines	95	.549	.05510	323
05 5309 90	Salt Creek at Rolling Meadows	76	.988	.05720	323
05 5315 00	Salt Creek at Western Springs	103	.994	.01640	281
05 5320 00	Addison Creek at Bellwood	103	.982	.01550	323
05 5325 00	Des Plaines River at Riverside	113	.936	.00072	323
05 5330 00	Flag Creek near Willow Springs	106	.992	.04920	323

[1] One-day autocorrelation coefficient.

[2] Measurement variance is not shown but equaled 0.00023 log base 10 units squared at all stations.

[3] Typical number of days during a year when stage-discharge relation is unaffected by ice.

Table 7.--Uncertainty function autocovariance parameters for gaging stations in Illinois--Continued

Station No.	Station name	Number of measurements analyzed	RHO[1]	Process variance[2] (log base 10)[2]	Length of period[3] (days)
05 5345 00	North Branch Chicago River at Deerfield	92	0.989	0.17500	281
05 5350 00	Skokie River at Lake Forest	94	.932	.00621	281
05 5350 70	Skokie River near Highland Park	90	.985	.04480	281
05 5355 00	West Fork of North Branch Chicago River at Northbrook	99	.973	.00926	281
05 5360 00	North Branch Chicago River at Niles	96	.400	.01030	281
05 5362 15	Thorn Creek at Glenwood	112	.985	.00496	365
05 5362 35	Deer Creek near Chicago Heights	52	.952	.03890	281
05 5362 55	Butterfield Creek at Flossmoor	82	.972	.03190	281
05 5362 65	Lansing Ditch near Lansing	46	.968	.00619	281
05 5362 75	Thorn Creek at Thornton	98	.964	.00678	365
05 5362 90	Little Calumet River at South Holland	109	.517	.00223	323
05 5363 40	Midlothian Creek at Oak Forest	82	.942	.01520	281
05 5365 00	Tinley Creek near Palos Park	94	.982	.06370	281
05 5375 00	Long Run near Lemont	100	.972	.04620	281
05 5390 00	Hickory Creek at Joliet	76	.982	.00549	281
05 5399 00	West Branch Du Page River near West Chicago	101	.985	.02440	323
05 5400 95	West Branch Du Page River near Warrenville	100	.959	.00456	323
05 5405 00	Du Page River at Shorewood	100	.981	.00047	281
05 5420 00	Mazon River near Coal City	73	.984	.01960	323
05 5435 00	Illinois River at Marseilles	110	.945	.00021	365
05 5482 80	Nippersink Creek near Spring Grove	96	.982	.00087	281
05 5500 00	Fox River at Algonquin	115	.966	.00024	323
05 5505 00	Poplar Creek at Elgin	105	.983	.02480	323
05 5512 00	Ferson Creek near St. Charles	92	.983	.01320	281
05 5517 00	Blackberry Creek near Yorkville	104	.992	.01200	281

05 5525 00	Fox River at Dayton	109	0.972	0.00079	323
05 5545 00	Vermilion River at Pontiac	111	.959	.00465	323
05 5553 00	Vermilion River near Leonore	90	.977	.00341	323
05 5565 00	Big Bureau Creek at Princeton	95	.994	.19000	281
05 5589 00	Illinois River at Henry	13	.956	.00660	365
05 5605 00	Farm Creek at Farmdale	102	.977	.25400	323
05 5615 00	Fondulac Creek near East Peoria	72	.975	.01360	323
05 5675 00	Mackinaw River near Congerville	106	.979	.01670	323
05 5685 00	Illinois River at Kingston Mines	118	.976	.00242	365
05 5688 00	Indian Creek near Wyoming	101	.996	.13500	281
05 5695 00	Spoon River at London Mills	103	.966	.00172	323
05 5700 00	Spoon River at Seville	104	.962	.00140	323
05 5703 50	Big Creek at St. David	91	.984	.07560	323
05 5703 60	Evelyn Branch near Bryant	81	.981	.00842	323
05 5703 70	Big Creek near Bryant	82	.977	.02870	323
05 5703 80	Slug Run near Bryant	57	.976	.02030	323
05 5709 10	Sangamon River at Fisher	47	.874	.02560	281
05 5720 00	Sangamon River at Monticello	122	.961	.00736	323
05 5735 40	Sangamon River at Rt. 48 at Decatur	43	.975	.08340	365
05 5758 00	Horse Creek at Pawnee	79	.986	.05520	323
05 5760 00	South Fork Sangamon near Rochester	126	.970	.01040	323
05 5775 00	Spring Creek at Springfield	94	.960	.03220	323
05 5785 00	Salt Creek near Rowell	103	.977	.01880	323
05 5795 00	Lake Fork near Cornland	103	.987	.03300	323
05 5800 00	Kickapoo Creek at Waynesville	106	.992	.01610	281
05 5809 50	Sugar Creek near Bloomington	64	.992	.03970	365
05 5820 00	Salt Creek near Greenview	111	.978	.00168	323
05 5830 00	Sangamon River near Oakford	106	.968	.00021	323
05 5845 00	La Moine River at Colmar	106	.982	.02040	323
05 5850 00	La Moine River at Ripley	102	.985	.00650	323

[1] One-day autocorrelation coefficient.

[2] Measurement variance is not shown but equaled 0.00023 log base 10 units squared at all stations.

[3] Typical number of days during a year when stage-discharge relation is unaffected by ice.

Table 7.--Uncertainty function autocovariance parameters for gaging stations in Illinois--Continued

Station No.	Station name	Number of measurements analyzed	RHO[1]	Process variance[2] (log base 10)^2	Length of period[3] (days)
05 5855 00	Illinois River at Meredosia	118	0.972	0.00115	365
05 5870 00	Macoupin Creek near Kane	97	.989	.03270	323
05 5879 00	Cahokia Creek at Edwardsville	100	.964	.06600	365
05 5880 00	Indian Creek at Wanda	92	.973	.09730	365
05 5900 00	Kaskaskia Ditch at Bondville	107	.989	.10300	365
05 5908 00	Lake Fork at Atwood	86	.975	.03180	323
05 5912 00	Kaskaskia River at Cooks Mills	104	.970	.00541	323
05 5915 50	Whitley Creek near Allenville	26	.988	.06640	323
05 5917 00	West Okaw River near Lovington	60	.893	.03120	323
05 5920 00	Kaskaskia River at Shelbyville	119	.984	.02120	365
05 5920 50	Robinson Creek near Shelbyville	30	.981	.02610	323
05 5921 00	Kaskaskia River near Cowden	99	.973	.00292	323
05 5925 00	Kaskaskia River at Vandalia	120	.976	.00357	323
05 5928 00	Hurricane Creek near Mulberry Grove	116	.992	.04180	323
05 5929 00	East Fork Kaskaskia River near Sandoval	26	.985	.01060	323
05 5930 00	Kaskaskia River at Carlyle	128	.966	.00123	365
05 5935 20	Crooked Creek near Hoffman	76	.977	.02690	323
05 5935 75	Little Crooked Creek near New Minden	103	.972	.09310	365
05 5939 00	East Fork Shoal Creek near Coffeen	98	.967	.18500	323
05 5940 00	Shoal Creek near Breese	46	.945	.00230	323
05 5941 00	Kaskaskia River near Venedy Station	39	.960	.00066	365
05 5944 50	Silver Creek near Troy	111	.989	.08020	323
05 5948 00	Silver Creek near Freeburg	124	.985	.02880	323
05 5952 00	Richland Creek near Hecker	122	.988	.01080	323
05 5957 30	Rayse Creek near Waltonville	28	.953	.01940	323

05 5970 00	Big Muddy River at Plumfield	109	.911	.00207	365
05 5975 00	Crab Orchard Creek near Marion	101	.994	.43600	323
05 5995 00	Big Muddy River at Murphysboro	124	.960	.00518	365

[1] One-day autocorrelation coefficient.

[2] Measurement variance is not shown but equaled 0.00023 log base 10 units squared at all stations.

[3] Typical number of days during a year when stage-discharge relation is unaffected by ice.

Table 8.--Summary of routes used in the K-CERA analysis

[Dash (-) denotes station is not a continuous-record streamflow station]

Route No.	Stations serviced on the route							
1	-05586690	05587000	-05586500	05512500	-05502020	05502040	05513000	05588000
	05587900	05594450	-05589500	05595200	05594800	05593575		
2	05593900	-05593600	-05593785	05592800				
3	05593000	05594000	05593520					
4	-05592600	05592500	05592800	-05593785	05593900	-05593600	-05586500	05512500
	-05502020	05502040	05513000	05587000	-05586690	05592900		
5	-05593505	05593000	05594000	05594450	05587900	05588000	-05589500	05595200
	05594800	05593575	05593520					
6	05594100							
7	-05586690	05587000	-05586500	05512500	-05502020	05502040	05513000	
8	-05593505	05592900	05594000					
9	05594450	05587900	05588000	-05589500				
10	05594800	05595200						
11	05594000	05593520	05593575					
12	05599500							
13	05597000	-05595950	-05595830					
14	-03381495	03381500	-03379950					
15	03380475	03380500	03378000					
16	-03380350	-03379600	03379500	-03378900	05592900			
17	03345500	03346000	-03344500	-03344000				
18	03378635	05592100	-05592195					
19	05592000	05592050						
20	-05592600	05592500	05592800					
21	-05593505	-05595700	05595730					
22	-03380350	-03379600	03379500	-03378900	03345500	03346000	-03344500	-03344000
	03378635	05592100	05592000	05592050	-05592195	-05592600	05592500	05592800
	05592900							
23	03384450	-03385000	03612000	-05600000				
24	03382100	-03382090						
25	-05595700	05595730	-05595830	03380475				

26	03380500							
27	-05595950	05597000	05597500					
28	-05597040	-05598050	-05598245					
29	-05595540	-05599200	-05597280					
30	03384450	-03385000	03612000	-05600000	05597500	-05598050	-05598245	
31	05597000	-05597040	-05595950					
32	05587000	-05586500	05512500	-05502020	05502040	05513000	05588000	05587900
	05594450	-05589500	05595200	05594800	05593575			
33	05593000	05594000						
34	-05592600	05592500	05592800	05593900	-05593600	-05586500	05512500	-05502020
	05502040	05513000	05587000	05592900				
35	05593000	05594000	05594450	05587900	05588000	-05589500	05595200	05594800
	05593575							
36	05592800	05593900	-05593600					
37	05587000	-05586500	05512500	-05502020	05502040	05513000		
38	05593000	05594000	05593575					
39	05597000	-05595950	-05595830					
40	-03381495	03381500						
41	03378635	05592100						
42	-03380350	-03379600	03379500	-03378900	03345500	03346000	-03344500	-03344000
	03378635	05592100	5592000	05592050	-05592600	05592500	05592800	05592900
43	03382100							
44	03384450	-03385000	03612000	-05600000	05597500	05597000	-05595950	
45	05599500	05594100						
46	-03381495	03381500	03382100					
47	03380500	03378000	-03379600					
48	05594800	05595200	05593575					
49	05593575	05594800	05595200	-05589500	05588000	05587900	05594450	
50	05594000	05593000	05592900					
51	05531500	05532000	05532500	05533000	05536215	05536235	05536255	05536265
	05536275	05536290	05536340	05536500	05537500	05539000	05540500	05551700
52	05414820	05419000	05446000	05444000	05446500	05447500	05448000	05466500
	05467000	05469000	-05468500	05466000				
53	05435500	05437500	-05438250	05438500	05439000	05439500	05440000	05443500
	-05547000	-05547500	-05548000	05548280	-05548500	-05549000	-05549500	05550000
	05551200							
54	05527800	05528000	05535000	05535070	05534500	05535500	05528500	05529500
	05529000	05536000	05530000	05530990	05550500	05539900	05540095	
55	05543500							

Table 8.--Summary of routes used in the K-CERA analysis--Continued

Route No.	Stations serviced on the route							
56	05558900							
57	05552500	-05557500	05556500	-05557000	05568800			
58	05444000	05443500	05446000	05419000	05414820	05435500	05437500	
59	05438500	05440000	05439000					
60	-05438250	-05549000	-05549500	-05548500	05548280	-05548000	-05547500	-05547000
	05527800	05528000						
61	05550000	05550500	05551200					
62	05539900	05540095	05551700					
63	05530990	05530000	05536000	05529000	05529500	05528500	05535000	05535070
	05534500	05535500	05532000	05439000				
64	05540500	05539000						
65	05532500	05531500	05533000	05536500	05536340	05536290	05536275	05536235
	05536265	05536215	05536255	05537500				
66	05446500	05447500	05448000	05466000	05466500	05467000	05469000	-05468500
	05568800	-05557000	05556500					
67	-05557500	05552500						
68	-05438250	05438500	05440000					
69	05439500	05437500						
70	05552500	05543500	-05557500	05556500	-05557000	05558900	05568800	-05468500
	05469000	05467000	05466500	05466000	05448000	05447500	05446500	
71	05444000	05443500	05446000	05419000	05414820	05435500		
72	05540500	05539000	05537500	05536500	05536340	05536255	05536235	05536215
	05536275	05536265	05536290	05533000	05531500	05532000	05532500	
73	-05549000	-05549500	-05548500	05548280	-05548000	-05547500	-05547000	05527800
	05528000	05535000	05535070	05534500	05535500	05528500	05529500	05529000
	05530000	05530990						
74	05439000	05558900						
75	05552500	05543500	05558900					
76	-05557500	05556500	-05557000	05568800	-05468500	05469000	05467000	05466500
	05466000	05448000	05447500	05446500	05446000	05443500		
77	05444000	05419000	05414820	05435500	05437500	05440000	05438500	05439500
	-05438250	-05549000	-05549500	-05548500	-05548000	05548280	-05547000	-05547500
	05550000							

78	05551200	05550500	05530990	05528500	05528000	05527800	05535000	05534500
	05535070	05535500	05529000	05529500	05530000	05536000	05532000	05531500
79	05539900	05540095	05532500	05533000	05536500	05536340	05536255	05536265
	05536235	05536215	05536255	05536290	05536275	05537500	05539000	05540500
	05551700							
80	05439000							
81	05551700	-05540290	05540500	05539000	-05534050	05537500	05536500	05536255
	05536215	05536235	05536265	05536275	05536290	05536340	05533000	05532000
	05532500	05531500						
82	-05418950	05414820	05419000	-05420100	05446000	-05447100	05444000	05447500
	05448000	05466500	05467000	05469000	-05468500	05466000		
83	05446500							
84	05568800	05552500	05556500	-05557000	-05557500	-00000003		
85	05527800	05535000	05535070	05534500	05535500	05528500	05529500	05529000
	05536000	05530000	05530990	-05530590	-05540210	05539900		
86	05540095	05550500	05528000					
87	05443500	-05442200	-05442020	-05440700	05437500	-05435800	05435500	05437695
	-05440520	05440000	-05438600	05439500	05438500	-05438201	-05438250	-05549000
	-05549500	-05548500	05548280	-05547000	-05547500	05550000	-05548000	
88	05551200	-05551000	-05551540	05439000	-00000001	-00000002		
89	05552500	05556500	-05557000	-05557500	05568800	-05468500	05469000	05467000
	05466500	05466000	05448000	05447500	05446500	-05447100	05446000	05443500
	-05442200							
90	05444000	-05420100	05419000	-05418950	05414820	05435500	-05435800	05437500
	-05438201	05437695	-05440700	-05442020	-05440520	05440000	-05438600	05439500
	05439000	05438500						
91	-05438250	-05549000	-05549500	-05548500	-05548000	05548280	-05547000	-05547500
	05527800	05528000	05535000	05534500	05535070	05535500	05528500	05550000
	05550500	-05551000	05551200	05539900	05540095			
92	05530990	05530000	05529500	05529000	05536000	-05530590	05532000	05531500
	05532500	05533000	05536500	05536340	05536265	05536235	05536215	05536255
	05536275	05536290	05539000					
93	-05540210	-00000001	-00000002	05537500	-05534050	05540500	-05540290	-05551540
	05551700							
94	05543500	05558900						
95	05444000	05443500	05446000	-05420100	05419000	-05418950	05414820	05435500

Table 8.--Summary of routes used in the K-CERA analysis--Continued

Route No.	Stations serviced on the route							
96	-05442200	-05442020	05439000					
97	05437500	-05435800	05437695	05438500	-05438201			
98	-05440700	-05440520	-05438600					
99	05439500	05440000	-05438250					
100	-05549000	-05549500	-05548500	05548280	-05548000	-05547500	-05547000	05527800
	05528000							
101	05550500	05540095						
102	05550000	05535000	05535070	05534500	05535500	05528500	05529500	05529000
	05530000	05530990	05536000	-05530590	05532000	05532500		
103	05531500	05533000	05536500	05536340	05536290	05536275	05536235	05536265
	05536215	05536255	05539000	05540500	05551700			
104	-05534050	05537500	-00000001	-00000002				
105	-05551540	-05540290	-05540210					
106	05539900	05551200	-05551000					
107	-00000003	05556500						
108	05446500	05447500	05448000	05466000	05466500	05467000	05469000	-05468500
	05568800	-05557000	-05447100					
109	-05438250	-05438201	05438500					
110	05437695	-05438600	05440000					
111	05439000	05439500	-05440520					
112	05550000	-05551000	05551200					
113	05539900	-05540290	-05540210					
114	05552500	-05557500	05556500	-05557000	05558900	05568800	-05468500	05469000
	05467000	05466500	05466000	05448000	05447500	05446500	-05447100	
115	-05442020	-05442200	05444000	05443500	05446000	-05420100	05419000	05414820
	-05418950	05435500	-05435800	05437500	-05440700			
116	05551700	05540500	05539000	-05534050	05537500	05536500	05536340	05536255
	05536235	05536215	05536275	05536265	05536290	05533000	-00000001	-00000002
	05531500	05532000	05532500	-05551540				
117	-05549000	-05549500	-05548500	05548280	-05548000	-05547500	-05547000	05535000
	05535070	05534500	05535500	05528500	05529500	05529000	-05530590	05530000
	05530990							

118	05540095	05550500	05527800	05528000				
119	05558900	-00000003						
120	05569500	05570000	-05584400	05584500	05585000	05495500	-05586000	
121	05570350	05570360	05570370	05570380	05583000			
122	05560500	05561500	05567500	05580950	05568500	05585500		
123	05560500	05561500	05567500	05580950	-05563000	-05563500	-05567000	-05568000
	-05585275	-05586100	05568500	05585500				
124	05568500	05585500						
125	05573540	05575800	05578500	05582000	05577500	05576000	05579500	-05580500
	-05581500	-05575500	-05576500					
126	05573540	05575800	05578500	05582000	05577500	05576000	05579500	-05580500
	-05581500	05580000	-05575500	-05576500	-05578000	-05573650	-05573800	
127	-03338000	05590000	05591550	05591700	03337000	03336900	03343400	03339000
	03336645							
128	-03338000	05590000	05591550	05591700	03337000	03336900	03343400	03339000
	03336645	05570910	05590800	-03337700	-03338097	-03338780	-03339147	-03341414
	-03341540							
129	05520500	05525000	05525500	05526000	05527500	05542000	05554500	05555300
130	05520500	05525000	05525500	05526000	05527500	05542000	05554500	05555300
	-05554000	-05555000						
131	05572000							
132	05585000	05495500	05584500	-05584400	05570000	05570360	05570350	05570370
	05570380							
133	05577500	05583000	05591200					
134	-05580500	-05581500	05579500	05578500	05575800	-05575500	05576000	-05576500
	05582000							
135	05591550	05572000	05590000	05591700	05573540	03337000		
136	03336900	03343400	03339000	03336645	05591200			
137	05520500	05525000	05525500	05526000	05527500	05542000	05554500	05555300
138	05560500	05561500	05567500	05568500	05569500	05580950	05585500	
139	05591200							
140	03337000							
141	05527500							

Table 9.--Additional stations included in evaluation of routes for Illinois' gaging-station network operation

[Footnotes are at end of table]

Map index number[1]	Station No.	Station name	Type of station[2]
139	[3]00 0000 01	Argonne National Laboratory (owner)	W
140	[4]00 0000 02	Argonne National Laboratory (owner)	W
141	[5]00 0000 03	Helen Croisant (owner)	W
142	03 3377 00	Saline Branch near Mayview, Ill.	CQ
143	03 3380 00	Salt Fork near Homer, Ill.	C
144	03 3380 97	Salt Fork near Oakwood, Ill.	CQ
145	03 3387 80	North Fork Vermilion River near Bismarck, Ill.	CQ
146	03 3391 47	Little Vermilion River near Georgetown, Ill.	CQ
147	03 3414 14	Brouilletts Creek near St. Bernice, Ind.	CQ
148	03 3415 40	Sugar Creek near Elbridge, Ill.	CQ
149	03 3440 00	Embarras River near Diona, Ill.	C
150	03 3445 00	Range Creek near Casey, Ill.	C
151	03 3789 00	Little Wabash River at Louisville, Ill.	C
152	03 3796 00	Little Wabash River at Blood, Ill.	C
153	03 3799 50	Elm River at Toms Prairie, Ill.	CQ
154	03 3803 50	Skillet Fork near Iuka, Ill.	C
155	03 3814 95	Little Wabash River at Main St. at Carmi, Ill.	DP,CQ
156	03 3820 90	Sugar Creek at Stonefort, Ill.	CQ
157	03 3850 00	Hayes Creek at Glendale, Ill.	C
158	05 4189 50	Apple River near Elizabeth, Ill.	CQ
159	05 4201 00	Plum River at Savanna, Ill.	CQ
160	05 4358 00	Pecatonica River at Harrison, Ill.	CQ
161	05 4382 01	Kishwaukee River at Garden Prairie Road at Garden Prairie, Ill.	CQ
162	05 4382 50	Coon Creek at Riley, Ill.	C
163	05 4386 00	Kishwaukee River above South Branch near Perryville, Ill.	CQ
164	05 4405 20	Killbuck Creek near New Milford, Ill.	CQ
165	05 4407 00	Rock River at Byron, Ill.	CQ
166	05 4420 20	Kyte River at Daysville, Ill.	CQ
167	05 4422 00	Rock River at Grand Detour, Ill.	CQ
168	05 4471 00	Green River near Deer Grove, Ill.	CQ
169	05 4685 00	Cedar Creek at Little York, Ill.	C
170	05 5020 20	Hadley Creek near Barry, Ill.	C
171	05 5305 90	Des Plaines River near Schiller Park, Ill.	CQ
172	05 5340 50	Des Plaines River at Lockport, Ill.	CQ
173	05 5402 10	East Branch Du Page River at Route 34 Bridge at Lisle, Ill.	CQ

Table 9.--Additional stations included in evaluation of routes for Illinois' gaging-station network operation--Continued

Map index number[1]	Station No.	Station name	Type of station[2]
174	05 5402 90	Du Page River near Naperville, Ill.	CQ
175	05 5470 00	Channel Lake near Antioch, Ill.	S
176	05 5475 00	Fox Lake near Lake Villa, Ill.	S
177	05 5480 00	Nippersink Lake at Fox Lake, Ill.	S
178	05 5485 00	Fox River at Johnsburg, Ill.	S
179	05 5490 00	Boone Creek near McHenry, Ill.	C
180	05 5495 00	Fox River near McHenry, Ill.	S
181	05 5510 00	Fox River at South Elgin, Ill.	CQ
182	05 5515 40	Fox River at Montgomery, Ill.	CQ
183	05 5540 00	North Fork Vermilion River near Charlotte, Ill.	C
184	05 5550 00	Vermilion River at Streator, Ill.	MS
185	05 5570 00	West Bureau Creek at Wyanet, Ill.	C
186	05 5575 00	East Bureau Creek near Bureau, Ill.	C
187	05 5630 00	Kickapoo Creek near Kickapoo, Ill.	C
188	05 5635 00	Kicakpoo Creek at Peoria, Ill.	C
189	05 5670 00	Panther Creek near El Paso, Ill.	C
190	05 5680 00	Mackinaw River near Green Valley, Ill.	C
191	05 5736 50	Sangamon River near Niantic, Ill.	CQ
192	05 5738 00	Sangamon River at Roby, Ill.	CQ
193	05 5755 00	South Fork Sangamon River at Kincaid, Ill.	C
194	05 5765 00	Sangamon River at Riverton, Ill.	C
195	05 5780 00	Sangamon River at Petersburg, Ill.	MS
196	05 5805 00	Kickapoo Creek near Lincoln, Ill.	C
197	05 5815 00	Sugar Creek near Hartsburg, Ill.	C
198	05 5844 00	Drowning Fork near Bushnell, Ill.	C
199	05 5852 75	Indian Creek at Arenzville, Ill.	CQ
200	05 5860 00	North Fork Mauvaise Terre Creek near Jacksonville, Ill.	C
201	05 5861 00	Illinois River at Valley City, Ill.	CQ,SED
202	05 5865 00	Hurricane Creek near Roodhouse, Ill.	C
203	05 5866 90	Macoupin Creek near Macoupin, Ill.	CQ
204	05 5895 00	Canteen Creek at Caseyville, Ill.	C
205	05 5921 95	Beck Creek at Herrick, Ill.	CQ
206	05 5926 00	Hickory Creek near Bluff City, Ill.	MS
207	05 5935 05	Crooked Creek near Odin, Ill.	CQ
208	05 5936 00	Blue Grass Creek near Raymond, Ill.	C

Table 9.--Additional stations included in evaluation of routes for Illinois' gaging-station network operation--Continued

Map index number[1]	Station No.	Station name	Type of station[2]
209	05 5937 85	Shoal Creek near Walshville, Ill.	CQ
210	05 5955 40	Marys River at Welge, Ill.	CQ
211	05 5957 00	Big Muddy River near Mt. Vernon, Ill.	MS
212	05 5958 30	Casey Fork at Route 37 near Mt. Vernon, Ill.	MS
213	05 5959 50	Rend Lake near Benton, Ill.	DP
214	05 5970 40	Pond Creek at West Frankfort, Ill.	CQ
215	05 5972 80	Little Muddy River near Elkville, Ill.	CQ
216	05 5980 50	Crab Orchard Creek below Crab Orchard Lake near Carterville, Ill.	CQ
217	05 5982 45	Crab Orchard Creek near Carbondale, Ill.	CQ
218	05 5992 00	Beaucoup Creek near Vergennes, Ill.	CQ
219	05 6000 00	Big Creek near Wetaug, Ill.	C

1 Reference to station location shown in figure 9.

2 C denotes a crest-stage partial record station,
CQ denotes a chemical quality station,
DP denotes a data collection platform (a battery-operated radio that transmits stage or other hydrologic data to a satellite relay station),
MS denotes a station where stage and discharge are measured periodically,
S denotes a station where only stage is continuously monitored,
SED denotes a station where suspended sediment is determined on a daily basis,
W denotes a ground-water well.

3 U.S. Geological Survey station number is 414217087592801.

4 U.S. Geological Survey station number is 414236087583301.

5 U.S. Geological Survey station number is 412220089280301.

Table 10.--Criteria for assigning a minimum number of visits

Criteria	Minimum visits required per year
1-hour recorder punch frequency	2
30-minute recorder punch frequency	3
15-minute recorder punch frequency	5
5-minute recorder punch frequency	17

Table 11.--Selected results of K-CERA analysis

[Footnotes are at end of table]

Station No.	Station name	Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site)					
		Current practice[3]		Budget, in thousands of 1983 dollars[4]			
		Missing record	No missing record	706.6	768.0	844.8	921.6
03 3366 45	Middle Fork Vermilion River above Oakwood, Ill.	23.0 [21.7] (9)	20.5 [20.5] (9)	22.5 [21.2] (10)	21.7 [20.5] (12)	19.8 [18.8] (17)	18.1 [17.1] (23)
03 3369 00	Salt Fork near St. Joseph, Ill.	23.6 [8.4] (9)	7.4 [7.4] (9)	22.5 [7.9] (10)	20.6 [7.1] (12)	17.5 [5.8] (17)	15.1 [5.0] (23)
03 3370 00	Boneyard Creek at Urbana, Ill.	35.7 [29.1] (27)	28.0 [28.0] (27)	35.7 [29.1] (27)	25.3 [20.6] (59)	20.9 [16.9] (88)	18.5 [14.9] (110)
03 3390 00	Vermilion River near Danville, Ill.	15.8 [5.8] (9)	5.1 [5.1] (9)	15.0 [5.5] (10)	13.8 [5.1] (12)	11.8 [4.3] (17)	10.2 [3.7] (23)
03 3434 00	Embarras River near Camargo, Ill.	34.7 [17.1] (9)	15.3 [15.3] (9)	33.0 [16.1] (10)	30.3 [14.5] (12)	25.6 [11.9] (17)	22.1 [10.0] (23)
03 3455 00	Embarras River at Ste. Marie, Ill.	33.3 [10.4] (9)	9.2 [9.2] (9)	37.2 [11.1] (7)	27.4 [9.4] (14)	23.3 [8.5] (20)	21.0 [7.9] (25)
03 3460 00	North Fork Embarras River near Oblong, Ill.	53.1 [27.7] (9)	24.5 [24.5] (9)	59.4 [32.0] (7)	43.1 [21.4] (14)	36.3 [17.4] (20)	32.6 [15.4] (25)
03 3780 00	Bonpas Creek at Browns, Ill.	60.8 [30.8] (9)	27.2 [27.2] (9)	52.2 [27.3] (13)	37.8 [20.4] (27)	31.8 [17.2] (39)	27.9 [15.1] (51)

03 3786 35	Little Wabash River near Effingham, Ill.	55.9 [42.1] (9)	38.5 [38.5] (9)	63.9 [45.5] (6)	51.1 [39.8] (12)	43.3 [35.2] (20)	39.5 [32.6] (26)
03 3795 00	Little Wabash River below Clay City, Ill.	44.8 [14.4] (9)	12.8 [12.8] (9)	57.9 [16.7] (5)	41.0 [13.7] (11)	34.7 [12.5] (16)	30.7 [11.6] (21)
03 3804 75	Horse Creek near Keenes, Ill.	60.3 [32.9] (9)	29.6 [29.6] (9)	48.0 [25.8] (14)	33.6 [17.6] (28)	28.3 [14.7] (39)	24.5 [12.6] (52)
03 3805 00	Skillet Fork at Wayne City, Ill.	46.3 [23.0] (12)	20.9 [20.9] (12)	44.6 [22.2] (13)	31.8 [15.8] (27)	26.7 [13.1] (39)	23.4 [11.4] (51)
03 3815 00	Little Wabash River at Carmi, Ill.	35.8 [11.1] (10)	9.8 [9.8] (10)	37.7 [11.7] (9)	32.6 [10.2] (12)	28.2 [8.9] (16)	24.6 [7.7] (21)
03 3821 00	South Fork Saline River near Carrier Mills, Ill.	36.0 [8.7] (9)	7.6 [7.6] (9)	36.0 [8.7] (9)	34.3 [8.2] (10)	30.3 [7.2] (13)	25.9 [6.0] (18)
03 3844 50	Lusk Creek near Eddyville, Ill.	69.3 [59.4] (9)	54.6 [54.6] (9)	69.3 [59.4] (9)	51.5 [43.7] (20)	42.9 [36.0] (30)	37.9 [31.5] (39)
03 6120 00	Cache River at Forman, Ill.	59.2 [42.8] (9)	38.7 [38.7] (9)	59.2 [42.8] (9)	40.3 [28.4] (20)	32.8 [22.8] (30)	28.7 [19.7] (39)
05 4148 20	Sinsinawa River near Menominee, Ill.	24.1 [7.7] (9)	7.0 [7.0] (9)	31.5 [10.8] (5)	29.0 [9.7] (6)	22.9 [7.3] (10)	20.2 [6.4] (13)
05 4190 00	Apple River near Hanover, Ill.	30.1 [7.9] (9)	7.1 [7.1] (9)	39.3 [9.8] (5)	36.2 [9.2] (6)	28.7 [7.6] (10)	25.4 [6.9] (13)

Table 11.--Selected results of K-CERA analysis--Continued

Station No.	Station name	Current practice[3] Missing record	Current practice[3] No missing record	Budget, in thousands of 1983 dollars[4] 706.6	768.0	844.8	921.6
		Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site)					
05 4355 00	Pecatonica River at Freeport, Ill.	11.8 [3.8] (9)	3.4 [3.4] (9)	15.4 [4.9] (5)	14.2 [4.5] (6)	11.2 [3.6] (10)	9.9 [3.2] (13)
05 4375 00	Rock River at Rockton, Ill.	7.4 [2.2] (9)	2.0 [2.0] (9)	9.7 [3.0] (5)	9.7 [3.0] (5)	9.7 [3.0] (5)	9.7 [3.0] (5)
05 4376 95	Keith Creek at Eighth Street at Rockford, Ill.	42.1 [16.2] (9)	14.4 [14.4] (9)	47.7 [18.7] (7)	33.8 [12.6] (14)	29.0 [10.7] (19)	25.8 [9.4] (24)
05 4385 00	Kishwaukee River at Belvidere, Ill.	9.6 [4.4] (9)	3.9 [3.9] (9)	12.5 [6.1] (5)	12.5 [6.1] (5)	12.5 [6.1] (5)	12.5 [6.1] (5)
05 4390 00	South Branch Kishwaukee River at De Kalb, Ill.	12.0 [7.5] (9)	6.8 [6.8] (9)	15.5 [10.2] (5)	13.4 [8.6] (7)	12.0 [7.5] (9)	9.8 [5.9] (14)
05 4395 00	South Branch Kishwaukee River near Fairdale, Ill.	15.8 [5.3] (9)	4.8 [4.8] (9)	20.7 [7.5] (5)	20.7 [7.5] (5)	16.7 [5.7] (8)	15.1 [5.0] (10)
05 4400 00	Kishwaukee River near Perryville, Ill.	9.6 [5.1] (9)	4.7 [4.7] (9)	10.8 [5.9] (7)	7.8 [4.1] (14)	6.8 [3.5] (19)	6.0 [3.1] (24)
05 4435 00	Rock River at Como, Ill.	5.3 [2.6] (9)	2.4 [2.4] (9)	5.1 [2.5] (10)	5.1 [2.5] (10)	4.4 [2.2] (14)	4.0 [2.0] (17)

05 4440 00	Elkhorn Creek near Penrose, Ill.	26.5 [5.9] (9)	5.3 [5.3] (9)	34.8 [8.6] (5)	32.0 [7.6] (6)	25.2 [5.5] (10)	22.2 [4.8] (13)
05 4460 00	Rock Creek at Morrison, Ill.	11.1 [7.8] (9)	7.2 [7.2] (9)	10.7 [7.6] (10)	10.7 [7.6] (10)	9.3 [6.6] (14)	8.6 [6.1] (17)
05 4465 00	Rock River near Joslin, Ill.	8.1 [1.4] (9)	1.2 [1.2] (9)	8.1 [1.4] (9)	8.1 [1.4] (9)	6.2 [1.3] (13)	5.2 [1.3] (17)
05 4475 00	Green River near Geneseo, Ill.	19.1 [4.6] (9)	4.2 [4.2] (9)	25.0 [6.6] (5)	19.1 [4.6] (9)	16.0 [3.8] (13)	14.1 [3.3] (17)
05 4480 00	Mill Creek at Milan, Ill.	49.5 [29.1] (9)	26.5 [26.5] (9)	65.2 [42.2] (5)	49.5 [29.1] (9)	41.4 [23.4] (13)	36.4 [20.0] (17)
05 4660 00	Edwards River near Orion, Ill.	26.0 [11.9] (9)	10.8 [10.8] (9)	34.0 [16.9] (5)	26.0 [11.9] (9)	21.8 [9.7] (13)	19.2 [8.3] (17)
05 4665 00	Edwards River near New Boston, Ill.	15.4 [9.8] (9)	8.9 [8.9] (9)	20.2 [13.8] (5)	15.4 [9.8] (9)	13.0 [7.9] (13)	11.4 [6.9] (17)
05 4670 00	Pope Creek near Keithsburg, Ill.	19.8 [16.2] (9)	15.1 [15.1] (9)	25.9 [22.5] (5)	19.8 [16.2] (9)	16.6 [13.2] (13)	14.6 [11.4] (17)
05 4690 00	Henderson Creek near Oquawka, Ill.	14.2 [7.7] (9)	7.0 [7.0] (9)	18.2 [10.0] (5)	14.2 [7.7] (9)	12.0 [6.5] (13)	10.6 [5.7] (17)
05 4955 00	Bear Creek near Marcelline, Ill.	26.7 [17.9] (9)	16.4 [16.4] (9)	34.4 [24.3] (5)	31.9 [22.2] (6)	26.7 [17.9] (9)	22.5 [14.6] (13)

Table 11.--Selected results of K-CERA analysis--Continued

Station No.	Station name	Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site): Current practice[3] Missing record	Current practice[3] No missing record	Budget, in thousands of 1983 dollars[4] 706.6	768.0	844.8	921.6
05 5020 40	Hadley Creek at Kinderhook, Ill.	50.3 [49.4] (9)	47.7 [47.7] (9)	53.4 [52.7] (8)	38.7 [37.1] (15)	32.6 [30.8] (21)	28.7 [26.9] (27)
05 5125 00	Bay Creek at Pittsfield, Ill.	68.7 [55.9] (9)	51.1 [51.1] (9)	72.7 [60.1] (8)	53.4 [41.1] (15)	45.2 [33.7] (21)	39.8 [29.2] (27)
05 5130 00	Bay Creek at Nebo, Ill.	33.8 [30.2] (9)	28.0 [28.0] (9)	35.7 [32.3] (8)	26.4 [22.6] (15)	22.4 [18.8] (21)	19.8 [16.4] (27)
05 5205 00	Kankakee River at Momence, Ill.	9.5 [3.5] (9)	3.1 [3.1] (9)	12.3 [4.4] (5)	10.0 [3.6] (8)	8.4 [3.1] (12)	7.6 [2.9] (15)
05 5250 00	Iroquois River at Iroquois, Ill.	14.7 [5.4] (9)	4.9 [4.9] (9)	19.0 [6.3] (5)	15.5 [5.6] (8)	13.0 [5.0] (12)	11.7 [4.6] (15)
05 5255 00	Sugar Creek at Milford, Ill.	28.2 [25.7] (9)	24.2 [24.2] (9)	36.6 [34.8] (5)	29.8 [27.4] (8)	24.6 [22.0] (12)	22.1 [19.5] (15)
05 5260 00	Iroquois River near Chebanse, Ill.	16.0 [4.3] (9)	3.9 [3.9] (9)	20.9 [5.7] (5)	16.9 [4.6] (8)	14.0 [3.8] (12)	12.6 [3.4] (15)
05 5275 00	Kankakee River near Wilmington, Ill.	7.5 [5.0] (15)	4.7 [4.7] (15)	9.3 [6.2] (9)	9.3 [6.2] (9)	8.3 [5.5] (12)	7.5 [5.0] (15)

05 5278 00	Des Plaines River at Russell, Ill.	18.4 [13.0] (9)	12.0 [12.0] (9)	23.3 [16.8] (5)	20.5 [14.6] (7)	16.9 [11.8] (11)	14.6 [10.1] (15)
05 5280 00	Des Plaines River near Gurnee, Ill.	14.4 [9.4] (9)	8.5 [8.5] (9)	14.4 [9.4] (9)	14.4 [9.4] (9)	13.1 [8.4] (11)	11.3 [7.1] (15)
05 5285 00	Buffalo Creek near Wheeling, Ill.	33.9 [26.7] (9)	24.7 [24.7] (9)	40.3 [32.6] (6)	29.7 [22.9] (12)	25.2 [19.0] (17)	21.7 [16.2] (23)
05 5290 00	Des Plaines River near Des Plaines, Ill.	19.5 [13.0] (9)	11.8 [11.8] (9)	18.6 [12.4] (10)	15.6 [10.3] (15)	13.4 [8.7] (21)	11.9 [7.7] (27)
05 5295 00	McDonald Creek near Mount Prospect, Ill.	32.8 [20.6] (9)	18.9 [18.9] (9)	31.3 [19.6] (10)	26.0 [16.0] (15)	22.2 [13.4] (21)	19.6 [11.8] (27)
05 5300 00	Weller Creek at Des Plaines, Ill.	70.3 [61.6] (9)	57.3 [57.3] (9)	69.0 [61.0] (10)	64.7 [58.8] (15)	61.5 [57.0] (21)	59.2 [55.5] (27)
05 5309 90	Salt Creek at Rolling Meadows, Ill.	32.5 [24.9] (9)	22.8 [22.8] (9)	30.9 [23.4] (10)	25.5 [18.6] (15)	21.6 [15.4] (21)	19.1 [13.4] (27)
05 5315 00	Salt Creek at Western Springs, Ill.	23.8 [11.8] (9)	10.7 [10.7] (9)	25.1 [12.6] (8)	20.7 [9.9] (12)	17.5 [8.2] (17)	15.5 [7.1] (22)
05 5320 00	Addison Creek at Bellwood, Ill.	27.4 [15.9] (9)	14.3 [14.3] (9)	35.5 [21.9] (5)	25.0 [14.2] (11)	20.3 [11.1] (17)	17.5 [9.4] (23)
05 5325 00	Des Plaines River at Riverside, Ill.	12.0 [6.2] (9)	5.6 [5.6] (9)	12.0 [6.2] (9)	10.4 [5.7] (13)	9.1 [5.2] (18)	8.2 [4.8] (23)

Table 11.--Selected results of K-CERA analysis--Continued

Station No.	Station name	Current practice[3] Missing record	Current practice[3] No missing record	Budget, in thousands of 1983 dollars[4] 706.6	768.0	844.8	921.6
		Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site)					
05 5330 00	Flag Creek near Willow Springs, Ill.	27.8 [18.2] (9)	16.4 [16.4] (9)	29.4 [19.5] (8)	23.4 [14.7] (13)	20.0 [12.2] (18)	17.8 [10.7] (23)
05 5345 00	North Branch Chicago River at Deerfield, Ill.	42.3 [37.5] (9)	35.2 [35.2] (9)	51.4 [47.2] (6)	36.7 [31.8] (12)	30.8 [26.2] (17)	26.5 [22.1] (23)
05 5350 00	Skokie River at Lake Forest, Ill.	21.7 [15.4] (9)	14.1 [14.1] (9)	25.1 [17.5] (6)	19.4 [13.9] (12)	16.8 [12.0] (17)	14.6 [10.5] (23)
05 5350 70	Skokie River near Highland Park, Ill.	24.5 [21.7] (9)	20.3 [20.3] (9)	29.4 [26.8] (6)	21.4 [18.5] (12)	18.0 [15.3] (17)	15.5 [13.0] (23)
05 5355 00	West Fork of North Branch Chicago River at Northbrook, Ill.	27.0 [13.6] (9)	12.4 [12.4] (9)	32.3 [16.8] (6)	23.6 [11.7] (12)	20.0 [9.7] (17)	17.3 [8.3] (23)
05 5360 00	North Branch Chicago River at Niles, Ill.	28.2 [25.0] (9)	23.5 [23.5] (9)	31.3 [26.5] (5)	27.8 [24.8] (10)	26.0 [24.0] (16)	25.0 [23.5] (22)
05 5362 15	Thorn Creek at Glenwood, Ill.	12.7 [8.7] (9)	7.8 [7.8] (9)	13.4 [9.2] (8)	10.8 [7.1] (13)	9.2 [6.0] (18)	8.2 [5.2] (23)
05 5362 35	Deer Creek near Chicago Heights, Ill.	40.6 [34.5] (9)	32.2 [32.2] (9)	42.5 [36.2] (8)	35.0 [29.4] (13)	30.2 [25.1] (18)	27.0 [22.2] (23)

05 5362 55	Butterfield Creek at Flossmoor, Ill.	35.8 [25.6] (9)	23.5 [23.5] (9)	37.7 [27.1] (8)	27.4 [18.9] (16)	22.1 [14.9] (25)	19.0 [12.6] (34)
05 5362 65	Lansing Ditch near Lansing, Ill.	26.0 [12.0] (9)	10.8 [10.8] (9)	27.4 [12.7] (8)	21.9 [9.9] (13)	18.7 [8.4] (18)	16.6 [7.4] (23)
05 5362 75	Thorn Creek at Thornton, Ill.	22.1 [14.7] (9)	13.2 [13.2] (9)	23.2 [15.5] (8)	18.9 [12.4] (13)	16.3 [10.6] (18)	14.5 [9.3] (23)
05 5362 90	Little Calumet River at South Holland, Ill.	17.5 [11.9] (9)	10.8 [10.8] (9)	18.1 [12.0] (8)	15.7 [11.4] (13)	14.5 [11.1] (18)	13.6 [10.8] (23)
05 5363 40	Midlothian Creek at Oak Forest, Ill.	33.7 [23.1] (9)	21.2 [21.2] (9)	35.3 [24.1] (8)	29.0 [19.9] (13)	25.1 [17.1] (18)	22.4 [15.3] (23)
05 5365 00	Tinley Creek near Palos Park, Ill.	39.3 [28.8] (9)	26.6 [26.6] (9)	41.5 [30.8] (8)	33.0 [23.4] (13)	28.2 [19.5] (18)	25.0 [17.1] (23)
05 5375 00	Long Run near Lemont, Ill.	39.5 [30.7] (9)	28.5 [28.5] (9)	50.3 [40.6] (5)	36.0 [27.7] (11)	30.2 [22.7] (16)	26.5 [19.6] (21)
05 5390 00	Hickory Creek at Joliet, Ill.	17.0 [8.8] (9)	8.0 [8.0] (9)	17.0 [8.8] (9)	19.1 [10.1] (7)	14.9 [7.5] (12)	13.0 [6.4] (16)
05 5399 00	West Branch Du Page River near West Chicago, Ill.	20.3 [17.3] (9)	16.1 [16.1] (9)	26.0 [23.4] (5)	21.3 [18.4] (8)	18.5 [15.6] (11)	16.5 [13.6] (14)
05 5400 95	West Branch Du Page River near Warrenville, Ill.	15.9 [11.8] (9)	10.8 [10.8] (9)	15.9 [11.8] (9)	15.9 [11.8] (9)	14.6 [10.8] (11)	13.2 [9.7] (14)

Table 11.--Selected results of K-CERA analysis--Continued

Station No.	Station name	Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site): Current practice[3] Missing record	Current practice[3] No missing record	Budget, in thousands of 1983 dollars[4] 706.6	768.0	844.8	921.6
05 5405 00	Du Page River at Shorewood, Ill.	10.3 [3.6] (9)	3.3 [3.3] (9)	13.4 [4.7] (5)	13.4 [4.7] (5)	10.8 [3.8] (8)	9.0 [3.2] (12)
05 5420 00	Mazon River near Coal City, Ill.	40.0 [16.8] (9)	15.0 [15.0] (9)	52.1 [23.9] (5)	42.2 [18.0] (8)	34.9 [14.2] (12)	31.4 [12.5] (15)
05 5435 00	Illinois River at Marseilles, Ill.	6.3 [3.3] (9)	2.9 [2.9] (9)	6.3 [3.3] (9)	6.3 [3.3] (9)	6.3 [3.3] (9)	6.3 [3.3] (9)
05 5482 80	Nippersink Creek near Spring Grove, Ill.	7.8 [3.6] (9)	3.2 [3.2] (9)	10.1 [4.8] (5)	10.1 [4.8] (5)	10.1 [4.8] (5)	10.1 [4.8] (5)
05 5500 00	Fox River at Algonquin, Ill.	7.6 [3.2] (9)	2.9 [2.9] (9)	9.1 [3.7] (6)	8.5 [3.5] (7)	7.6 [3.2] (9)	7.3 [3.1] (10)
05 5505 00	Poplar Creek at Elgin, Ill.	29.6 [19.2] (9)	17.4 [17.4] (9)	29.6 [19.2] (9)	27.0 [17.2] (11)	23.3 [14.4] (15)	20.3 [12.3] (20)
05 5512 00	Ferson Creek near St. Charles, Ill.	22.9 [13.2] (9)	12.0 [12.0] (9)	29.8 [18.3] (5)	21.8 [12.5] (10)	18.0 [10.0] (15)	15.7 [8.5] (20)
05 5517 00	Blackberry Creek near Yorkville, Ill.	17.8 [8.9] (9)	8.0 [8.0] (9)	23.3 [12.6] (5)	17.8 [8.9] (9)	15.5 [7.5] (12)	13.9 [6.6] (15)

05 5525 00	Fox River at Dayton, Ill.	14.7 [4.5] (9)	4.0 [4.0] (9)	19.1 [6.0] (5)	19.1 [6.0] (5)	19.1 [6.0] (5)	17.7 [5.5] (6)
05 5545 00	Vermilion River at Pontiac, Ill.	19.2 [12.1] (9)	10.9 [10.9] (9)	24.2 [15.3] (5)	20.1 [12.6] (8)	16.9 [10.6] (12)	15.3 [9.5] (15)
05 5553 00	Vermilion River near Leonore, Ill.	22.6 [8.3] (9)	7.4 [7.4] (9)	29.4 [11.5] (5)	23.9 [8.9] (8)	19.8 [7.2] (12)	17.8 [6.4] (15)
05 5565 00	Big Bureau Creek at Princeton, Ill.	37.2 [28.7] (9)	26.6 [26.6] (9)	49.2 [40.8] (5)	35.4 [27.0] (10)	30.0 [22.3] (14)	26.6 [19.4] (18)
05 5589 00	Illinois River at Henry, Ill.	14.5 [14.2] (18)	13.8 [13.8] (18)	17.2 [16.9] (9)	17.2 [16.9] (9)	17.2 [16.9] (9)	17.2 [16.9] (9)
05 5605 00	Farm Creek at Farmdale, Ill.	75.0 [73.4] (9)	70.7 [70.7] (9)	75.0 [73.4] (9)	75.0 [73.4] (9)	64.9 [62.7] (12)	57.9 [55.3] (15)
05 5615 00	Fondulac Creek near East Peoria, Ill.	47.4 [17.2] (9)	15.3 [15.3] (9)	47.4 [17.2] (9)	47.4 [17.2] (9)	41.4 [14.7] (12)	37.3 [13.0] (15)
05 5675 00	Mackinaw River near Congerville, Ill.	32.7 [17.5] (9)	15.7 [15.7] (9)	32.7 [17.5] (9)	32.7 [17.5] (9)	28.6 [14.9] (12)	25.8 [13.2] (15)
05 5685 00	Illinois River at Kingston Mines, Ill.	8.5 [7.3] (9)	6.7 [6.7] (9)	8.5 [7.3] (9)	8.5 [7.3] (9)	7.5 [6.4] (12)	6.8 [5.7] (15)
05 5688 00	Indian Creek near Wyoming, Ill.	31.1 [20.5] (9)	18.8 [18.8] (9)	40.9 [29.3] (5)	31.1 [20.5] (9)	26.1 [16.6] (13)	22.9 [14.3] (17)

Table 11.--Selected results of K-CERA analysis--Continued

Station No.	Station name	Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site): Current practice[3] Missing record	Current practice[3] No missing record	Budget, in thousands of 1983 dollars[4] 706.6	768.0	844.8	921.6
05 5695 00	Spoon River at London Mills, Ill.	15.8 [7.0] (9)	6.3 [6.3] (9)	20.4 [9.2] (5)	20.4 [9.2] (5)	17.6 [7.9] (7)	15.8 [7.0] (9)
05 5700 00	Spoon River at Seville, Ill.	13.7 [6.6] (9)	5.9 [5.9] (9)	17.6 [8.5] (5)	16.3 [7.8] (6)	13.7 [6.6] (9)	11.6 [5.6] (13)
05 5703 50	Big Creek at St. David, Ill.	29.4 [29.4] (9)	29.3 [29.3] (9)	29.4 [29.4] (9)	28.0 [28.0] (10)	24.7 [24.6] (13)	21.7 [21.5] (17)
05 5703 60	Evelyn Branch near Bryant, Ill.	19.0 [11.9] (9)	10.7 [10.7] (9)	19.0 [11.9] (9)	18.1 [11.2] (10)	16.0 [9.7] (13)	14.1 [8.4] (17)
05 5703 70	Big Creek near Bryant, Ill.	22.2 [22.0] (9)	21.4 [21.4] (9)	22.2 [22.0] (9)	21.2 [21.0] (10)	18.9 [18.5] (13)	16.7 [16.2] (17)
05 5703 80	Slug Run near Bryant, Ill.	25.0 [19.9] (9)	18.3 [18.3] (9)	25.0 [19.9] (9)	23.8 [18.9] (10)	21.2 [16.5] (13)	18.6 [14.3] (17)
05 5709 10	Sangamon River at Fisher, Ill.	36.9 [35.1] (9)	33.4 [33.4] (9)	40.9 [38.6] (5)	39.7 [37.5] (6)	36.1 [34.4] (10)	32.7 [31.2] (15)
05 5720 00	Sangamon River at Monticello, Ill.	17.5 [14.6] (9)	13.5 [13.5] (9)	21.4 [18.2] (5)	19.2 [16.1] (7)	16.8 [14.0] (10)	15.6 [12.9] (12)

05 5735 40	Sangamon River at Route 48 at Decatur, Ill.	41.2 [41.2] (9)	41.2 [41.2] (9)	42.0 [41.5] (8)	29.4 [29.4] (18)	25.5 [25.5] (24)	22.8 [22.8] (30)
05 5758 00	Horse Creek at Pawnee, Ill.	51.0 [26.1] (9)	23.4 [23.4] (9)	57.3 [30.4] (7)	42.8 [21.0] (13)	35.6 [16.9] (19)	31.8 [14.8] (24)
05 5760 00	South Fork Sangamon River near Rochester, Ill.	21.4 [16.0] (9)	14.6 [14.6] (9)	23.7 [17.9] (7)	18.2 [13.3] (13)	15.2 [11.0] (19)	13.7 [9.7] (24)
05 5775 00	Spring Creek at Springfield, Ill.	53.3 [32.0] (9)	28.8 [28.8] (9)	59.2 [35.7] (7)	45.3 [26.9] (13)	37.9 [22.2] (19)	33.9 [19.6] (24)
05 5785 00	Salt Creek near Rowell, Ill.	29.5 [19.1] (9)	17.3 [17.3] (9)	32.9 [21.8] (7)	24.9 [15.7] (13)	20.8 [12.8] (19)	18.6 [11.2] (24)
05 5795 00	Lake Fork near Cornland, Ill.	39.6 [25.8] (9)	23.3 [23.3] (9)	44.2 [29.4] (7)	33.4 [21.1] (13)	27.9 [17.2] (19)	24.9 [15.1] (24)
05 5800 00	Kickapoo Creek at Waynesville, Ill.	29.7 [9.8] (9)	8.8 [8.8] (9)	39.0 [14.2] (5)	29.7 [9.8] (9)	24.0 [7.6] (14)	21.9 [6.8] (17)
05 5809 50	Sugar Creek near Bloomington, Ill.	26.3 [17.5] (9)	15.7 [15.7] (9)	26.3 [17.5] (9)	26.3 [17.5] (9)	23.0 [14.8] (12)	20.7 [13.0] (15)
05 5820 00	Salt Creek near Greenview, Ill.	17.9 [5.8] (9)	5.1 [5.1] (9)	20.0 [6.6] (7)	15.0 [4.8] (13)	12.5 [3.9] (19)	11.2 [3.5] (24)
05 5830 00	Sangamon River near Oakford, Ill.	11.2 [2.4] (9)	2.1 [2.1] (9)	11.2 [2.4] (9)	11.2 [2.4] (9)	11.2 [2.4] (9)	11.2 [2.4] (9)

Table 11.--Selected results of K-CERA analysis--Continued

Station No.	Station name	Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site)					
		Current practice[3]		Budget, in thousands of 1983 dollars[4]			
		Missing record	No missing record	706.6	768.0	844.8	921.6
05 5845 00	La Moine River at Colmar, Ill.	32.9 [17.8] (9)	16.0 [16.0] (9)	42.7 [24.8] (5)	39.4 [22.4] (6)	32.9 [17.8] (9)	27.7 [14.4] (13)
05 5850 00	La Moine River at Ripley, Ill.	17.7 [9.5] (9)	8.5 [8.5] (9)	22.9 [13.2] (5)	21.2 [12.0] (6)	17.7 [9.5] (9)	14.9 [7.7] (13)
05 5855 00	Illinois River at Meredosia, Ill.	7.9 [6.0] (9)	5.4 [5.4] (9)	7.9 [6.0] (9)	7.9 [6.0] (9)	7.0 [5.3] (12)	6.4 [4.8] (15)
05 5870 00	Macoupin Creek near Kane, Ill.	24.5 [17.4] (9)	15.8 [15.8] (9)	25.9 [18.6] (8)	19.2 [13.0] (15)	16.3 [10.7] (21)	14.5 [9.4] (27)
05 5879 00	Cahokia Creek at Edwardsville, Ill.	55.8 [46.2] (9)	42.3 [42.3] (9)	49.6 [40.4] (12)	36.8 [29.0] (23)	30.4 [23.5] (34)	27.0 [20.7] (43)
05 5880 00	Indian Creek at Wanda, Ill.	77.2 [51.7] (9)	46.4 [46.4] (9)	67.0 [44.2] (12)	48.2 [30.7] (23)	39.4 [24.7] (34)	35.0 [21.7] (43)
05 5900 00	Kaskaskia Ditch at Bondville, Ill.	44.2 [33.2] (9)	30.1 [30.1] (9)	53.2 [42.2] (6)	38.6 [28.1] (12)	32.6 [22.9] (17)	27.5 [18.9] (24)
05 5908 00	Lake Fork at Atwood, Ill	27.8 [25.2] (9)	23.6 [23.6] (9)	34.7 [32.5] (5)	32.6 [30.2] (6)	26.6 [23.9] (10)	22.1 [19.5] (15)

05 5912 00	Kaskaskia River at Cooks Mills, Ill.	13.9 [11.1] (13)	10.4 [10.4] (13)	16.1 [13.0] (9)	16.1 [13.0] (9)	16.1 [13.0] (9)	16.1 [13.0] (9)
05 5915 50	Whitley Creek near Allenville, Ill.	27.1 [25.8] (9)	24.6 [24.6] (9)	32.6 [31.7] (6)	23.7 [22.2] (12)	20.0 [18.4] (17)	16.9 [15.3] (24)
05 5917 00	West Okaw River near Lovington, Ill.	36.9 [36.9] (9)	36.9 [36.9] (9)	38.5 [38.4] (6)	35.0 [35.0] (12)	32.3 [32.2] (17)	29.0 [29.0] (24)
05 5920 00	Kaskaskia River at Shelbyville, Ill.	24.9 [23.8] (9)	22.6 [22.6] (9)	29.8 [29.0] (5)	28.3 [27.4] (6)	23.9 [22.8] (10)	20.9 [19.6] (14)
05 5920 50	Robinson Creek near Shelbyville, Ill.	20.7 [19.9] (9)	19.0 [19.0] (9)	26.1 [25.7] (5)	24.5 [23.9] (6)	19.8 [18.9] (10)	17.0 [16.0] (14)
05 5921 00	Kaskaskia River near Cowden, Ill.	13.3 [8.2] (9)	7.4 [7.4] (9)	15.8 [10.0] (6)	11.7 [7.1] (12)	9.2 [5.5] (20)	8.1 [4.8] (26)
05 5925 00	Kaskaskia River at Vandalia, Ill.	12.2 [9.4] (9)	8.6 [8.6] (9)	15.3 [12.0] (5)	15.3 [12.0] (5)	15.3 [12.0] (5)	13.5 [10.5] (7)
05 5928 00	Hurricane Creek near Mulberry Grove, Ill.	22.0 [18.5] (10)	17.2 [17.2] (10)	18.7 [15.4] (14)	14.7 [11.7] (23)	12.8 [10.0] (31)	11.1 [8.7] (41)
05 5929 00	East Fork Kaskaskia River near Sandoval, Ill.	14.0 [11.7] (9)	10.8 [10.8] (9)	15.7 [13.4] (7)	12.3 [10.1] (12)	10.4 [8.3] (17)	9.2 [7.3] (22)
05 5930 00	Kaskaskia River at Carlyle, Ill.	16.5 [7.3] (9)	6.4 [6.4] (9)	21.1 [9.0] (5)	19.6 [8.4] (6)	17.4 [7.6] (8)	15.1 [6.7] (11)

Table 11.--Selected results of K-CERA analysis--Continued

Station No.	Station name	Standard error of instantaneous discharge, in percent[1] [Equivalent Gaussian spread, in percent][2] (Number of visits per year to site): Current practice[3] Missing record	Current practice[3] No missing record	Budget, in thousands of 1983 dollars[4] 706.6	768.0	844.8	921.6
05 5935 20	Crooked Creek near Hoffman, Ill.	42.3 [23.0] (9)	20.7 [20.7] (9)	42.3 [23.0] (9)	29.3 [15.3] (19)	24.6 [12.6] (27)	21.6 [10.9] (35)
05 5935 75	Little Crooked Creek near New Minden, Ill.	75.8 [56.2] (9)	50.8 [50.8] (9)	57.0 [40.7] (17)	40.1 [27.4] (35)	33.2 [22.3] (51)	29.6 [19.7] (64)
05 5939 00	East Fork Shoal Creek near Coffeen, Ill.	84.4 [74.4] (9)	69.3 [69.3] (9)	80.5 [70.4] (10)	59.0 [49.4] (19)	49.4 [40.5] (27)	43.2 [35.0] (35)
05 5940 00	Shoal Creek near Breese, Ill.	42.6 [10.1] (9)	8.9 [8.9] (9)	37.3 [9.1] (12)	28.0 [7.1] (22)	23.3 [5.9] (32)	20.9 [5.3] (40)
05 5941 00	Kaskaskia River near Venedy Station, Ill.	9.8 [5.0] (9)	4.4 [4.4] (9)	9.8 [5.0] (9)	9.8 [5.0] (9)	9.8 [5.0] (9)	9.8 [5.0] (9)
05 5944 50	Silver Creek near Troy, Ill.	47.3 [28.1] (9)	25.3 [25.3] (9)	41.2 [23.6] (12)	30.1 [16.3] (23)	24.8 [13.2] (34)	22.1 [11.6] (43)
05 5948 00	Silver Creek near Freeburg, Ill.	37.7 [19.9] (9)	17.9 [17.9] (9)	37.7 [19.9] (9)	28.7 [14.3] (16)	24.1 [11.7] (23)	21.1 [10.1] (30)
05 5952 00	Richland Creek near Hecker, Ill.	43.8 [11.2] (9)	9.9 [9.9] (9)	43.8 [11.2] (9)	32.9 [8.0] (16)	27.5 [6.6] (23)	24.0 [5.7] (30)

05 5957 30	Rayse Creek near Waltonville, Ill.	35.5 [25.8] (9)	23.5 [23.5] (9)	44.0 [31.9] (5)	32.7 [23.7] (11)	27.9 [20.0] (16)	24.6 [17.5] (21)
05 5970 00	Big Muddy River at Plumfield, Ill.	22.1 [10.7] (9)	9.4 [9.4] (9)	27.3 [11.8] (6)	23.5 [11.0] (8)	19.2 [9.9] (12)	17.2 [9.4] (15)
05 5975 00	Crab Orchard Creek near Marion, Ill.	80.4 [49.2] (9)	44.4 [44.4] (9)	72.9 [43.3] (11)	51.9 [28.6] (22)	43.8 [23.6] (31)	38.6 [20.6] (40)
05 5995 00	Big Muddy River at Murphysboro, Ill.	14.4 [12.4] (10)	11.4 [11.4] (10)	15.0 [12.9] (9)	15.0 [12.9] (9)	15.0 [12.9] (9)	15.0 [12.9] (9)
Average per station[5]		36.5	23.8	38.5	30.8	26.2	23.4

1 Square root of the expected total error variance of the percentage errors of estimated instantaneous discharge (V_T) for a given frequency of measuring discharge.

2 Nearly two-thirds of the errors in instantaneous discharge will be within plus or minus EGS percent of the reported value.

3 Current practice and associated errors for 1983 budget of $768,000. Effects of missing stage record are indicated by comparing columns labeled "missing record" and "no missing record."

4 Optimal practice and associated errors that minimize the sum of standard errors, for all gaging stations, for the given budget.

5 Average standard error for the stream-gaging program, in percent.

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