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

Chapter A13

COMPUTATION OF CONTINUOUS RECORDS OF STREAMFLOW

By E. J. Kennedy

Book 3

APPLICATIONS OF HYDRAULICS

method to check the sign of the shifts is to add the shift adjustment algebraically to the gage height of the measurement and enter the rating table at the adjusted gage height; if the rating discharge at that point equals the measured discharge, the shift has been computed correctly.

If the percent differences are reasonably well balanced (about as many plus as minus) and the shift adjustments are satisfactory, the rating may be considered final and ready for use in computing the record. The hydrographers responsible for analyzing and checking the rating should initial the table in the space provided. Compare the high-water part of the new rating to the prior rating to check the need for revising past records.

Master curve sheets

A master curve sheet, usually hand drawn and neatly lettered in ink on a standard form, is used for the permanent record and to make copies for field and office use. A variety of standard forms is available, large and small, logarithmic or rectangular, and combination log-rectangular. Some forms are reverse printed for ease of erasing and for superior diazo copies. Others are front printed for the best electrostatic reproduction. Figure 13 illustrates one type of master curve sheet, prepared from the figure 11 worksheet and plotted on a combination sheet (standard form 9–279–S or P). Note that the use of a 1.0-ft gage-height scale offset instead of the 1.2-ft offset used in the descriptor makes the plotting simpler. However, this change makes the curve segments between the descriptor coordinate points bend slightly. The curvature is not apparent in the parts of the rating above 10 ft^3/s in figure 13 but would cause scalloping at lower flows if the 1.0-ft scale offset were used on the worksheet.

Select an appropriate standard form for the master sheet, no larger than necessary to illustrate the rating. Logarithmic sheets are best for narrow-range ratings, and combination log-rectangular sheets are usually preferable for ratings that extend down to zero flow. With a combination sheet, a log scale different from the one on the worksheet can be used for best placement of the main curve on the sheet and for scale simplicity. Some hydrographers prefer to use the normal log scales for all curves which, if used, should be prominently titled "Gage height, in feet—(offset) feet."

Choose the scales for the rectangular portion of a combination sheet to provide some overlap with the log curve and to insure that each principal grid division is a multiple of 1, 2, or 5 and not 2.5 or 4. A scale that permits GZF to be plotted is desirable.

Plot all measurements made during the water year, others that were used to define the rating, and all high-water measurements ever made at the site. Such drafting details as circle size, flag angle and length, and marginal information are matters of district or personal preference. Each measurement may be plotted only once when a log-rectangular combination sheet is used, using the log plot for measurements that fit and the rectangular plot for the rest. Additional measurement plotting on the rectangular part of the sheet is optional.

The part of the highest rating ever used for a published record at the station, that extends above the current rating, should be plotted as a dashed line to indicate the relation of the current curve to previous ratings. If a special high-water rating was prepared for flood-forecasting use by another agency, plot its curve with a distinctive line to indicate any need for updating as additional high-water measurements become available.

Identify each curve with its table number, and list the tables and their dates of use for final records (not primary computations). Tabulate the information concerning years, measurement numbers, and extremes in the spaces provided so that the criteria for omitting measurements from the plot is clear.

Manual Computation of Gage-Height Record

The computation of the gage-height record from a digital recorder is incidental to the automatic discharge record computation by an ADP program, and its discussion is included under "Computation of Discharge Record." Gage-height record computation is a separate step in

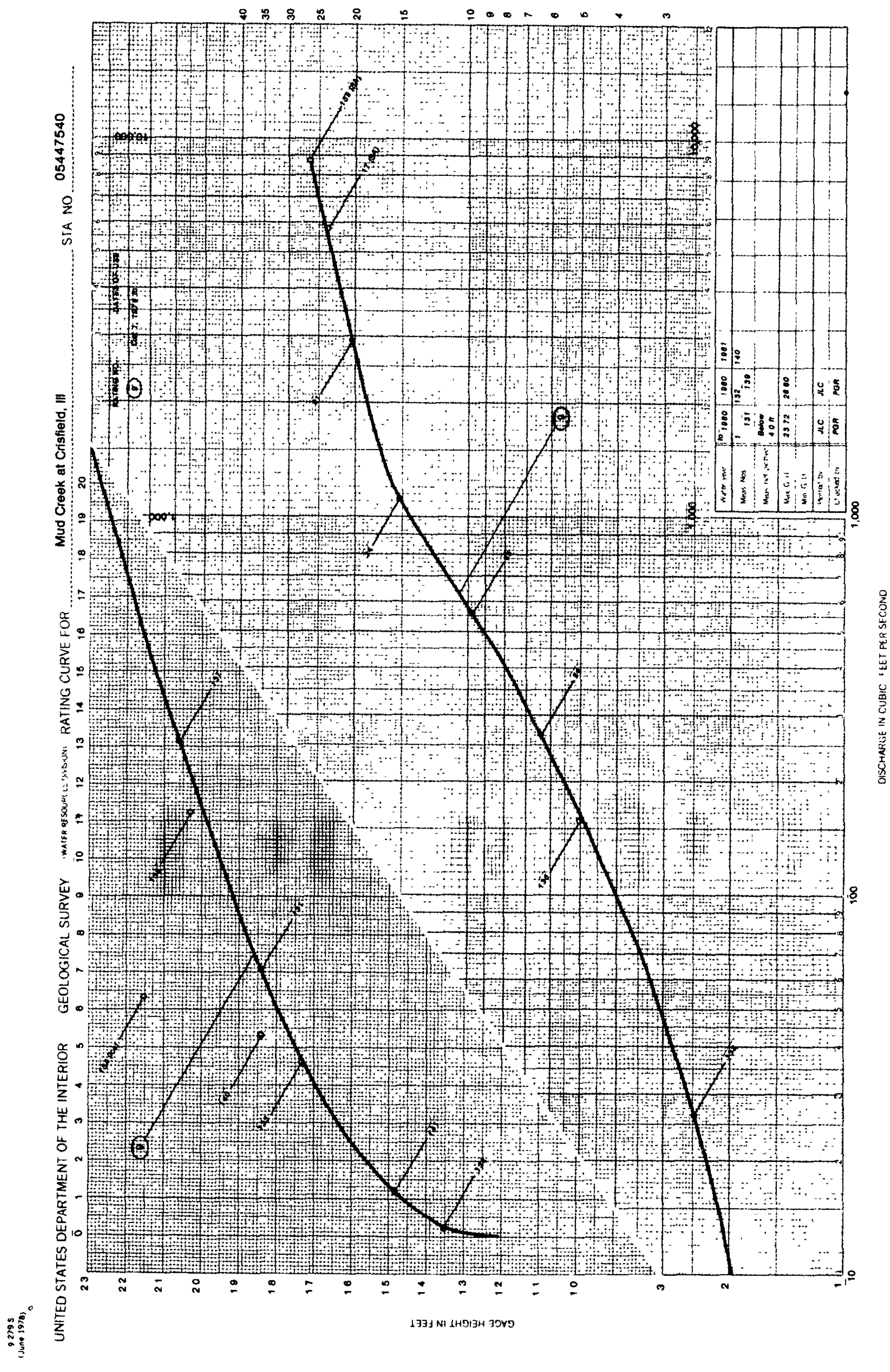


FIGURE 13.—Master curve sheet.

the manual processing of graphic-recorder and nonrecording gages and is described in this section.

Graphic recorders

The strip charts (fig. 6) are removed periodically from the graphic recorder and brought to the office for processing. Examine them for abnormalities. Compare the end of each chart segment with the start of the next segment for agreement with each other and with the discharge measurement notes. Sudden rises or falls, unless caused by local rain, should not ocucur except on a regulated stream. Sudden vertical jumps may denote clock stoppage, bubble-gage orifice movement or blockage, or unplugging of the intakes. Horizontal traces show possible intake blockage, dead batteries, electrical problems, or a bubble-gage orifice out of water. Vertical jumps or horizontal traces may also indicate faulty recorder action. If any suspicious periods are apparent, check the field notes to see if field personnel have noted an abnormal condition. Sometimes it is necessary to compare the chart with one from a nearby station to judge the reasonability of an odd-looking trace.

All notes and computations on the recorder chart must be neat, legible, aligned, and thoughtfully placed in soft black pencil to facilitate their interpretation and checking. No writing should obscure the pen trace or the reversal checks.

Dating recorder charts

Date the recorder charts by numbering each day prominently below the lower baseline of the chart on the noon line. Show the month and year on the first and last day of each month and on about every fifth day in between. Be sure the dates and gage heights on the discharge measurements agree with those on the recorder record.

Pen corrections for time

Determine and apply time corrections where necessary. Make a note on the chart at each inspection stating whether the pen-reading was correct or how slow or fast it was at that point. Inspect the record carefully where time corrections are large or erratic to be sure the clock has not stopped and restarted. Apply the time corrections to the nearest hour. Prorate corrections on a straight-line basis between gage inspections. A graphic method of distributing corrections is shown in figure 14. Simple mental arithmetic is the most rapid method for distributing small adjustments. Draw a short, heavy vertical line on the chart to indicate each adjusted midnight line, making sure to apply the corrections in the correct direction—ahead of the printed line if the pen is fast and behind it if the pen is slow. If there has been practically no range of stage during the period, small time corrections may be ignored as they would have no effect upon the figures of mean daily gage height computed from the graph.

Pen corrections for gage height

Determine the gage-height corrections to the recorder trace next. These are derived from any differences between readings of the recorder pen and the principal gage at inspections after any datum or gage height corrections to the principal gage have been applied. The corrections will usually be distributed according to time in essentially the same manner as time corrections and will be applied to figures of gage height obtained from the graph, whether instantaneous readings or mean figures for part or all of a day. An error in setting the pen at the start of a strip of chart will ordinarily be constant throughout the length of the strip; however, the total error may be increased or decreased by other factors.

It is sometimes necessary to correct recorder charts for reversal errors; that is, when the pen reverses either past the margin line or short of it. Reversal errors are caused by several things, such as expansion or contracton of the chart paper, lateral travel of the chart, incorrect setting of the pen, or mechanical error due to wear or maladjustment of the recorder. Most of these causes can be minimized by careful maintenance and servicing of the recorder, but paper expansion is a special problem related to humidity in the gage shelter. The strip-chart gradua-

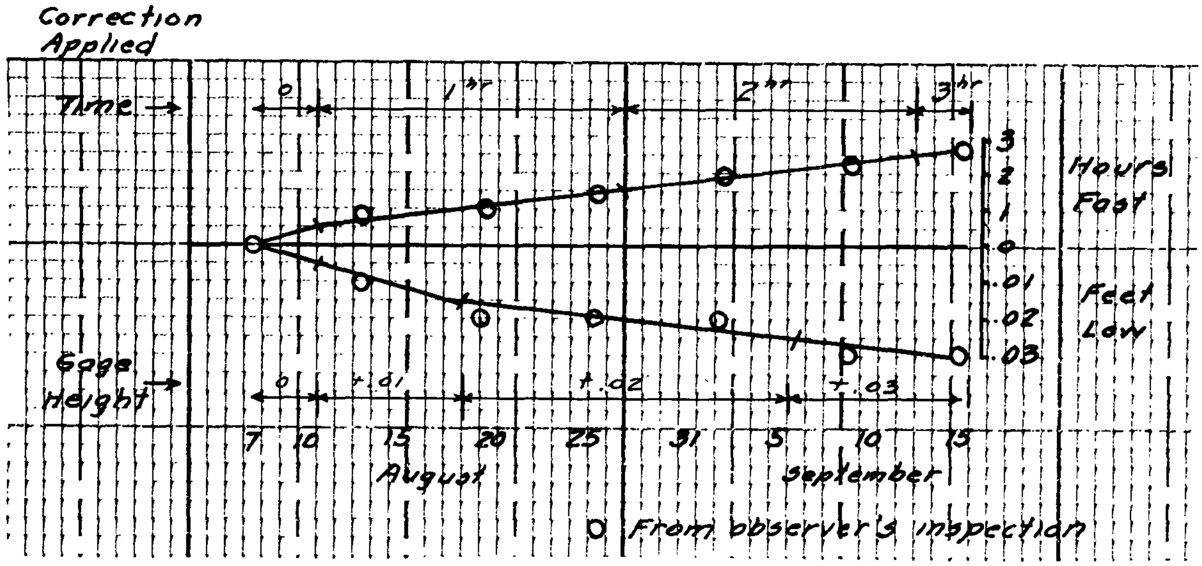


FIGURE 14.—Interpolation of pen corrections from graph plotted on recorder chart.

tions are 10 in wide when printed, 9.95 in wide in an extremely dry environment, and 10.4 in wide when the paper is completely saturated. The recorder is calibrated for a 10.00-in grid and with a perforated tape or beaded cable and splined-float wheel reverses at stages exactly 5 ft apart (10 ft apart for 1:12 ratio recorders). Reversal corrections less than 0.03 ft are normally disregarded. Larger corrections are applied to the pen readings at reversals and are prorated with stage for application to intermediate pen readings. Reversal errors are usually combined with other errors and without additional information are extremely difficult to correct. A step-reversal check, made in the field when a new strip of chart is started and again when it is removed, leaves steps whose true gage heights are known on the chart's ends. This information makes it possible to apply reversal corrections rapidly and accurately. Figure 15 illustrates a completed recorder chart affected seriously by reversal error and slightly by lateral paper travel. The step-reversal check lines at both ends of the chart strip were used to define the stage-graduated gage-height corrections applied to the recorder pen trace.

Computing mean daily gage heights

After the recorder chart has been dated and corrected, the mean daily gage heights and any other gage-height data required may be computed. Most mean daily gage heights are determined graphically by using a thin, rectangular guide made of transparent plastic about 2 by 8 in in size, through the middle of one side of which has been scribed a visible straight line parallel to the long edge. A pencil-point size hole at the center of the line is an added convenience. The plastic guide is placed over a 24-h segment of the recorder chart and moved into a position with the straight line approximately over the pen trace, so that all areas lying above the straight line and below the graph are equal to all areas lying below the straight line and above the graph. When the areas are thus balanced, the point at which the straight line intersects the noon line represents the uncorrected mean daily gage height. An example of this graphical method of determining mean daily gage height is shown for April 8, 1981, in figure 15.

List the figure of mean daily gage height thus determined on the noon line for that day, between 1 and 2 in above the base line. If a pen correction for gage height is applicable, enter it just below the uncorrected gage height, add or subtract the correction, and write the corrected gage height immediately below.

It is imperative that the recorder chart be adjusted with reference to the principal gage, the gage used for determining mean gage heights for the discharge measurements. Otherwise, it

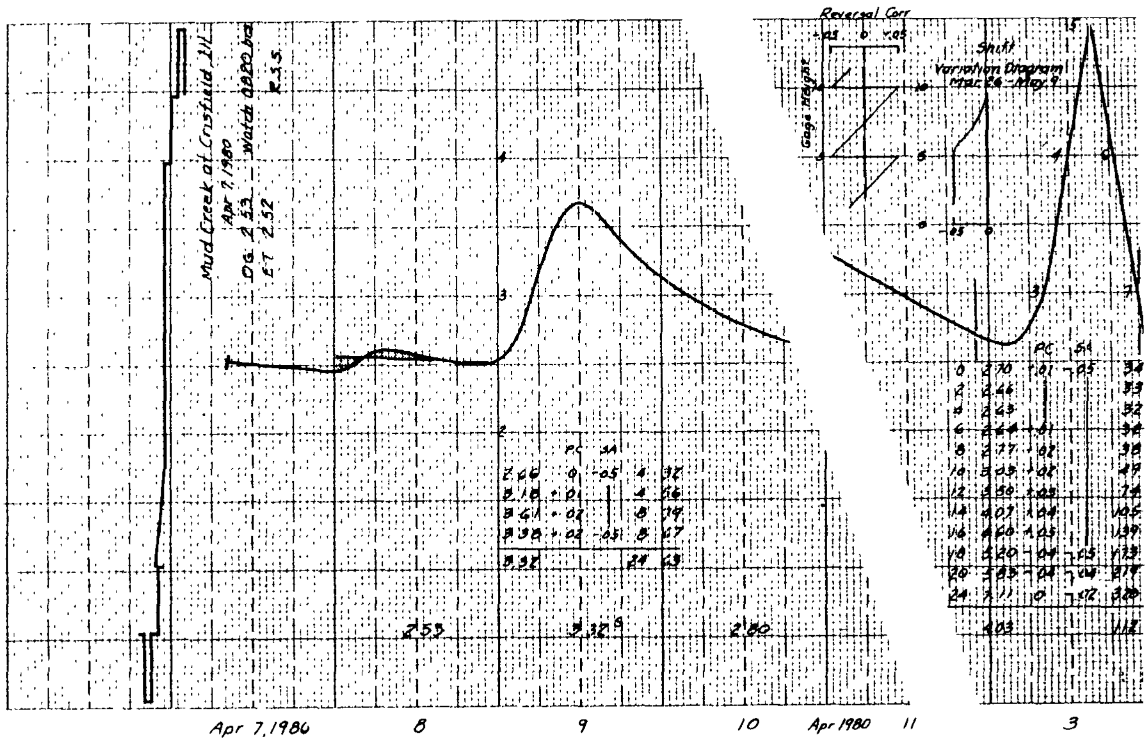


FIGURE 15.—Gage-height and discharge computations on graphic-recorder chart.

would be possible for large errors to enter into the computation of discharge. The inside float-type gage that drives the recorder is normally used as the principal gage for all graphic-recorder gage-height computations.

Allowable range in stage

The relation of discharge to gage height is nonlinear. The discharge corresponding to the mean gage height for a day of widely ranging stage is more or less than the actual discharge. If the rating curve is concave downward on rectangular paper, the mean gage height applied to it will be too low. The reverse is true for any concave upward parts of rectangularly plotted ratings.

The usual practice is to subdivide the daily gage-height graph wherever the error in the mean daily discharge produced by not subdividing would exceed 4 percent. An allowable range-in-stage table is used to determine the need for subdivision. One method of computing an allowable range-in-stage table from a rating table is first to select a gage height near the lower end of the rating table and observe the corresponding discharge. Then, by trial and error, determine the distance, in feet, equally in each direction that it is possible to move without the average of the two corresponding discharges differing by more than 4 percent from the discharge at the selected gage height. The difference between the latter two gage heights represents the allowable range of stage before subdivision is necessary. Repeat the process for as many stages as are necessary to develop a suitable table. This method was used to compute the allowable-range table in figure 17 from the rating table in figure 16.

Where shift adjustments are used, the adjusted gage heights are applied to the range table. A range table prepared from one rating can be used with a different rating as long as both have generally similar shapes and the discharges being computed are not extremely low.

Subdivided days

When a day is subdivided, it becomes necessary to determine mean gage heights for periods

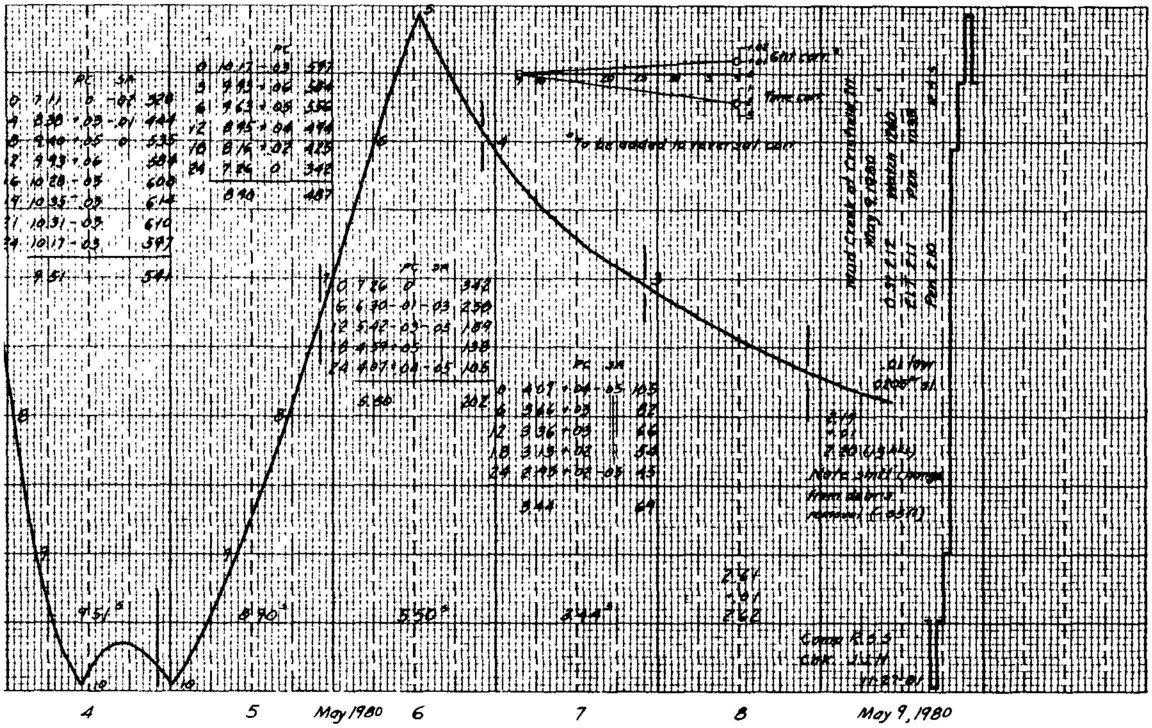


FIGURE 15.—Gage-height and discharge computations on graphic-recorder chart—Continued.

of less than 24 hours, and to combine the several figures of gage height and corresponding discharge arithmetically to obtain mean daily values. Two methods, both described in this section, are used: mean interval subdivision and midinterval or flood subdivision. Where sediment or chemical-quality computations are included, the variations in those constituents must be considered, in addition to rating curvature, for the selection of subdivision intervals.

In selecting intervals to use when subdividing gage-height graphs, a good method is to start at the lowest point on the graph and move upward as far as the allowable-rise table will permit. The length of the period can usually be rounded upward to the nearest hour lines. The periods should be in multiples of 2, 3, or 4-hours insofar as possible to simplify the arithmetic.

Computation of daily mean gage heights for subdivided days is optional but does provide a convenient means of checking discharge computations for gross errors and adequate subdivision.

Mean interval subdivision

When the mean gage height for an interval is determined graphically by averaging areas, the subdivision is known as the mean interval method. The mean gage heights for parts of days adjusted for corrections and shifts are applied to the rating table and the daily mean discharge is computed from the time-weighted values of those discharges. The method is illustrated for April 9, 1981, on the sample gage-height chart (fig. 15). Mean discharges computed by this method, using a range table to select the interval, are usually about 2-4 percent less than the true discharge unless the rating curve on rectangular paper bends upward within the stage range and causes the computed discharge to be greater than the true discharge.

With experience, the need for subdivision can sometimes be judged without a range table by considering the shape of the rating curve and the character of the recorder chart. Many rating curves have considerable curvature at the lower

UNITED STATES DEPARTMENT OF THE INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION

EXPANDED RATING TABLE   DATE PRINTED 09-01-81

05447540   TYPE LOG (SCALE OFFSET = 1.20)   RATING NO. 9

BASED ON ______ DISCHARGE MEASUREMENTS, NO. ________, AND _____, AND IS _____ WELL DEFINED BETWEEN _____ AND ______
FROM ________ TO ________, FROM ________ TO ________   *COMP BY ______ DATE ______
*CKD. BY ______ DATE ______

GAGE HEIGHT IN FEET	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09	DIFF IN Q PER TENTH GH
	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)										
1.20				.009	.017	.027	.041	.057	.076	.099	
1.30	.124	.153	.184	.220	.258	.300	.345	.394	.446	.502	.437
1.40	.561	.624	.691	.761	.835	.913	.994	1.08	1.17	1.26	.79
1.50	1.36	1.46	1.56	1.67	1.78	1.90	2.02	2.14	2.27	2.40	1.18
1.60	2.54	2.68	2.83	2.97	3.13	3.28	3.44	3.61	3.78	3.95	1.59
1.70	4.13	4.31	4.50	4.69	4.88	5.08	5.29	5.50	5.71	5.92	2.01
1.80	6.14	6.37	6.60	6.83	7.07	7.32	7.56	7.81	8.07	8.33	2.46
1.90	8.60	8.87	9.14	9.42	9.70	9.99	10.3	10.6	10.9	11.2	2.9

GAGE HEIGHT IN FEET	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9	DIFF IN Q PER FOOT GH
	DISCHARGE IN CUBIC FEET PER SECOND (EXPANDED PRECISION)										
2.00	11.5	14.4	17.6	20.9	24.4	28.0	31.9	36.0	40.2	44.6	37.7
3.00	49.2	53.9	58.9	64.0	69.3	74.6	79.8	85.1	90.5	96.1	52.6
4.00	101.8	107.6	113.6	119.7	125.8	132.1	138.5	145.0	151.6	158.3	63.3
5.00	165.1	171.9	178.9	185.9	193.0	200.3	207.6	215.0	222.5	230.1	72.7
6.00	237.8	245.6	253.5	261.5	269.6	277.6	285.8	294.3	302.6	311.1	81.9
7.00	319.6	328.4	337.1	346.0	354.9	363.9	372.9	382.1	391.3	400.6	90.3
8.00	410.0	418.3	426.7	435.1	443.5	452.0	460.6	469.2	477.8	486.5	85.2
9.00	495.2	503.9	512.7	521.6	530.5	539.4	548.3	557.3	566.4	575.5	89.4
10.00	584.6	593.7	602.9	612.2	621.4	630.8	640.1	649.5	658.9	668.4	93.3
11.00	677.9	687.4	697.0	706.6	716.2	725.9	735.6	745.4	755.2	765.0	96.9
12.00	774.8	784.7	794.7	804.6	814.6	824.6	834.7	844.8	854.9	865.1	100.4
13.00	875.2	885.5	895.7	906.0	916.3	926.7	937.1	947.5	957.9	968.4	103.7
14.00	978.9	989.4	1000	1012	1024	1036	1049	1061	1073	1086	119
15.00	1098	1111	1123	1136	1149	1161	1174	1187	1200	1221	144
16.00	1242	1263	1284	1306	1328	1350	1377	1405	1433	1462	248
17.00	1490	1520	1549	1579	1609	1640	1671	1703	1735	1767	310
18.00	1800	1841	1883	1926	1970	2014	2059	2104	2151	2198	446
19.00	2246	2295	2344	2394	2445	2497	2550	2603	2658	2713	523
20.00	2769	2825	2883	2942	3001	3061	3122	3185	3248	3311	607
21.00	3376	3442	3509	3576	3645	3714	3785	3856	3929	4002	701
22.00	4077	4153	4229	4307	4385	4465	4546	4628	4711	4795	803
23.00	4880	4966	5053	5142	5232	5322	5414	5507	5602	5697	914
24.00	5794	5892	5991	6091	6193	6296	6400	6505	6612	6719	1035
25.00	6829	6939	7051	7164	7279	7394	7512	7630	7750	7871	1165
26.00	7994	8118	8244	8370	8499	8629	8760				

FIGURE 16.—Rating table corresponding to figure 17 allowable-range table.

end; when sharp rises occur at times of low flow, even though the range in stage may not be large, the subdivided discharge may be several times the discharge obtained from the daily mean gage height. If a range table is not used, the daily mean gage heights should be computed to compare the subdivided and unsubdivided discharge to monitor the hydrographer's judgment.

Subdivision is merely manual integration. Mechanical integrators and electronic digitizers have been developed to compute the discharge for stations having large and frequent fluctuations in stage such as for those stations below power plants. However, digital recorders are usually more practical than graphic recorders for stations that require unusually frequent subdivision.

Midinterval subdivision

An alternate way to subdivide a day is to list the time and gage height at the start and end of the day and at enough intermediate times to define the variations in stage adequately. The gage-height change between intervals should be within the allowable-range table limits. The method is called "midinterval subdivision" because of the way daily values are computed. The listed value for each time is considered constant during the period starting halfway between the listed and previous listed times and ending halfway between the listed and subsequent listed times. This is the same concept used to compute discharge measurement subsection widths. Midinterval subdivision computations are laborious, especially with unequal

BASIC RELATIONS

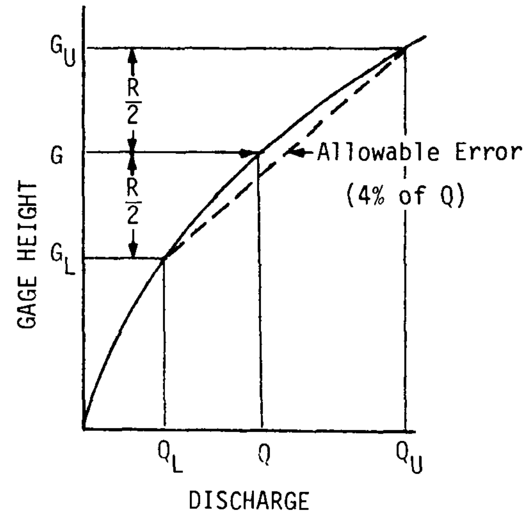
Symbols

G = Selected gage height
G_L = Gage height at lower limit of allowable range
G_U = Gage height at upper limit of allowable range
Q = Discharge at selected gage height
Q_L = Discharge at lower limit of allowable range
Q_U = Discharge at upper limit of allowable range
R = Allowable range

From graph at right

$$\frac{Q_L + Q_U}{2} = Q + 0.04Q = 1.04Q$$

$$Q_L + Q_U = 2.08Q$$



COMPUTATIONS

Selected Gage Height G	Q (from rating)	2.08Q	Widest Range with $Q_L + Q_U$ < 2.08Q					Allowable Rise $G_U - G_L$ (Feet)
			G_L	Q_L	G_U	Q_U	$Q_L + Q_U$	
1.3	0.12	0.25	1.29	0.10	1.31	0.13	0.23	0.02
1.5	1.35	2.81	1.45	.91	1.55	1.90	2.81	.1
2.0	11.5	23.9	1.8	6.1	2.2	17.7	23.8	.4
3.0	49.2	102	2.5	28.0	3.5	74.6	102.6	1.0
5.0	165	343	3.8	90.5	6.2	254	344	2.4
9.0	495	1030	6.0	238	12.0	775	1013	6.0
13	875	1820	10.0	585	16.0	1240	1825	6.0
15	1100	2290	13.5	927	16.5	1350	2280	3.0
18	1800	3740	17.0	1490	19.0	2250	3740	2.0
23	4880	10200	21.0	3380	25.0	6830	10200	4.0

ALLOWABLE-RANGE TABLE
(Listing of G_L and Allowable Rise)

Gage Height	Allowable Rise	Gage Height	Allowable Rise
1.29	0.02	6.0	6.0
1.45	.1	10.0	6.0
1.8	.4	13.5	3.0
2.5	1.0	17.0	2.0
3.8	2.4	21.0	4.0

FIGURE 17.—Derivation of an allowable-range table.

intervals or points between whole hours, but a programmable calculator can simplify the work. The sample chart (fig. 15) illustrates midinterval subdivision for May 3-7, 1981. Some hydrographers prefer to list the subdivision computations on separate sheets to avoid clutter on the recorder charts.

Flood reports and other special studies contain flow data in the midinterval-subdivision format. The computed daily figures for the special report, usually prepared after the annual report has been published, should agree exactly with the daily figures in the annual report but rarely do unless the same subdivisions were used for both. Some cooperating agencies specify midinterval subdivision for all periods of substantial flooding to avoid such discrepancies in their reports. Some hydrographers prefer the midinterval method for all subdivision despite its shortcomings for small short rises where numerous irregular time increments must be used. One common practice is to use midinterval subdivision for all high-water periods that contain a peak above a chosen base discharge and to use the simpler mean interval method for smaller rises.

Gage-height record checking

After a recorder chart is computed, each of the steps must be carefully checked. When the mean daily gage heights are computed on recorder charts, one unconsciously tends to concentrate primarily on the hundredth of a foot and gives somewhat less attention to the larger graduations. This results in fairly frequent mistakes of feet, half feet, and tenths. The primary duty of the checker should be to give particular attention to the large units and somewhat less attention to the hundredths. Approximately half of a checker's time can be saved by concentrating on the large units, because for many days this type of check can be made without using the plastic straight-line device. This procedure is not a lowering of accuracy standards but is actually a step toward better accuracy—with an attendant saving in time.

Accordingly, except for certain special studies or stations with extremely flat ratings, changes to mean daily gage heights by the checker are limited to 0.02 ft or more. Changes of 0.01 ft are not generally made because they almost invariably produce insignificant changes in discharge. There are times when there is justification for making a change of 0.01 ft; for example, if it is obvious that there was no change in discharge from one day to the next, but the computed daily gage height indicates a jog that did not occur. In other words, it is important to make those small changes if by so doing the daily gage heights are made to indicate the day-to-day trend.

Checking is done using a colored pencil to make a small dot after each checked figure or, after erasing an incorrect one, to replace it with a neat figure in the same space.

The following questions pertain to areas where errors of computation most often appear: (1) Were the "end of period" notes recorded properly? (2) Were indicated gage-height, pen, and datum corrections applied? Were they applied with the right sign? (3) Was the time correction applied? Was it applied in the right direction? (If time is slow, the line is in back of the midnight line; if time fast, it is ahead.) (4) Were corrections for reversal and mechanical errors applied properly? (5) Were the periods of reversal checked? (It is easy to compute a gage height as 4.80 (before reversal) when it should be 5.20 (after reversal).) (6) Was the mean gage height recorded to the correct foot, half foot, or tenth? (7) (Check this whenever any period of chart record looks suspicious.) Was a correct appraisal of the recorder operation used in the computation? Remember, the checker assumes all responsibility for the accuracy of the record. The checker's initial and the date are placed near the end of each chart segment.

Notes for station analysis

Notes to be included later in the "station analysis" should be written at this time. (See "Station Analysis" section.) Any changes in location or equipment should be described in the paragraph headed "Equipment." All irregularities in the gage-height record, such as clock stoppage or faulty-intake action, should be discussed and listed by dates in the "Gage-height record" paragraph.

Nonrecording gages

The observer records the gage readings, generally twice daily, in a quarterly book (one page is illustrated in figure 18) usually kept at the gage. Each week the observer copies the past week's readings on a special card and sends it to the field office. At the time of each visit, the hydrographer determines the stages of high-water marks left on the streambanks or recorded on a crest-stage gage, enters the readings made for discharge measurements in the book, and, preferably with the observer's help, determines the date of peak stages since the last inspection and reconciles any inconsistent readings. Examine the books for any abnormalities left unresolved in the field.

Computing daily mean gage heights

Enter the corrections previously listed for inclusion in the station analysis in the spaces provided in the gage books at the bottom of each left page. Compute the average of the morning and afternoon readings for days of little change in stage and enter them in the book under "Obs." Add the applicable correction, if any, to the average figure and enter the result in the book under "Corr."

Draw a stage hydrograph on a piece of graphic recorder chart for all high-water periods and other days when the mean of the two readings would not be a reasonable approximation of the daily mean. Use the same time and gage-height scales for all flood period graphs so that

GAGE HEIGHTS FOR WEEK ENDING SATURDAY, May 9, 1980

16—24264—1

Day and Date	Time	Gage Height	Mean Gage Height Obs.	Mean Gage Height Corr.*	REMARKS Follow "Instructions for Gage Observer" in the front of this book
Sun. 3	A. M. 6:40	2.68	9 4.06		
	P. M. 6.00	5.14			
Mon. 4	A. M. 7:30	9.35	9 9.50		
	P. M. 7:00	10.30			HWMK 10.3 (hand level) R.S.S.
Tues. 5	A. M. 7:30	9.50	9 8.90		
	P. M. 7:00	8.00			
Wed. 6	A. M. 6:15	6.20	9 5.51		
	P. M. 6:45	4.58			
Thurs. 7	A. M. 6:45	3.64	9 3.44		
	P. M. 6:30	3.13			
Fri. 8	A. M. 6:30	2.77	2.64		
	P. M. 6:30	2.50			
Sat. 9	A. M. 6:50	2.24	2.17	Var. shift	2.11 at 12:40 2.06 at 12:50 after debris removal
	P. M. 6:30	2.00			(SEND regular CARD today) R.S.S.

* Correction 0

Mean Gage Ht. Computed by RSS Date 11-24-81

Mean Gage Ht. Checked by JJH Date 11-27-81

FIGURE 18.—Computed page of nonrecording-gage observer's book.

a flood-stage hydrograph template similar to the one in figure 19 can be used to shape the graph. The template is made on recorder chart paper by tracing the shapes of previous flood-stage hydrographs that were well defined by gage readings. Given the observer's readings and the peak stage, plotted on chart paper, and with the template under the paper as a shaping guide, the best possible graph of the data can be drawn. Be sure to include the last previous low-water day on the graph.

Subdivision of days is identical to that for graphic-recorder stations, using an allowable-range table and midinterval subdivision. Figure 20 illustrates a typical graph and subdivisions.

All computations and plotting are checked in the same manner as graphic chart work. After checking, the gage-height graphs may be folded and taped into the gage-reading books for storage.

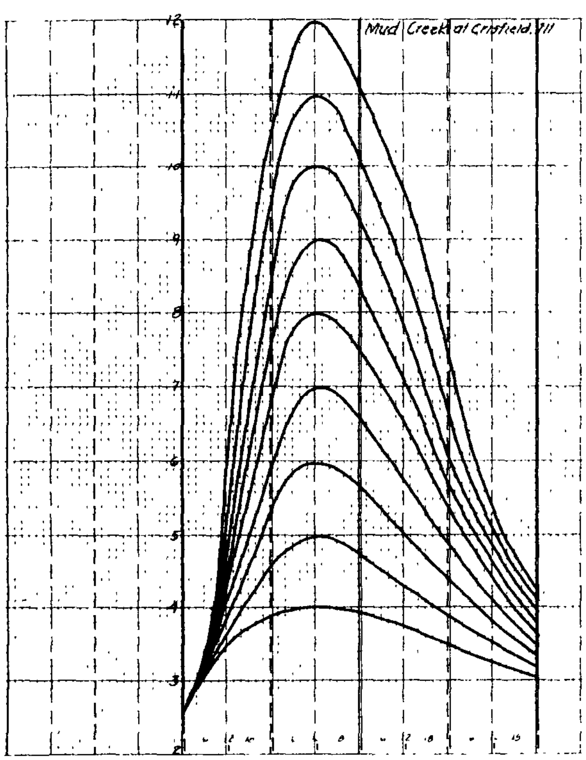


FIGURE 19.—Template for shaping nonrecording-gage graphs.

Copying gage heights on form 9-192a

Form 9-192a (fig. 21) is the basic computation sheet for stations whose discharge records are computed manually. A similar form 9-192b with extra columns for additional rating factors (fall, rate of change, and shift) is sometimes used. The form is often distributed to fill requests for data so it is carefully aligned and lettered in India ink for ozalid reproduction. The original is kept in the files as the official record, and future revisions to the published record will be noted on the original form 9-192a.

Fill in the headings in the spaces provided. Copy the daily mean gage heights from the recorder charts or gage books. If the mean gage height for a subdivided day was computed, list the figure with a lower case "s" at the left edge of the discharge column. If no mean gage height was computed, show an "s" in the center of the gage-height column.

Heavy black lines are used to indicate certain conditions. A line across the gage-height column indicates the date of a change in datum or location. A line across the discharge column shows the date of a rating change. A vertical line between the gage-height and discharge column signifies that the discharge was computed by a method other than the application of a rating to the gage height.

Check the above work. The copier's work and the checker's work are initialed and dated in the appropriate boxes. The form is then ready for the next step.

Computation of Discharge Record

Discharge records are computed by applying the gage-height record, with adjustments where the shifting-control method is used, to the applicable discharge rating. This computation is made for each instantaneous gage height from a digital recorder. For a graphic recorder or nonrecording gage, only one computation is made for each day or interval of a subdivided day. Form 9-192a is the worksheet for manual computations, and a special computer printout, the primary computation sheet, is its equivalent for

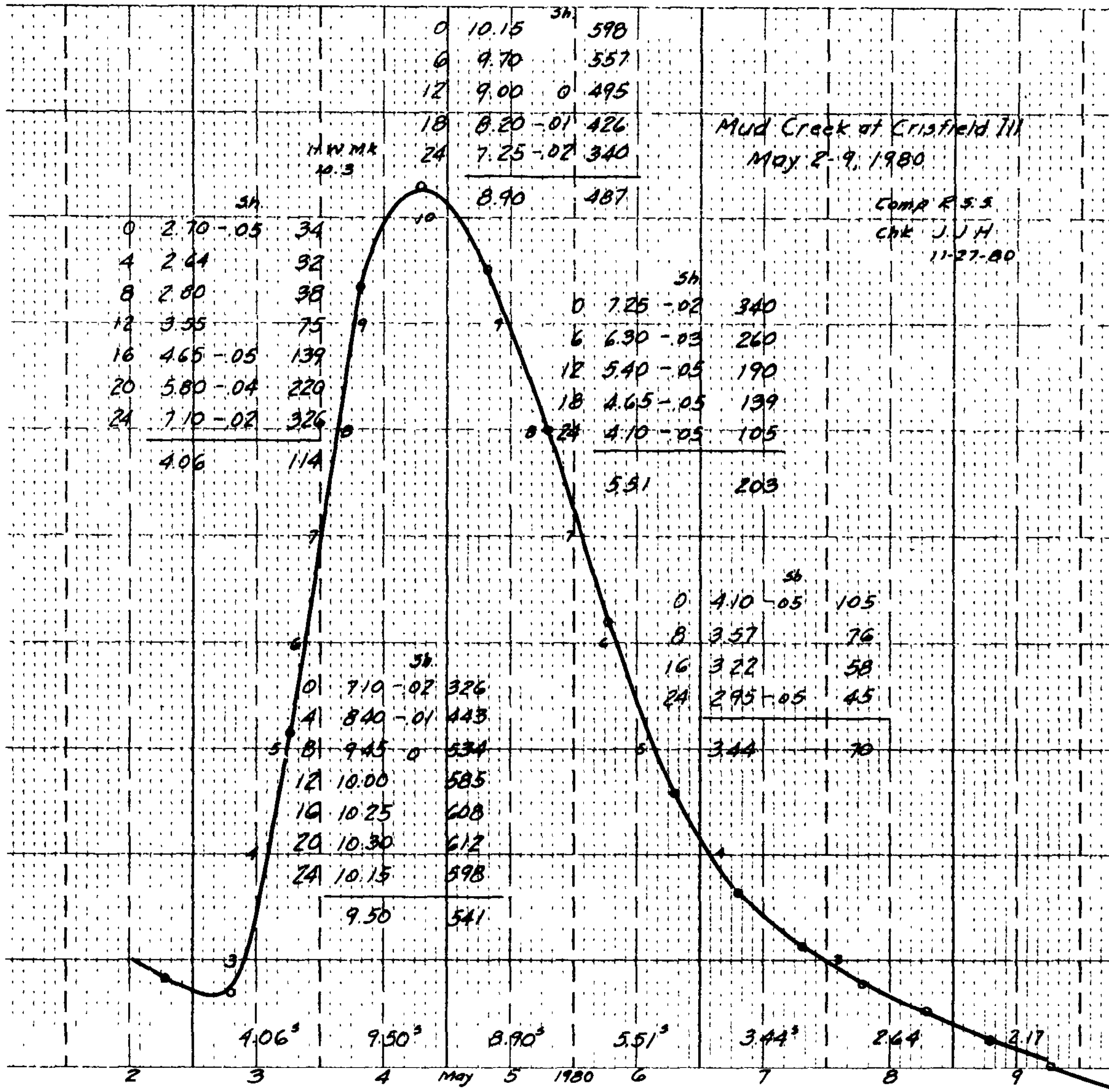


Figure 20.—Computed nonrecording-gage graph.

for ADP records. Discharge for periods of ice effect, missing gage-height record, or variable backwater is estimated or computed by using special methods.

The discharge computation for ordinary periods of record is a mechanical process except for distributing the shift adjustments. These adjustments tend to vary with time, stage, or both simultaneously, and different methods have been developed to distribute them under nearly all rating situations. After the distribution computations described in the next paragraphs have been made, the daily shift adjustments for graphic and nonrecording stations are listed on form 9-192a for nonsubdivided days (fig. 21), and those for subdivided day intervals are usually entered on the recorder charts (fig. 15) or gage-height graphs (fig. 20). The WATSTORE User's Guide contains instructions for entering manually distributed shift adjustments into the ADP system or for providing for various automatic shift distributions (constant, time varied, stage varied, or simultaneous time and stage varied) between the measurement-defined shifts.

Mud Creek at Crisfield, Ill -1980

9-192-a (Rev. May 1971)

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
WATER RESOURCES DIVISION

Daily Gage Height, in Feet, and Discharge, in Cubic Feet, per Second, of Mud Creek at Crisfield, Ill. for the Year Ending September 30, 1980

Station Number 05447540

Used rating table dated No. 9

Drainage Area 58.7 Square Miles. Water-Stage Recorder Stevens A-35 Ratio 1 : 6 Gage Read Weekly by A.J. Rouse

Peak discharge (base, 450 ft³/s) -- Feb 19 (0945) 8,760 ft³/s (26.60 ft); May 4 (1900) 614 ft³/s (10.32 ft).

Max Disch 8,760 CFS at 0945 on Feb 19 (G H 26.60 ft) Max G H 26.60 ft at 0945 on Feb 19.

Min Disch 0 CFS on June 21 to Aug 29, Sept 10-30

a-No gage-height record. b-Stage-discharge relation affected by ice. g-Computed from graph of daily gage readings. s-Subdivided day. v-Variable shift adjustment.

Day	Oct Gage height (1.70)	Oct Discharge (4.0)	Nov Gage height	Nov Discharge	Dec Gage height	Dec Discharge	Jan Gage height	Jan Discharge	Feb Gage height	Feb Discharge	Mar Gage height	Mar Discharge
1	1.70	4.1	1.62	2.8	1.57	2.1	1.99	b 4.5	2.00	b 4.8	1.86	6.4
2	1.68	3.7	1.62	2.8	1.63	3.0	2.04	5.0	2.00	4.6	1.84	5.9
3	1.67	3.6	1.62	2.8	1.70	4.1	2.09	5.5	2.01	4.6	1.82	5.5
4	1.66	3.4	1.62	2.8	1.73	4.7	2.10	5.5	2.04	4.6	1.84	b 5.4
5	1.66	3.4	1.62	2.8	1.74	4.9	2.15	6.0	2.05	4.4	1.88	5.0
6	1.65	3.3	1.62	2.8	1.76	5.3	2.15	6.0	2.07	4.4	1.92	4.8
7	1.65	3.3	1.65	3.3	1.77	5.5	2.15	6.2	2.07	4.4	1.89	4.7
8	1.65	3.3	1.64	3.1	1.76	5.3	2.15	6.3	2.08	4.4	1.93	b 6.5
9	1.65	3.3	1.61	2.7	1.76	5.3	2.15	6.5	2.09	4.2	2.00	10
10	1.70	4.1	1.61	2.7		a 5.3	2.15	6.5	2.09	4.2	1.93	8.1
11	1.61	2.7	1.61	2.7		5.3	2.15	6.5	2.05	4.2	1.88	6.8
12	1.61	2.7	1.61	2.7		4.9	2.12	6.5	2.02	4.2	2.14	14
13	1.61	2.7	1.61	2.7		a 4.7	2.09	6.5	1.97	4.0	2.46	25
14	1.60	2.5	1.62	2.8	g 1.73	4.7	2.05	6.5	1.94	4.0	2.33	20
15	1.60	2.5	1.64	3.1	g 1.72	4.5	2.02	6.5	1.94	3.8	2.20	16
16	1.60	2.5	1.62	2.8	g 1.72	4.5	2.02	6.5	1.81	b 3.8	2.15	14
17	1.60	2.5	1.61	2.7	g 1.72	4.5	1.98	6.5	2.40	s 30	2.05	12
18	1.60	2.5	1.61	2.7	g 1.70	4.0	1.95	6.2	8.92	s 510	2.00	10
19	1.60	2.5	1.61	2.7	g 1.72	b 3.5	1.95	6.2	23.87	s 5,720	1.97	9.1
20	1.60	2.5	1.56	2.0	1.78	3.8	1.95	6.0	16.75	s 1,470	1.91	7.6
21	1.61	2.7	1.58	2.3	1.85	4.0	1.95	6.0	6.03	s 248	1.89	7.1
22	2.50	s 30	1.62	2.7	1.89	4.2	1.93	5.5	3.50	s 75	1.85	6.1
23	2.43	s 26	1.65	3.3	1.92	4.2	1.93	5.5	2.68	33	1.82	5.5
24	2.12	15	1.63	3.0	1.92	4.5	1.91	5.2	2.26	18	1.80	5.1
25	1.81	6.4	1.61	2.7	1.92	4.5	1.91	5.2	2.06	12	1.77	4.5
26	1.73	4.7	1.60	2.5	1.94	4.5	1.92	5.2	2.00	10	1.75	4.1
27	1.66	3.4	1.60	2.5	1.95	4.5	1.91	5.0	1.93	8.1	1.72	3.6
28	1.65	3.3	1.59	2.4	1.95	4.5	1.93	5.0	1.90	7.3	1.70	3.3
29	1.64	3.1	1.58	2.3	1.96	4.5	1.95	5.0			1.68	3.0
30	1.63	3.0	1.57	2.1	1.97	4.5	1.97	4.8			1.67	2.8
31	1.62	2.8			1.98	b 4.5	1.98	b 4.8			1.65	2.5
Total		161.5		81.3		138.3		179.1		8,210.0		244.4
Mean												
Maximum												
Minimum												
Runoff in inches												
Acre feet												

Day	Apr Gage height	Apr Discharge	May Gage height	May Discharge	June Gage height	June Discharge	July Gage height	July Discharge	Aug Gage height	Aug Discharge	Sept Gage height	Sept Discharge
1	4.95	s 162	4.07	s 130	1.52	1.6		.00		.00	2.42	s 29
2	2.46	25	3.01	47	1.49	1.2		.00		.00	2.00	10
3	1.85	6.1	4.03	s >112	1.47	.99		.00		.00	1.80	5.3
4	1.74	4.0	9.51	>541	1.45	.83		.00		.00	1.51	1.1
5	1.71	3.4	8.90	>487	1.43	.69		.00		.00	1.44	.56
6	1.69	3.1	5.50	s >202	1.41	.56		.00		.00	1.41	.39
7	2.51	s 34	3.44	s 69	1.39	.45		.00		.00	1.38	.26
8	2.53	27	2.62	31	1.38	.39		.00		.00	1.35	.15
9	3.32	s 66	2.08	>13	1.37	.34		.00		.00	1.32	.08
10	2.80	38	1.84	7.1	1.35	.26		.00		.00	1.26	.00
11	2.40	23	1.75	5.1	1.34	.22		.00		.00	1.20	.00
12	2.20	16	1.68	3.8	1.33	.18		.00		.00	1.18	.00
13	2.06	12	1.61	2.7	1.32	.15		.00		.00	1.15	.00
14	2.20	16	1.56	2.0	1.31	.12		.00		.00	1.11	.00
15	2.04	11	1.52	1.6	1.31	.12		.00		.00	1.08	.00
16	1.93	8.1	1.49	1.3	1.30	.10		.00		.00		.00
17	1.90	7.3	1.47	1.1	1.28	.06		.00		.00		.00
18	1.80	5.1	1.45	.91	1.25	.02		.00		.00		.00
19	1.74	4.0	1.43	.76	1.22	.00		.00		.00		.00
20	1.72	3.6	1.41	.62	1.21	.00		.00		.00		.00
21	1.68	3.0	1.54	s 2.0	1.21	.00		.00		.00		.00
22	1.65	2.5	1.82	s 6.9		.00		.00		.00		.00
23	1.62	2.1	1.88	8.1		.00		.00		.00		.00
24	1.59	1.8	1.75	5.1		.00		.00		.00		.00
25	1.57	1.6	1.66	3.4		.00		.00		.00		.00
26	1.56	1.4	1.70	s 4.5		.00		.00		.00		.00
27	1.53	1.2	1.65	3.3		.00		.00		.00		.00
28	1.51	.99	1.72	4.5		.00		.00		.00		.00
29	1.50	.91	1.65	3.3		.00		.00		.00		.00
30	1.49	.83	1.60	2.5		.00		.00	1.43	s .65		.00
31			1.56	2.0				.00	1.91	s 11		
Total		491.03		1,704.59		8.28		.00		11.65		46.45
Mean												
Maximum												
Minimum												
Runoff in inches												
Acre feet												

Calendar Year 1979: 8,228.42

Period Year: 11,276.60

Computed / Checked / Date: PTS 11-21-80; RSS 11-19-80

U.S. GOVERNMENT PRINTING OFFICE: 1971—420-766

FIGURE 21.—Computed form 9-192a.

The basic operations for the shifting-control method are essentially the same for ADP or manual computations.

Distribution of shift adjustments

The shift adjustments, if any, that apply at the times of discharge measurements were computed previously and listed tentatively on form 9-207 (fig. 10). The shift adjustments that apply during the periods between the measurements must be interpolated by an appropriate method before the discharge records can be computed. The method used will depend on the hydrographer's judgment considering the nature of the shifting, the frequency of measurements, and the type of channel and control.

Small shifts that change gradually may be distributed satisfactorily by inspection using mental interpolation. Larger shifts, whose variations are adequately defined by discharge measurements, warrant a more rigorous analysis with some form of graphic shift-adjustment-variation diagram. The accuracy of discharge records computed from a rating with large and erratic shifts depends to a great extent on the frequency of discharge measurements, and particularly unstable streams may need weekly or even daily measurements to define the day-to-day shift-adjustment variation.

The shift-adjustment variation between discharge measurements of unstable channels may be too great for the usual interpolation methods and a special technique may be needed. One procedure involves varying the shifts smoothly between the measurement-defined values until a smooth daily-discharge hydrograph (see "Discharge Hydrographs" section) that follows the trends indicated by the discharge measurements is obtained. A streamflow record should be computed from the data collected at the site, and, except for estimated portions, be free from the influence of other streamflow records. For this reason the use of records for other stations to distribute shift adjustments is normally avoided. If shift adjustments interpolated to produce a smooth hydrograph are above or below the range of adjustments indicated by the two adjacent discharge measurements, the discharge records for that period should be considered as estimated rather than computed and their accuracy rating downgraded accordingly.

Shift-adjustment variation diagrams

A shift-adjustment variation diagram (V diagram), a graph of the relation between shift adjustment and either time or stage, is commonly used to interpolate shift adjustments between measurement-defined values. The V-diagram shifts can be graduated with time, stage, or time and stage simultaneously either manually or as part of the ADP primary or update procedures.

When a low-water control is scoured or filled or affected by backwater from leaves, debris, or aqueous growth, the corresponding rating shift is greatest at low water and normally tapers to zero at some higher stage. This is called a stage-variable shift. If the channel is alluvial and its bed is raised and lowered by sediment being picked up or deposited, the shift variation with stage may be negligible compared to its variation with time, and the shifts are called "time variable." Most streams have shifts that must be graduated with stage while the stage graduation is changing with time.

Time-variable-shift distribution can be made manually by using a V diagram, similar to the one in figure 22, where measurement-defined shifts are plotted and curvilinear interpolations are made visually. The corresponding ADP process prorates the shift adjustments linearly between measurement-defined points, but arbitrary data points may be used to obtain other distributions.

Stage-variable-shift distribution can be made by using V diagrams similar to those in figure 23. Each diagram involves a base-rating curve (the numbered rating in effect at the time); a shift-rating curve (a rating curve drawn to fit the measurements that define the shift, usually only on the rating work-curve sheet); and the V diagram (the gage-height differences between the base curve and shift curve, plotted against stage). The shift curve should normally be drawn first with the same consideration given to its shape as would be given to a numbered

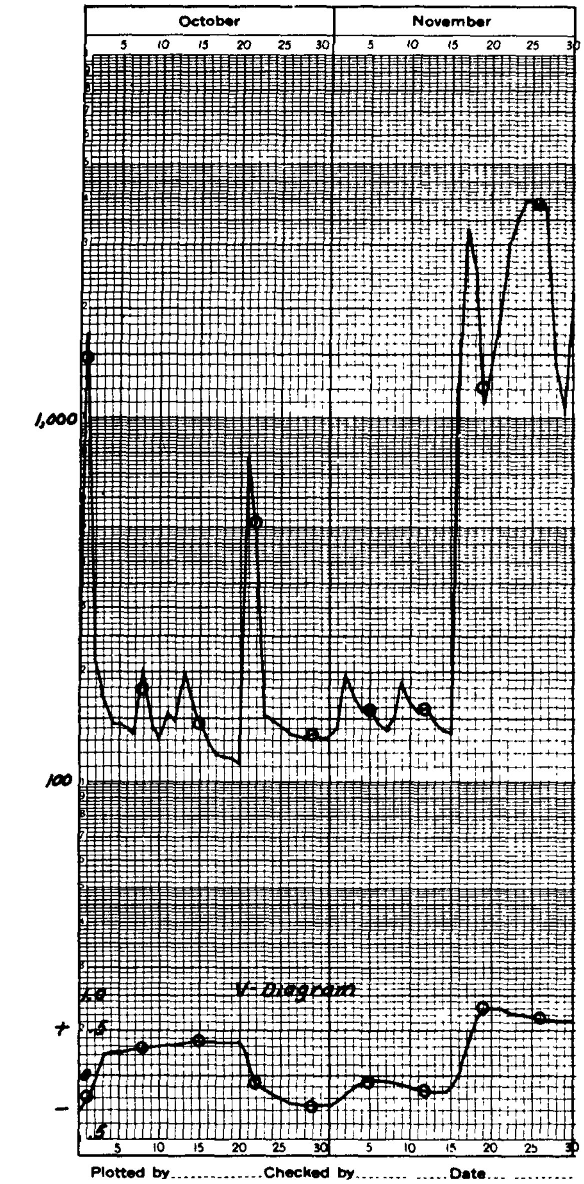


FIGURE 22.—Time-shift-variation diagram with corresponding hydrograph.

rating. The V diagram is best defined by drawing its corresponding shift curve first. The V diagrams of the type in figure 23*A*, for relatively small shifts, may be defined directly from measurement-defined shifts without drawing a shift curve, but this process is not recommended with other V-diagram types or for large shifts where it could lead to grossly misshapen equivalent ratings and dubious discharge records.

A stage-variable V diagram may be expanded, contracted, or reversed (mirror image), and the change in shape may be graduated with time. The process can be done manually or automatically to distribute shift adjustments with respect to time and stage simultaneously.

Shift adjustments varied with time only

Figure 22 illustrates a time-shift V diagram plotted below the corresponding daily hydrograph. The type of shift illustrated varies only with time, but the variation is faster at high stages than at low stages. The shift-distribution process requires a hydrograph or readable gage-height record as a guide for the shift distribution, so its greatest use is for manually computing records or updating of ADP records.

To use the process (1) plot the measurement-defined shifts on the days of measurements by using a convenient improvised shift scale; (2) connect the plotted points with a smooth curve so that no interpolated daily shift is above or below the range of the adjacent measurement-defined shifts; (3) apply the shifts from the V diagram to the daily mean gage heights (or equivalent gage heights for ADP records) and plot the computed discharges on the hydrograph; (4) look for anomalies in the hydrograph such as odd-looking rises or recessions or rising hydrographs during falling-stage periods and modify the V diagram to correct them; and, (5) for ADP records, enter the resulting V-diagram shift data in the update program described in the WATSTORE User's Guide (vol. 1). These shifts will be applied to equivalent gage heights stored in the Daily Values File and used with the appropriate rating to compute the updated mean daily discharges.

Shift adjustments varied with stage only

The use of a stage-varied-shift adjustment is equivalent to drawing a new numbered rating curve and may be preferable for temporary rating changes. The principal use for stage-shift diagrams is as one step in the process used for varying shifts with both stage and time as explained in a subsequent section.

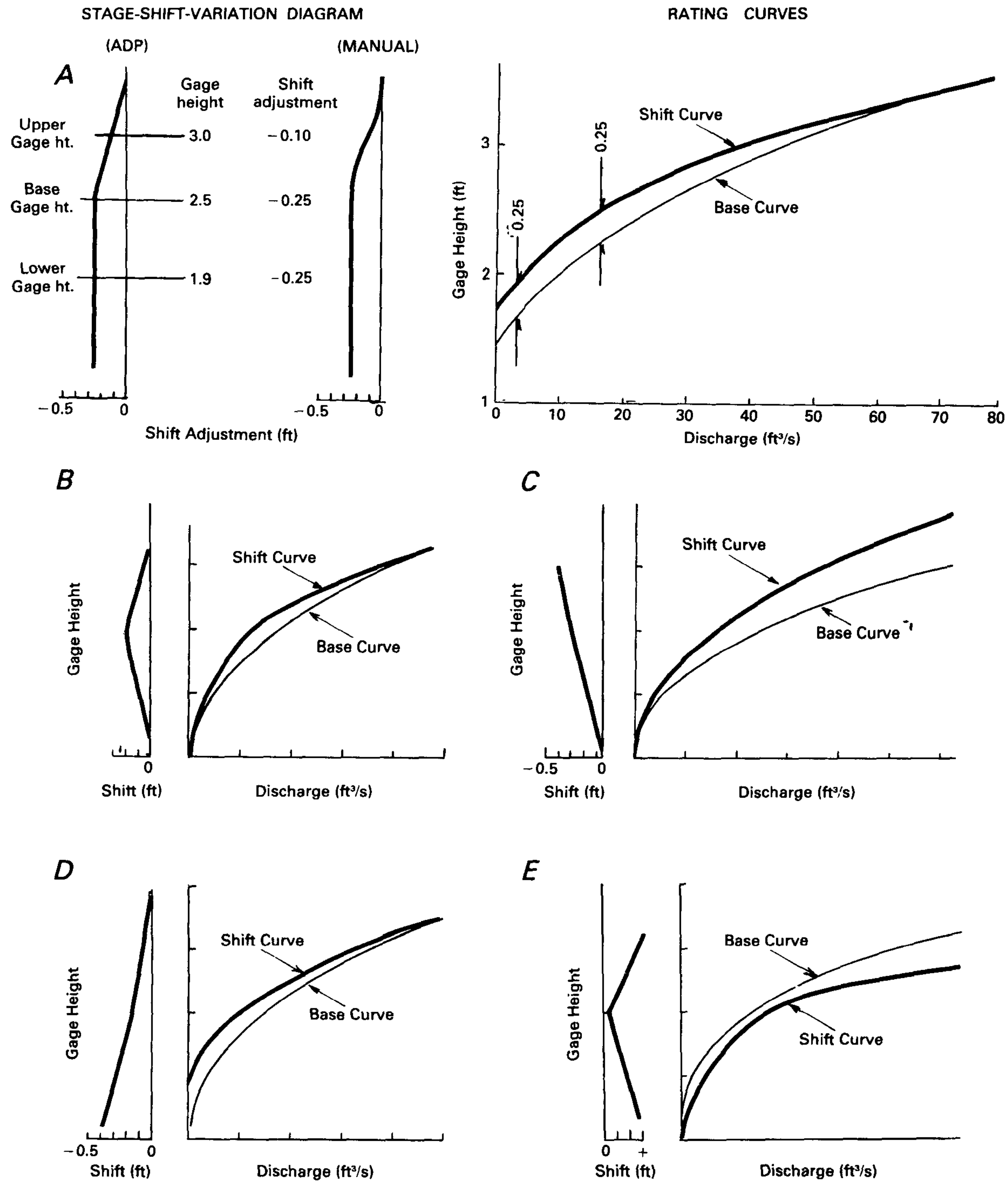


FIGURE 23.—Effect of various stage-shift-variation diagram shapes on shift-curve shape.

Figure 23 illustrates typical stage-shift V diagrams and the relations between their corresponding base curves and shift curves. The V diagrams for manual application are usually curved, but the curve must be approximated by two straight lines for ADP use (in 1982). An ADP version is defined by six descriptors; three gage heights called "upper," "base," and "lower"; and a shift adjustment corresponding to each of those three gage heights. The figure 23*A* (manual) V diagram is curved, and the ADP straight-line approximation of it has the following descriptors: upper, 3.0, -0.10; base, 2.5, -0.25; and lower, 1.9, -0.25. The upper descriptors could just as well be 3.33, 0.00, which would describe the same upper line of the diagram. The V diagrams (manual and ADP) describe a shift curve 0.25 ft above the base curve for stages below 2.5 ft that merges with the base curve at 3.33-ft gage height. The manual version can be either a graph or a table. The V diagram in figure 23*B* describes a shift curve identical to the base curve at low and high stages and above it at medium stages. The V-diagram shapes in figure 23*A* and 23*B*, in positive or negative versions, cover all ordinary rating situations. The other three shapes in figure 23 may be needed for unusual rating conditions but probably indicate an improper base-rating shape.

The gage-height difference between the shift curve and the base curve at a given stage, used for V-diagram definition, must be measured from a point at the given gage height on the shift curve to a point on the base curve directly above or below that point. Figure 24 illustrates the procedure for plotting a point on the shift curve given the gage height and the magnitude of the shift adjustment. Measuring from the point where the base curve intersects the given gage height is a frequent mistake that results in a serious error wherever the shift adjustment is large and the rating is sharply curved.

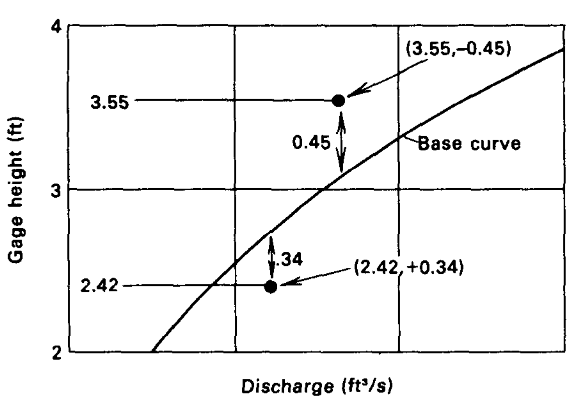


FIGURE 24.—Plotting positions of stage-shift-variation diagram points on the shift curve.

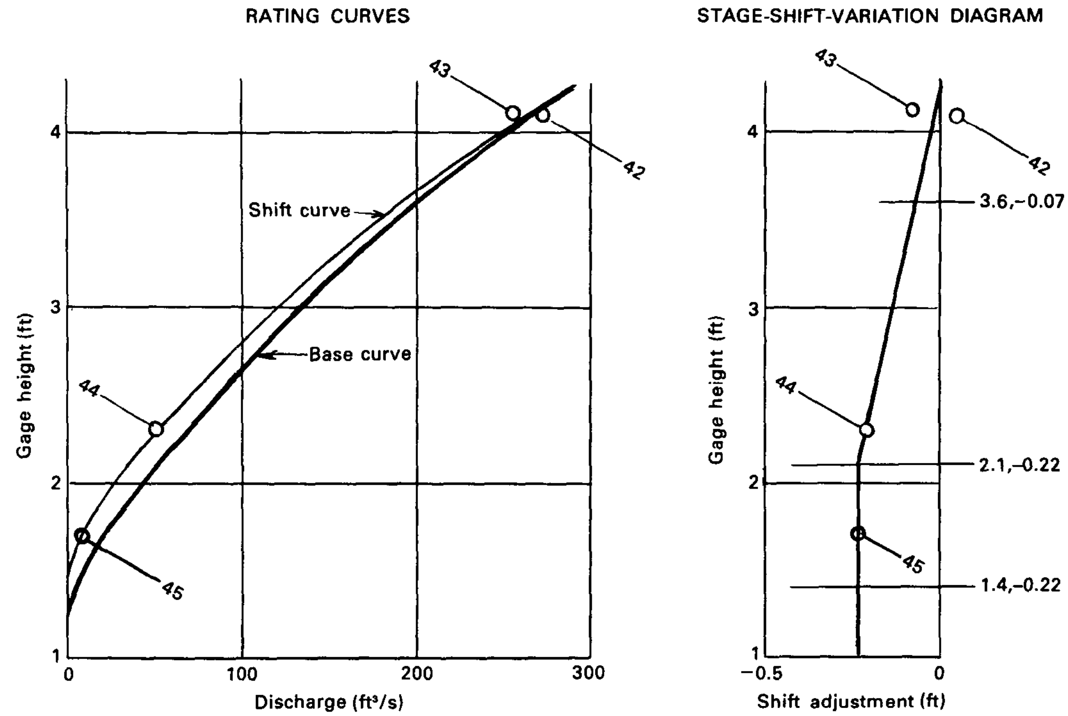
To prepare a stage-shift diagram (1), on the rating curve worksheet, mark the measurements that define the shift curve and draw the trial shift curve based on them; (2) plot the measurement-defined shift adjustments and the gage-height differences between the base and shift curves at several gage heights (fig. 25), on a rectangular grid; (3) draw a V diagram considering all of the plotted points; (4), for ADP, approximate the V diagram with two intersecting straight lines and list the three coordinate sets (gage height and shift adjustment as illustrated in figure 23*A*); (5) replot the shift curve by using the V diagram and, if the shift curve is poorly shaped, modify the V diagram as necessary to correct it; and (6) determine from the V diagram the shift adjustment applicable to each discharge measurement and recompute its percent difference if necessary.

The process is illustrated in figure 25. Note that the tentative shift adjustment listed on form 9-207 (list of discharge measurements) for a specific discharge measurement is final only if the shift curve and V diagram are drawn through that measurement's plotted points. The shift curve in figure 25 averages 42 and 43, so the originally computed shifts (+0.05 and −0.07) must be changed to the values from the V diagram (−0.02 and −0.02) that are used to compute the discharge record. The shift curve and V diagrams go through the measurement 44 and 45 values, so no revisions to their shift adjustments are necessary on form 9-207.

The coordinates of the finished V diagram are entered into the ADP system as described in the WATSTORE User's Guide. For manually computed records, the shift adjustments are taken from the V diagram or table and entered on form 9-192a or the recorder chart.

Shift adjustments varied with time and stage

One stage-shift V diagram, modified to fit the day-to-day shifting caused by changes to the control, is used to vary the shift distribution simultaneously with time and stage for primary computations by ADP or, with modifications, for manually computed records. This procedure can also be used for updating ADP records if the base and shift curves are roughly parallel. It



COMPUTATIONS

No.	Date	Gage height	Discharge	Shift adjustment computed from: Meas.	Shift adjustment computed from: V-diag.	% diff.
42	May 7	4.09	273	+0.05	−0.02	+4.2
43	May 8	4.10	257	− .07	− .02	−3.8
44	June 10	2.30	53.2	− .20	− .20	--
45	July 7	1.70	9.7	− .22	− .22	--

FIGURE 25.—Development of a stage-shift-variation diagram.

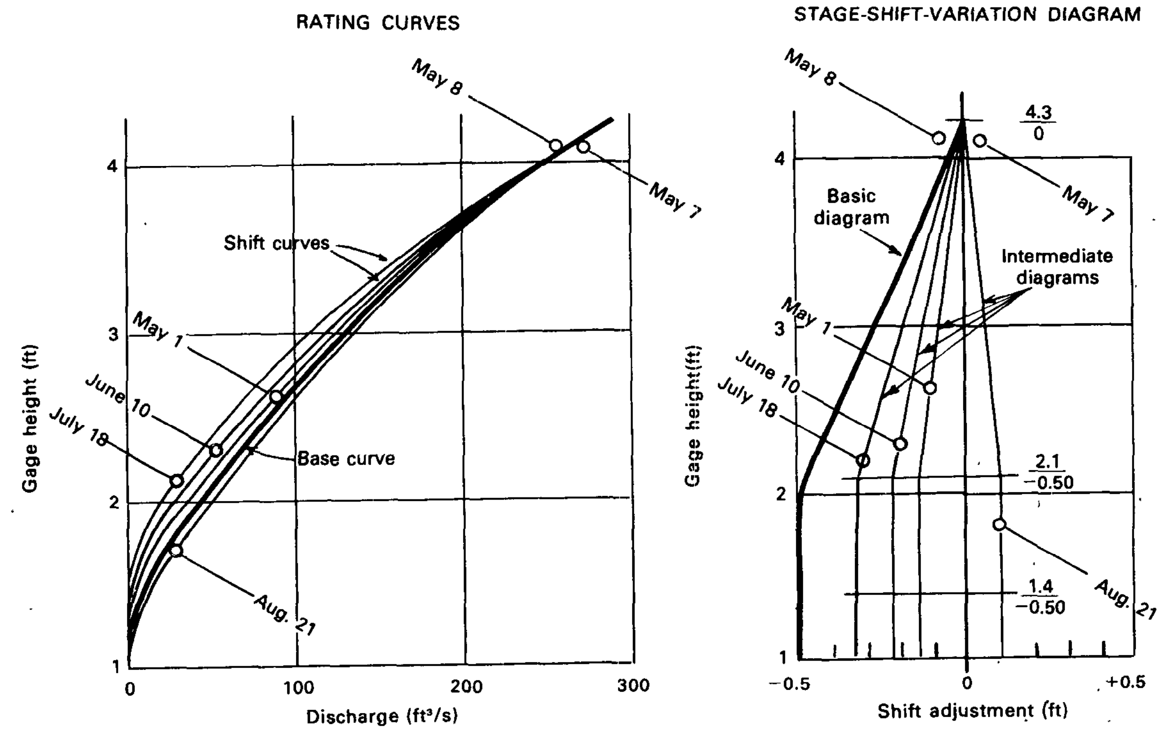
should not be used to correct the effect of an erroneously shaped base rating used for the primary computation. In that event, manual computation of the updated figures or rerunning the primary computations is necessary.

ADP procedure

The computer program details and the data input format are explained in the WATSTORE User's Guide. The data requirements, in addition to the usual material for a primary or update computation, are (1) the descriptors for a basic V diagram; (2) the dates, gage heights, and shift adjustments of most of the discharge measurements with gage heights within the V diagram range (ice measurements, disregarded measurements, and measurements outside the V diagram limits or inside but close to the limits are not used); and (3) the dates, gage heights, and shift adjustments of arbitrary data points (synthetic discharge-measurement data used to control the time-varied distribution). The program expands, contracts, or reverses one basic V diagram to generate a perfectly fitting and proportionally shaped diagram for each day of a discharge measurement or arbitrary data point. The V diagrams for the other days are interpolated, linearly with time, between the data point diagrams and are used to compute an appropriate shift adjustment for each recorded gage height.

The procedure for distributing time- and stage-variable shifts requires considerable judgment and is relatively simple for some gages and very intricate for others. One procedure for analysis of a typical distribution, suggested for the first few uses by a hydrographer with limited experience in rigorous shift distribution, is illustrated in figure 26 and outlined as follows:

1. Develop the base rating by the usual method and compute the measurement-defined shift adjustments.



COMPUTATIONS

No.	Date	Gage height	Discharge	Shift adjustment computed from		% diff.
				Meas.	V-diag.	
41	May 1	2.63	90.0	−0.10	−0.10	--
42	May 7	4.09	273	+ .05	− .02	+4.2
43	May 8	4.10	257	− .07	− .02	−3.8
44	June 10	2.30	53.2	− .20	− .20	--
45	July 18	2.13	29.6	− .30	− .30	--
46	Aug. 21	1.70	30.1	+ .10	+ .10	--

FIGURE 26.—Development of a time-varied stage-shift diagram.

2. Use the largest practical rectangular graph paper worksheet and plot the shift-prone portion of the base-rating curve on it. Also, plot the shift adjustments for the measurements to a suitable scale near the right margin.
3. Select the most appropriate V-diagram shape and the upper, base, and lower gage heights for the diagram. Base the selections on a scrutiny of the logarithmic work-curve sheet of the base rating and knowledge of the control characteristics of the stream.
4. Plot a trial basic V-diagram on the rectangular worksheet so that the diagram is outside the greatest shift adjustment and its base shift is 1.0-, 0.5-, or 0.1-ft (-0.5 ft in figure 26).
5. Draw an intermediate V diagram, a widened or narrowed version of the basic diagram, through the greatest shift (July 18 in figure 26). Plot the corresponding shift curve on the worksheet. If the shift-curve shape is unsatisfactory, revise the V diagram gage heights or shape until a satisfactory shift curve is obtained.
6. Identify any measurements, such as 42 and 43 in figure 26, that are so close to a limit of the V-diagram range that an intermediate diagram drawn through one would be unreasonable at some stages. Draw the most reasonable intermediate diagram for such a measurement and note the shift from the the diagram at the gage height of the measurement (-0.02 ft at 4.10 ft for measurement 43 in figure 26) and also the shift at the base gage height (-0.20 ft at 2.1 ft in figure 26). The base gage-height shift will be used as an arbitrary data point (see step 7), and the shift (-0.02 ft) for the measurement gage height will be used on form 9-207 (fig. 10) to compute the measurements percent difference.
7. Select arbitrary data points to modify the linear interpolation of intermediate V diagrams between the times of discharge measurements if desired. If an arbitrary data point with the same gage height and shift as the preceding or following data point is inserted, the V diagram and shift curve will be held constant between the two dates. Assuming that the gage-height record for the example in figure 26 showed rises on May 7, July 1, and August 12, arbitrary data points (May 6, 2.63, -0.10; May 8, 2.3, -0.20; June 30, 2.3, -0.20; July 2, 2.13, -0.30; August 11, 2.13, -0.30; August 30, 1.70, +0.10) could be added to the measurement-defined points. The corresponding shift distribution would be equivalent to using one shift curve for May 1-6, another for May 7 to June 30, another for July 1 to August 11, and still another for August 12-27. This would be the most logical shift distribution for a stream with a gravel control that changes only during rises. Without the arbitrary points, the time shift between measurements would be the most logical shift distribution for a sand channel. Arbitrary data points can be based on the hydrographer's judgment, the gage observer's notes, or the gage-height record appearance.
8. Enter the data for the measurement-defined shifts and arbitrary data points (omit measurements that were disregarded, ice affected, outside the V-diagram range, or too close to the V-diagram limits) as instructed the WATSTORE User's Guide.

Shortcuts in the above procedure are practical for experienced hydrographers, and other approaches, more or less detailed, may be superior for use at some stations. The procedure is designed for primary computations but can also be applied to most updates.

Manual procedure

The distribution of shifts graduated with time and stage can be made for manually computed records in much the same way as they are with ADP. A V diagram for manual use can be either curvilinear or composed of straight lines and may be either a graph or a table. The widening or narrowing of the manual version of a V diagram is done by applying a coefficient to the V-diagram shifts. The magnitude of the coefficient at the time of a discharge measurement is the measurement-indicated shift divided by the V-diagram shift. The coefficients for each day are obtained from a graph somewhat similar to the time-shift V diagram in figure 21 and are applied to the shift adjustments obtained from the basic stage-shift V diagram. The resulting shift adjustments are entered on form 9-192a (fig. 21) or on the recorder chart (fig. 15) and used to compute the daily discharges.

Figure 27 illustrates the use of coefficients to generate intermediate V diagrams to fit the individual discharge measurements.

Records from digital recorders

Digital recorder tape segments are processed individually by a "primary computation." This process converts the punched values into a listing similar to figure 28, usually called the primary computation sheet, or "PPO." The discharge figures are tentative, and the gage-height figures are usually final. The printed figures are scanned manually for evidence of equipment malfunction, edited and corrected where necessary, and used in an "update" computation to produce either a corrected record of daily discharges or, at the end of the year, the final record (fig. 29) that is used as a page of the published record.

Primary computation

The punched-tape segment, rating descriptors or table, and information regarding datum corrections and shift adjustments are entered into the ADP system by using the formats prescribed in the WATSTORE User's Guide. The program applies each recorded instantaneous gage height, modified by any datum and shift adjustments, to the rating and obtains the instantaneous discharge. The average of all the instantaneous gage heights (corrected for datum error) and discharges for each day are printed (fig. 28). This procedure subdivides every day into segments one-punch interval long regardless of the range in stage. The daily mean gage heights are adjusted for the effect of subdivision, and the adjusted values are printed as "equivalent gage heights." Daily discharges can usually be revised later, without reprocessing the recorder tapes, by applying a different rating or revised-shift adjustments to the equivalent gage heights. A daily discharge computed from an equivalent gage height and revised rating is practically the same as one that would be computed by rerunning the primary computation with that rating if the revised and original rating curves (or shift curves, if used) have roughly similar shapes. The few exceptions include all days with periods of zero flow indicated by either the primary or update effective ratings and a few days where the primary or update effective ratings are practically the same at the equivalent gage height but not at other gage heights recorded during that day. Discharges for these days may be computed manually or by rerunning the recorder tapes.

A primary computation is a rapid and simple operation if the equipment functions properly, the datum correction is well defined, and the discharge rating remains stable throughout the period. Equipment problems such as faulty punching, or float tape or cable jumping its splines, make the task much more difficult. These problems can be minimized by careful field maintenance and the use of surge chains or other devices to maintain tension in the float tape while the recorder is locked for punching. The datum correction needs careful consideration before each primary computation because the only way that a subsequent change can be reflected in the printed list of gage heights is to rerun the primary computation.

A primary computation is normally made as soon as possible after the removal of the recorder tape to provide a readable gage-height record for the identification of any recorder malfunctions. The computed discharges—final, approximate, or grossly in error—will normally be stored in the WATSTORE Daily Values File until the update process. Several protection options described in the WATSTORE User's Guide are available to prevent a user from retrieving erroneous data from the daily records file.

Many primary computations can be run in such a way that the discharge figures will be useful or even final. For those few gaging stations where the discharge rating is stable and shift adjustments are not needed, the primary computation will usually generate final discharge records without any special effort. If the high and medium parts of the discharge rating are stable and the low-water part shifts only during substantial rises, use the latest