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Techniques of Water-Resources Investigations of the United States Geological Survey

Chapter A6

GENERAL PROCEDURE FOR GAGING STREAMS

By R. W. Carter and Jacob Davidian

Book 3

APPLICATIONS OF HYDRAULICS

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PREFACE

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TWI 5-A1. Methods for determination of inorganic substances in water and fluvial sediments, by M.W. Skougstad and others, editors. 1979. 626 pages.

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[1]Spanish translation also available.

TWI 5-A2. Determination of minor elements in water by emission spectroscopy, by P.R. Barnett and E.C. Mallory, Jr. 1971. 31 pages.

TWI 5-A3. Methods for the determination of organic substances in water and fluvial sediments, edited by R.L. Wershaw, M.J. Fishman, R.R. Grabbe, and L.E. Lowe. 1987. 80 pages. This manual is a revision of "Methods for Analysis of Organic Substances in Water" by Donald F. Goerlitz and Eugene Brown, Book 5, Chapter A3, published in 1972.

TWI 5-A4. Methods for collection and analysis of aquatic biological and microbiological samples, edited by P.E. Greeson, T.A. Ehlke, G.A. Irwin, B.W. Lium, and K.V. Slack. 1977. 332 pages.

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CONTENTS

FIGURES

GENERAL PROCEDURE FOR GAGING STREAMS

By R. W. Carter and Jacob Davidian

Abstract

This chapter briefly describes the objectives and procedures used in obtaining streamflow records. It is considered an introduction to other chapters on surface-water techniques which treat individual procedures in greater detail.

Introduction

Measurement of the flow of streams was begun by the U.S. Geological Survey in 1888 as part of special studies relating to the irrigation of public lands. Since that time systematic records of streamflow have been obtained at more than 16,000 places in the United States by the Geological Survey. In 1967 the stream-gaging network comprised about 9,000 continuous-record stations. In addition, there were about 7,200 partial-record stations where data on only floodflow or low flow were obtained.

Stream gaging is the largest operation among the various hydrologic networks. Streamflow is the only part of the hydrologic cycle in which moisture is so confined as to permit reasonably accurate measurements of the volumes involved. All other measurements in the hydrologic cycle are at best only inadequate samples of the whole.

Water in streams serves man in many ways; it provides water supply for man and animals, irrigation water for plants, dilution and transport for removal of waste, energy for production of power, channels for water transport, and a medium of recreation. Records of streamflow are important in each of these uses.

Water in streams can also be a hazard. Floods cause extensive damage and hardship. Records of flood events obtained at gaging stations serve as the basis for the design of highway bridges and culverts, dams, and flood-control reservoirs and for flood-plain delineation and flood-warning systems.

The network of stream-gaging stations is designed to meet the various needs for information on streamflow. Many stations are operated to provide current information for use in the day-by-day management of water supplies or for use in forecasting flood events. Most of the stations, however, are operated as a part of the hydrologic network. Records for these stations reflect the natural hydrologic characteristics of the basins and can thus be used as samples of the variations of streamflow in time and space.

The design of streamflow networks is governed to some extent by the ability to measure stage and discharge at a given site to the required degree of accuracy. The continued development of new instrumentation and analytical techniques has improved the capability of obtaining streamflow records under difficult conditions.

This chapter describes in general terms the techniques used in obtaining continuous streamflow records—from selection of site to publication of records. It is considered an introduction to four other chapters in book 3, section A, surface-water techniques, which describe in detail the instruments and techniques used in making specific measurements. This series of chapters may be considered an updating of Water-Supply Paper 888, "Stream Gaging Procedure."

General Objective and Procedures

The objective in operating a gaging station is to obtain a continuous record of stage and discharge at the site. The exact location of the station is chosen to take advantage of the best available condition for stage and discharge measurements and for developing discharge ratings.

A continuous record of stage is obtained by installing instruments that sense and record the water-surface elevation in the stream. Discharge measurements are initially made at various stages to define the relation between stage and discharge. Discharge measurements are then made at periodic intervals, usually monthly, to verify the stage-discharge relation or to define any change in the relation owing to changes in channel geometry.

At many sites the discharge is not a unique function of stage; variables other than stage also must be continuously measured to obtain a discharge record. For example, stream slope is measured by the installation of an auxiliary stage gage downstream if variable backwater occurs. At other sites a continuous measure of stream velocity at a point in the cross section is obtained and used as an additional variable in the discharge rating. The rate of change of stage can be an important variable at sites having considerable unsteadiness of flow.

Low weirs and dams are constructed at some stations to stabilize the stage-discharge relations in the low-flow range. These control structures are calibrated by stage and discharge measurements in the field.

The data obtained at the gaging station are reviewed and analyzed by engineering personnel at the end of the water year. Discharge ratings are established, and the gage-height record is reduced to mean values for selected time periods. The mean discharge for each day and extremes of discharge for the year are computed. The data are then prepared for publication.

Selection of Gaging Site

The selection of gaging sites is dictated by the needs of water management or by the requirements of the hydrologic network. In fulfilling water-management needs there is little or no freedom of choice in selecting gaging sites, and frequently records must be obtained under very adverse hydraulic conditions. For example, many of the principal streams in the United States have been converted into a series of pools by the construction of dams; yet, very precise records are needed for operation. Records are also needed in tidal reaches of stream channels in connection with water supply, salinity contamination, or waste disposal.

Hydrologic network requirements allow more choice in selecting good sites for gaging, although in some places gaging conditions are poor throughout an entire region. For example, all streams in a given region may have unstable beds and banks, which result in continually changing stage-discharge relations. However, before a stream-gaging station is constructed, a general reconnaissance is made in order that the most suitable site for the gage may be selected. This reconnaissance is facilitated by an examination of geologic, topographic, and other maps of the area. Tentative sites for gaging stations may be indicated on the maps, each site being subject to critical examination of the physical characteristics of the stream channel. In selecting a site consideration should be given to the following items:

1. Channel characteristics relative to a fixed and permanent relation between stage and discharge at the gage. A rock riffle or falls, as shown in figure 1, indicates an ideal site. If a site on a stream with a movable bed must be accepted—for example, a sand-channel stream—it is best to locate the gage in as uniform a reach as possible, away from obstructions in the channel such as bridges.
2. Opportunity to install an artificial control.
3. Possibility of backwater from downstream tributaries or other sources. If a site

Figure 1.—Gage and natural control, Little Spokane River at Elk, Wash.

where backwater occurs must be accepted, a uniform reach for measurement of slope should be sought, in addition to the proper placement of an auxiliary gage. Unsteady flow such as occurs in tide-affected stream channels requires similar consideration but, in addition, line power must be available to insure simultaneous recording of stage at the two gages.
4. Availability of a nearby cross section where good discharge measurements can be made.
5. Proper placement of a stage gage with respect to the measuring section and to that part of the channel which controls the stage-discharge relation.
6. Suitability of existing structures for use in making high-flow discharge measurements, or the proper placement of a cableway for this purpose.
7. Possibility of flow bypassing the site in ground water or in flood channels.
8. Availability of line power or telephone lines where needed, for special instrumentation or for Telemark units.
9. Accessibility of the site by roads, particularly during flood periods.

The gage on Kaskaskia River at Bondville, Ill., shown in figure 2, satisfies several of the above requirements. Low-flow measurements are made by wading upstream from the artificial control, and high-flow measurements are made from the bridge. The bridge site provides accessibility, convenience to power lines, and a good location for an outside gage, shown on the downstream handrail.

Artificial Controls

Artificial controls are structures built in a stream channel to stabilize the stage-discharge relation and thereby simplify the procedure of obtaining accurate records of discharge. They may be low dams, broad-crested weirs conforming to the general shape and height of the streambed, or flumes similar in design to the Parshall flume. The adverse effects of unstable conditions due to shifting bed or banks, the formation of ice in winter, progressive growth of aquatic vegetation during the summer, and other phenomena which at times affect the stage-discharge relation at low stages may generally be eliminated or alleviated by the construction of an artificial control. The structure is seldom designed to function as a complete control throughout the entire range of stage. Generally it is impracticable to build it high enough to eliminate the effects of downstream conditions at high stages unless there is a steep fall below the gage. If the downstream slope is flat, so that with an increase in discharge the water below the control rises faster than the water above it, the control may be completely effective only for low and medium stages. Figure 3 shows the artficial control on Mill Creek near Coshocton, Ohio. A differently shaped artificial control is shown in figure 4, for the gage on the Delaware River near Red Bluff, N. Mex. Note the shallow V-notch in the broad-crested weir, to improve sensitiveness.

Although the artificial control is usually constructed in the form of a dam or a weir, it is seldom if ever desirable to attempt the use of a weir formula as its rating. The rating for each station should be determined by a current-meter or other method of measuring discharge. The conditions or facilities for the accurate measurement of small streams and for the measurement of the low-water flow of larger streams commonly can be improved by the use of artifical controls.

In the design of artificial controls the following four major points should be considered:
1. The shape of the structure should permit the the passage of water without creating undesirable disturbances in the channel above or below the control.
2. The structure must be of sufficient height to eliminate the effects of variable downstream conditions.
3. The profile of the crest of the control should be designed so that a small change in discharge at low stages will cause a measurable change in stage, and the relation of changes in stage to changes in discharge should produce a rating curve of a shape that may be extended to peak stages without serious error.
4. The control should have structural stability and should be permanent.

The artificial control should be self-cleaning and

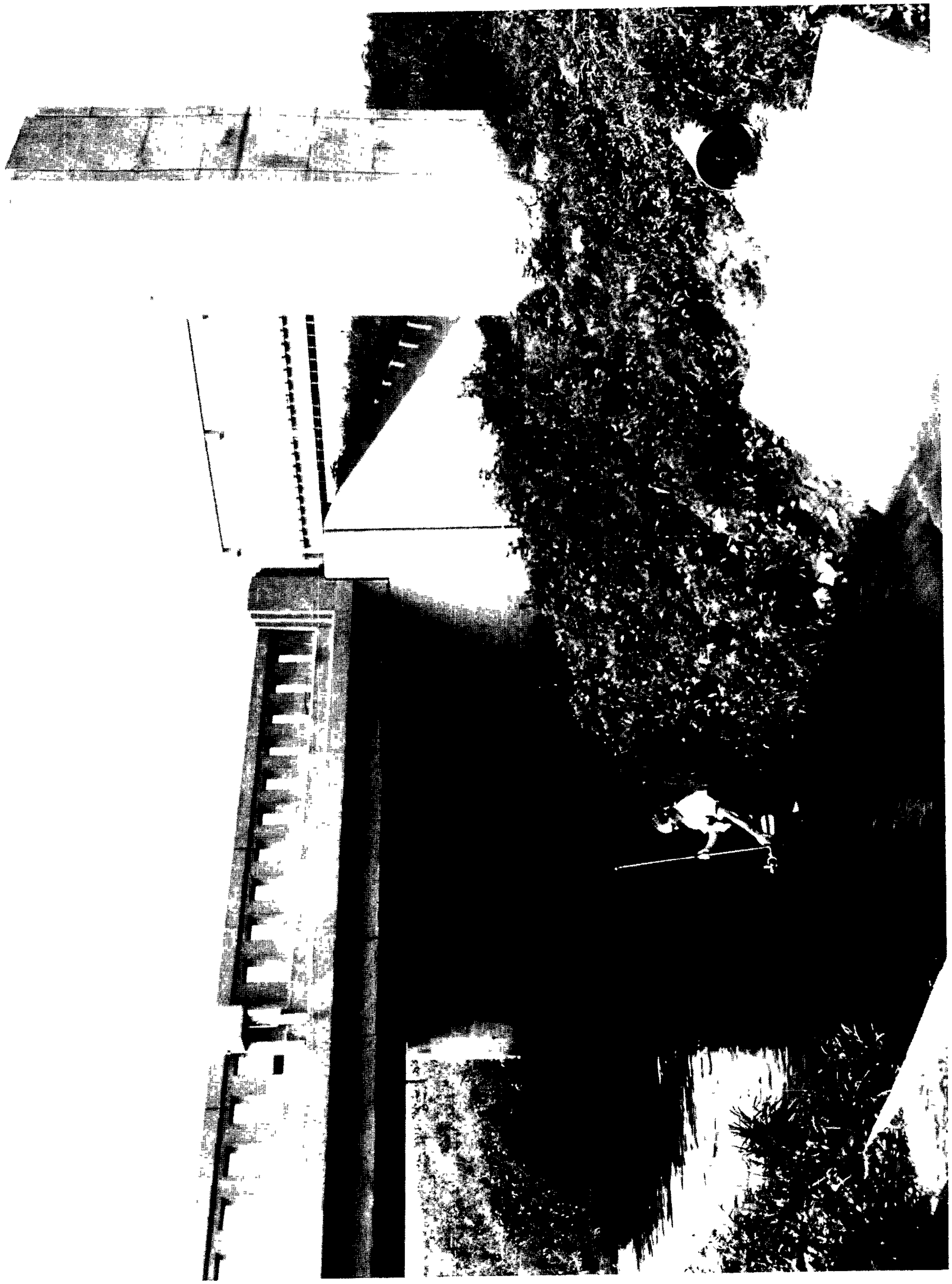

Figure 2.—Gage, concrete control, outside gage on bridge, and an engineer making a wading measurement, Kaskaskia River at Bondville, Ill

Figure 3.—Concrete artificial control on Mill Creek near Coshocton, Ohio.

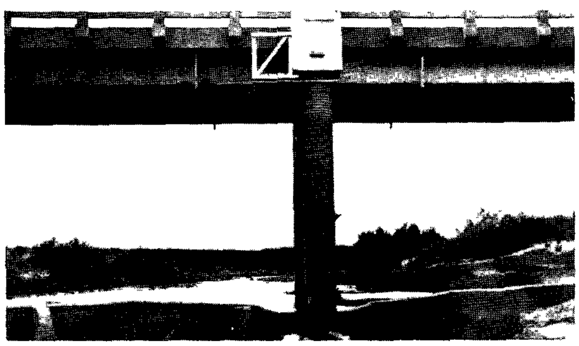

Figure 4.—Artificial control on Delaware River near Red Bluff, N. Mex., with shallow V-notch in the broad-crested weir.

should not be subject to obstruction by debris and ice or to deposits of sand, gravel, or silt in its immediate vicinity, either upstream or downstream.

Measurement of Stage

The stage of a stream is the height of the water surface above an established datum plane. Measurements of stream stage are used in determining records of stream discharge. In addition, records of stream stage are useful in themselves, such as in the design of structures affected by stream elevation or in the planning of the use of flood plains.

A record of stage can be obtained by systematic observations of a nonrecording gage. In the early days of the Geological Survey, this was the means generally used, but now the water-stage recorder is used at practically all gaging stations. The advantages of the nonrecording gage are the low initial cost and the ease of installation. The disadvantages are the need for an observer and the lack of accuracy of the estimated continuous stage graph sketched through the points of observation. For long-term operation the advantages of the recording gage far outweigh those of the nonrecording gage, and thus the use of the nonrecording gage is no longer considered a feasible method of obtaining a stage record.

Methods of sensing stage

Stage is usually sensed by a float in a stilling well that is connected to the stream by intake pipes. The stilling well protects the float and dampens the fluctuation in the stream caused by wind and turbulence. Stilling wells, though usually placed in the bank of the stream, are often placed directly in the stream as in figure 4, attached to a bridge pier or abutments. The bottom of the stilling well should be below the minimum anticipated stage and its top above the maximum anticipated stage. The intake to the well must be of proper size and location to prevent lag during periods of rapid change in stage and to prevent velocity-head effects at its end.

Stage may also be sensed by a gas-purge system known as a bubble gage. This system does not require a stilling well. A gas is fed through a tube and bubbled freely through an orifice that is permanently mounted in the stream. The gas pressure in the tube is equal to the piezometric head on the bubble orifice at any gage height. The pressure in the tube is measured by a zero-displacement mercury manometer with the associated electrical components to drive a stage recorder.

The bubble gage is used primarily at sites where it would be expensive to install a stilling well. It is also used on sand-channel streams because the gas tends to keep the orifice from being covered with sand and the tube may be easily extended to follow a stream channel that shifts its location. However, the float stilling-well installation is cheaper to install at most sites, and its performance is more reliable than is that of the bubble gage. The two systems have about the same accuracy—±0.01 foot. The choice of systems thus depends on the characteristics of the site.

Water-stage recorders

Both strip-chart and digital-tape water-level recorders are in general use. Either recorder may be actuated by the float or bubble-gage system. Figure 5 shows a bubble-gage digital-punch arrangement.

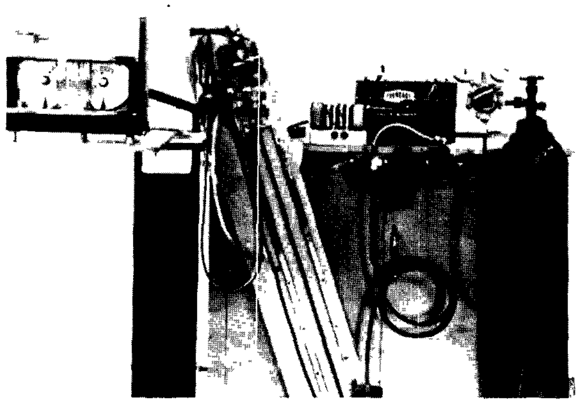

Figure 5.—Bubble-gage digital-recorder arrangement. Gas tank on right; digital-punch recorder on left.

A strip-chart recorder produces a graphic record of the rise and fall of the water surface with respect to time. A gage-height scale of 1:6 and a time scale of one day being equal to 2.4 inches are commonly used. Continuous recorders such as the Stevens A–35 will operate unattended for periods of 60–90 days and provide a very satisfactory record of stage.

A digital stage recorder punches coded values of stage on paper tape at preselected time intervals. A time interval of 15 minutes is normally used. The Fischer-Porter recorder is battery operated and will run unattended for periods of 60–90 days. The code consists of four groups of four punches each; the four punches represent 1, 2, 4, and 8 in each group. The punching of a stage requires only a 0.1-inch advance of paper tape. The recorder is actuated by a cam on a battery-driven mechanical clock.

Digital recorders are gradually replacing strip-chart recorders at gaging stations in the United States. The two recorders are about equal in accuracy, reliability, and cost, but the digital recorder is compatible with the use of electronic computers in computing discharge records. This automated system as developed by the Geological Survey offers greater economy and flexibility in the computation-publication process than do manual methods associated with graphical recording. However, the use of graphical recorders will be continued at those sites where a graphical record is necessary to detect ice effects, backwater, or frequent malfunctions of the recording system.

Reference gages

Because of the possibility of plugged intakes or other malfunctions, a nonrecording gage is installed so that the water level in the stream can be directly measured. Comparative readings on the inside and outside gages are taken during each visit to the station by engineering personnel. Datum of all gages is checked at periodic intervals—usually every 2 or 3 years. In figure 2, the outside gage is on the bridge. Outside staff gages are visible in figures 3 and 4 in the pools near the gage structures.

Discharge Measurements

Discharge measurements are made at each gaging station to define the discharge rating for the site. The discharge rating may consist of a simple relation between stage and discharge or a more complex relation in which discharge is a function of stage, slope, rate of change of stage, or other factors.

Discharge measurements are normally made by the current-meter method, which consists of determinations of velocity and area in the parts of a stream cross section. However, indirect methods are frequently used in determining flood peak discharges. These methods utilize hydraulic equations in conjunction with the information on channel characteristics and floodmarks obtained in a field survey after the flood event.

Discharge measurements may also be made by the dilution method. This method depends on determination of the degree of dilution of an added tracer solution by the flowing water.

Current-meter measurements

In the making of a discharge measurement the cross section is divided into 20–30 partial sections, and the area and mean velocity of each is determined separately. A partial section is a rectangle whose depth is equal to the sounded depth at a meter location (a vertical) and whose width is equal to the sum of half the distances to the adjacent verticals. At each vertical the following observations are made: (1) The distance to a reference point on the bank, (2) the depth of flow, and (3) the velocity as indicated by current meter at one or two points in the vertical. These points are at either the 0.2 and 0.8 depths (two-point method) or the 0.6 depth (one-point method) from the water surface. The average of the two velocities, or the single velocity at 0.6 depth, is taken to be the mean velocity in the vertical. The discharge in each partial section is computed as the product of mean velocity times depth at the vertical times the sum of half the distances to adjacent verticals. The sum of the discharges in all the partial sections is the total discharge of the stream.

The measurement can be made by wading the stream with a current meter which slides on a graduated depth rod as shown in figures 2 and 6, or it can be made from a supporting structure such as a bridge (see fig. 7), cableway, or boat, the meter being suspended by a cable.

The Price current meter is used to observe velocity, except in shallow depths where the pygmy current meter is used. The rotor on both these meters has a vertical axis and six cone-shaped cups. Each meter is individually calibrated in the rating flume at the National Bureau of Standards. Figure 8 shows a velocity-azimuth-depth assembly, which has been in use since 1958, primarily on large rivers and in estuarine studies.

These methods and the associated equipment have been developed by the Geological Survey over a period of 60 years. Satisfactory results have been obtained in measuring discharges ranging from the trickle of a small stream to the 7,500,000-cfs flow of the Amazon River. Methods and equipment used in making discharge measurements by the current-meter method are described in detail in book 3, chapter A8, of this series, by Buchanan and Somers.[1]

Indirect discharge measurements

During floods, it is frequently impossible or impractical to measure the peak discharges when they occur, because of conditions beyond control. Roads may be impassable; structures from which current- meter measurements might have been made may be nonexistent, not suitably located, or destroyed; knowledge of the flood rise may not be available sufficiently in advance to permit reaching the site near the time of the peak; the peak may be so sharp that a satisfactory current-meter measurement could not be made even with an engineer present at the time; the flow of debris or ice may be such as to prevent use of a current meter; or limitations of personnel might make it impossible to obtain direct measurements of high-stage discharge at numerous locations during a short flood period. Consequently, many peak discharges must be determined after the passage of the flood by indirect methods such as slope-area, contracted-opening, flow-over-dam, or flow-through-culvert, rather than by direct current-meter measurement.

To evaluate the accuracy of indirect methods, comparisons have been made at every opportunity. When it has been possible to compare peak discharge computed by indirect means with peak discharge measured by current meter or other direct means, the agreement, in general, has supported confidence in the auxiliary methods.

Indirect measurements make use of the energy equation for computing discharge. The specific equations differ for different types of flow, such as open-channel flow, flow over dams, and flow through culverts. These equations relate the discharge to the water-surface profiile and the geometry of the channel. A field survey is made after the flood to determine the location and elevation of high-water marks and the geometry of the channel.

[1] Buchanan, T. J., and Somers, W. P., Discharge measurements at gaging stations: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, chap. A8, unpub. data.

Figure 6.—Measuring discharge with current meter by wading.

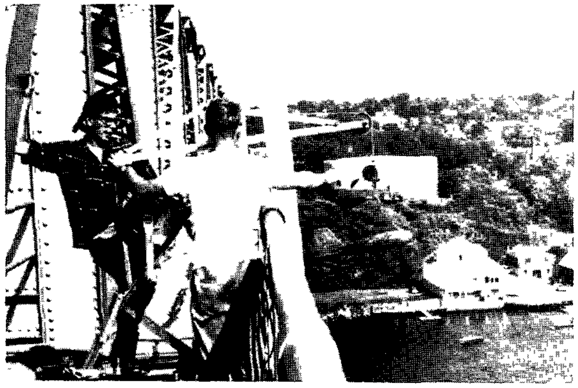

Figure 7.—Measuring discharge with current meter from bridge over the Hudson River at Poughkeepsie, N.Y

Detailed descriptions of the procedures used in collecting field data and in computing the discharge are given in Benson and Dalrymple (1967), Dalrymple and Benson (1967), Bodhaine (1968), Matthai (1967), and Hulsing (1967), which are book 3, chapters A1–A5, of this series. The use of electronic computers in these computations is explained by Anderson and Anderson [2] and by Somers and Selner.[3]

Dilution method

Measurement of discharge by this method depends on determination of the degree of dilution of an added tracer solution by the flowing water. A solution of a stable or radioactive chemical is injected into the stream as either a constant rate or all at once. The solution becomes diluted by the discharge of the stream. Measurement of the rate of injection, the concentration of the tracer in the injected solution, and the concentration of the tracer at a cross

[2] Anderson, D. B., and Anderson, W. L., Computation of water-surface profiles in open channels; U.S. Geol. Survey Techniques Water-Resources Inv., unpub. data.

[3] Somers, W. P., and Selner, G. I., Computation of stage-discharge relationships at culverts and Computer technique for slope-area measurements: U.S. Geol. Survey Techniques Water-Resources Inv., unpub. data.

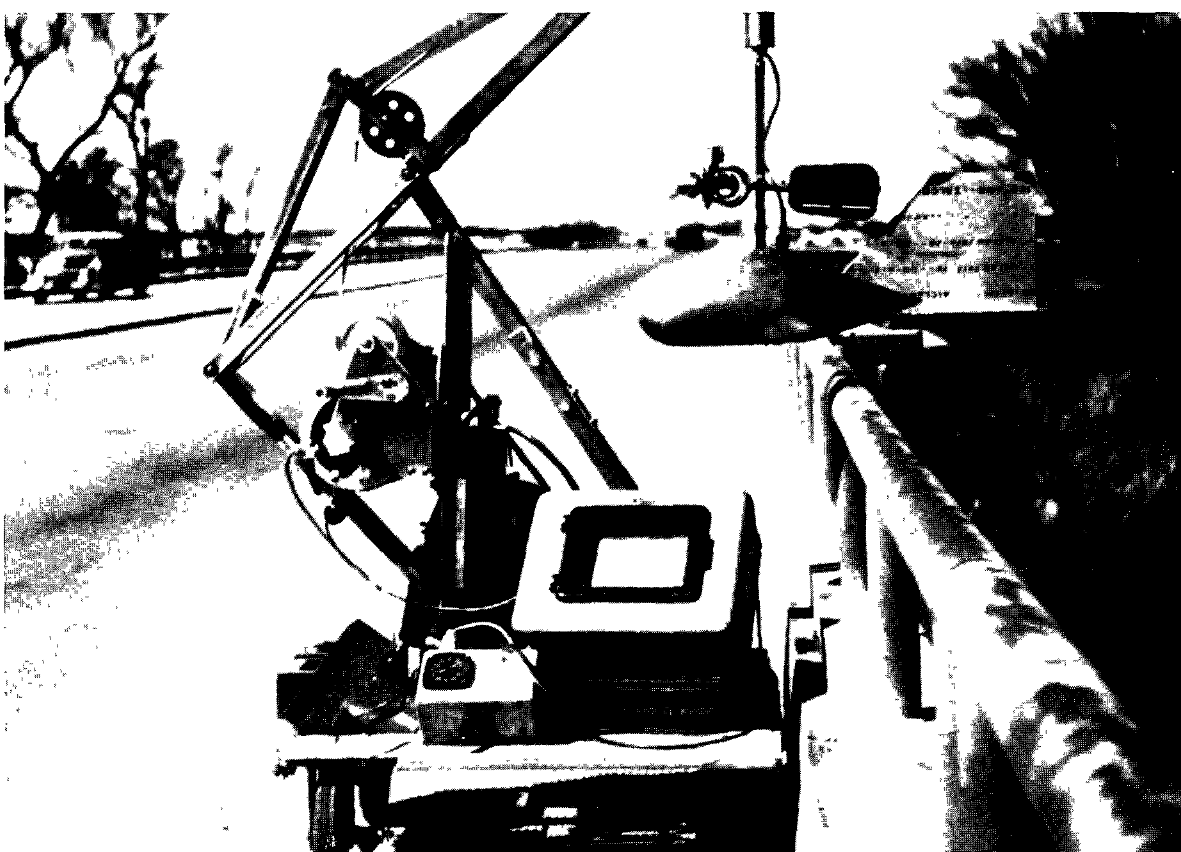

Figure 8.—VADA (velocity-azimuth-depth-assembly) equipment in use for measurement from bridge.

section downstream from the injection point permits the computation of stream discharge. The accuracy of the method critically depends upon complete mixing of the injected solution through the stream cross section before the sampling station is reached and upon no adsorption of the tracer on stream-bottom materials. The method is recommended only for those sites where conventional methods cannot be employed owing to shallow depths, extremely high velocities, or excessive turbulence. A detailed description of the procedures and equipment used in measuring discharge by a dye-dilution method is given by Cobb and Bailey.[4] Figure 9 shows the pressurized constant-rate tanks used to inject fluorescent dye solutions into the streams, and figure 10 shows collected sample bottles ready for field testing with a fluorometer on the tailgate of a vehicle.

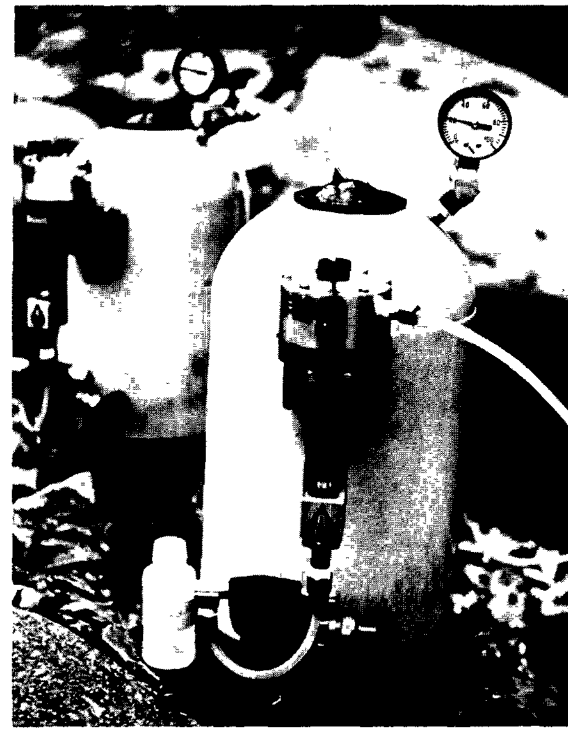

Figure 9.—Pressurized constant-rate injection tanks for injection of dye into streams.

Discharge Ratings

The computation of continuous records of discharge at gaging stations depends on definition of the discharge rating for the channel. Discharge ratings may be simple or complex. The rating may consist of a simple relation between stage and discharge or of several relation curves which define discharge as a function of stage, slope, rate of change of stage, or other variables. The expression "discharge rating" is an all-inclusive term to describe the one or more relations used to determine the discharge from measured parameters of flow.

Stage-discharge relations

Discharge ratings at a large majority of gaging stations consist of relations between stage and discharge. These stage-discharge relations are rarely permanent, particularly at low flow, because of changes in the stream channel such as scour and fill, aquatic growth, ice, or debris or because of changes in bed roughness. Frequent discharge measurements are necessary to define the stage-discharge relation at any time.

The relation of stage to discharge is generally controlled by a section or reach of channel below the gage, known as the station control. Section controls may be either natural or constructed, and may consist of a ledge of rock across the channel, a boulder-covered riffle, an overflow dam or any other physical feature capable of maintaining a fairly stable relation between stage and discharge. Section controls are commonly effective only at low discharges, and are completely submerged by channel control at medium and high discharges. Channel control consists of all the physical features of the channel which determine the stage of the river at a given point for a certain rate of flow. These features include the size, slope, roughness, alinement, constrictions and expansions, and shape of the channel. The reach of channel which acts as the control may lengthen as the discharge increases; such changes introduce new features which affect the stage-discharge relation.

Knowledge of the channel features which

[4] Cobb, E. D., and Bailey, J. F., Measurement of discharge by dye-dilution methods: U.S. Geol. Survey Techniques Water-Resources Inv., unpub. data.

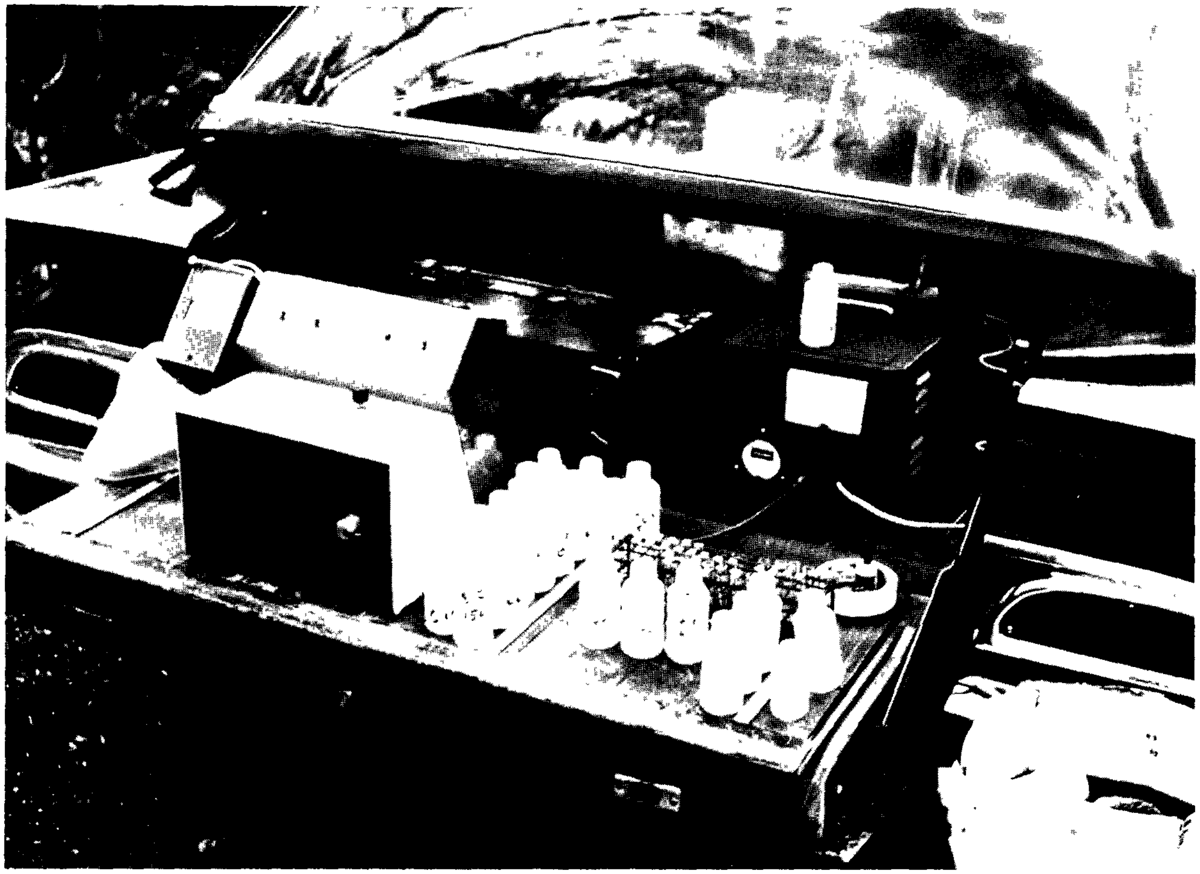

Figure 10.—Equipment for fluorometer testing of water samples in the field.

control the stage-discharge relation is important. The development of stage-discharge curves where more than one control is effective and the number of measurements is limited generally requires judgment in interpolating between measurements and in extrapolating beyond the highest measurements. This judgment is particularly necessary where the controls are not permanent and various discharge measurements represent different positions of the stage-discharge curve.

Stage-discharge relations are developed from a graphical analysis of the data plotted on either rectangular-coordinate or logarithmic plotting paper. A good analysis of the data requires a knowledge of the characteristics of the channel and a knowledge of open-channel hydraulics. The discharge measurements available for the analysis rarely define a unique stage-discharge relation because of changes in the channel during the period represented by the measurements. The determination of the proper shape of the rating curve and its position at various times requires considerable engineering knowledge, experience, and judgment. In general, a base stage-discharge relation is used, and deviations from this relation with time (shifts) are determined by consideration of the plotting of individual discharge measurements. These shifts, in the form of a stage adjustment, are then used with the base rating in computing the discharge record.

The stability of the stage-discharge relation governs the number of discharge measurements that are necessary to define the relation at any time. If the channel is stable, one measurement a month is generally sufficient; in sand-channel streams, three measurements a week may be required because of the random shifting of the stream channel.

Complex discharge ratings

If variable backwater or highly unsteady flow exists at a gaging station, the discharge rating cannot be described by stage alone.

Variable backwater may be caused by a tributary stream that enters the control reach downstream from the gage, by manipulation of gates at a dam, or by flow of water into and from overbank storage created by natural constrictions in the stream channel. The discharge under these conditions is a function of both stage and the slope of the energy gradient, which is approximated by the slope of the water surface between two stage gages. Stage-fall-discharge ratings are usually determined empirically from observations of (1) discharge, (2) stage at the base gage, and (3) the fall of the water surface between the base gage and an auxiliary stage gage downstream. The general procedures used in developing these ratings are described in book 3, chapter A9, of this series, by Carter and Davidian.[5]

If the flow is very unsteady, as in a tidal reach, the acceleration head governs the energy slope. Under this condition unsteady-flow equations must be used to describe the variation of discharge with time. This method is described by Davidian.[6]

A special type of unsteady flow is treated under the heading "Uniformly progressive flow" in Carter and Davidian.[5] For such flow the stage and rate of change of stage observed at a single gage are used to establish the discharge rating.

Computation and Preparation of Discharge Records

A continuous record of flow at a gaging station is computed from records of stage and the discharge rating for the station. The type of stage recorder used at the station determines whether the computations are done manually or by an electronic computer. In either system the engineer must study the data and prepare what is termed a station analysis before computations are performed.

Station analysis

A station analysis, which documents the result of the study of the data, is prepared for each station at the end of each water year. The study includes the following items:

1. A review of field surveys of gage datum and a determination of the datum corrections, if any, to be applied to gage readings taken during the year.
2. A review of discharge-measurement notes.
3. An analysis of the discharge rating and the determination of the rating (or shifts) applicable during each period of the year.
4. The preparation of tables which express the discharge rating.

Manual computations

If stage is recorded at the station on a strip-chart recorder, all computations are performed manually in the following order:

1. Determination and application of gage-height and time corrections to the gage-height chart.
2. Computation of the mean gage height for each day, or for shorter periods if the range in discharge during the day is large. Subdivision is necessary because of curvature in the discharge rating.
3. Computation of discharge for each period from mean values of stage and the discharge rating, including any shift corrections.
4. Computation of peak values of gage height and discharge.
5. Listing of the values of mean daily gage heights and discharge and momentary peaks.
6. Computation of mean flow for each month and the year in cubic feet per second and in inches.
7. Review and comparison of the record of discharge with that of nearby streams.

[5] Carter, R. W., and Davidian, Jacob, Discharge ratings at gaging stations: U.S. Geol. Survey Techniques Water-Resources Inv., book 3, chap. A9, unpub. data.

[6] Davidian, Jacob, Computation of discharge in tidal reaches: U.S. Geol. Survey Techniques Water-Resources Inv., unpub. data.

Automatic computations

If stage is recorded on a digital tape at the station, the computations just outlined are performed by an electronic computer. The input to the computer is the digital record of stage, with a list of any datum corrections, and the discharge rating, with a list of any necessary shift corrections. For stations at which the stage-fall-discharge type of rating is applicable, the digital-tape records of stage from both the primary and the auxiliary gages are furnished to the computer. In addition to the stage-discharge relation, supplementary information such as the stage-fall relation and the relation of fall ratio versus discharge ratio are supplied.

The output from the computer consists of two forms. The first includes a listing of the maximum, the minimum, and the mean gage height for each day, bihourly gage heights for each day, and the mean discharge for each day. The second form includes a listing of mean daily discharges and the monthly and yearly summaries in the same format as is used for publication. Besides being published, the daily discharges and yearly summaries are stored on magnetic tape. Corrections are made on the tape where necessary after the computed records are reviewed by engineering personnel in the district offices.

Publication of Records

Through September 30, 1960, the records of discharge of streams and contents of lakes or reservoirs were published in an annual series of Geological Survey water-supply papers entitled "Surface Water Supply of the United States." Each volume in the series covered an area whose boundaries coincided with those of certain natural drainage basins.

Beginning with the 1961 water year, streamflow records and related data have been released by the Geological Survey in annual reports on a State-boundary basis. These reports are prepared and released by the district offices soon after the close of the water year.

Daily discharges and annual summaries are also being published in water-supply papers at intervals of 5 years. The first series to be published covers the period 1961–65.

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