USGS
science for a changing world

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

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.

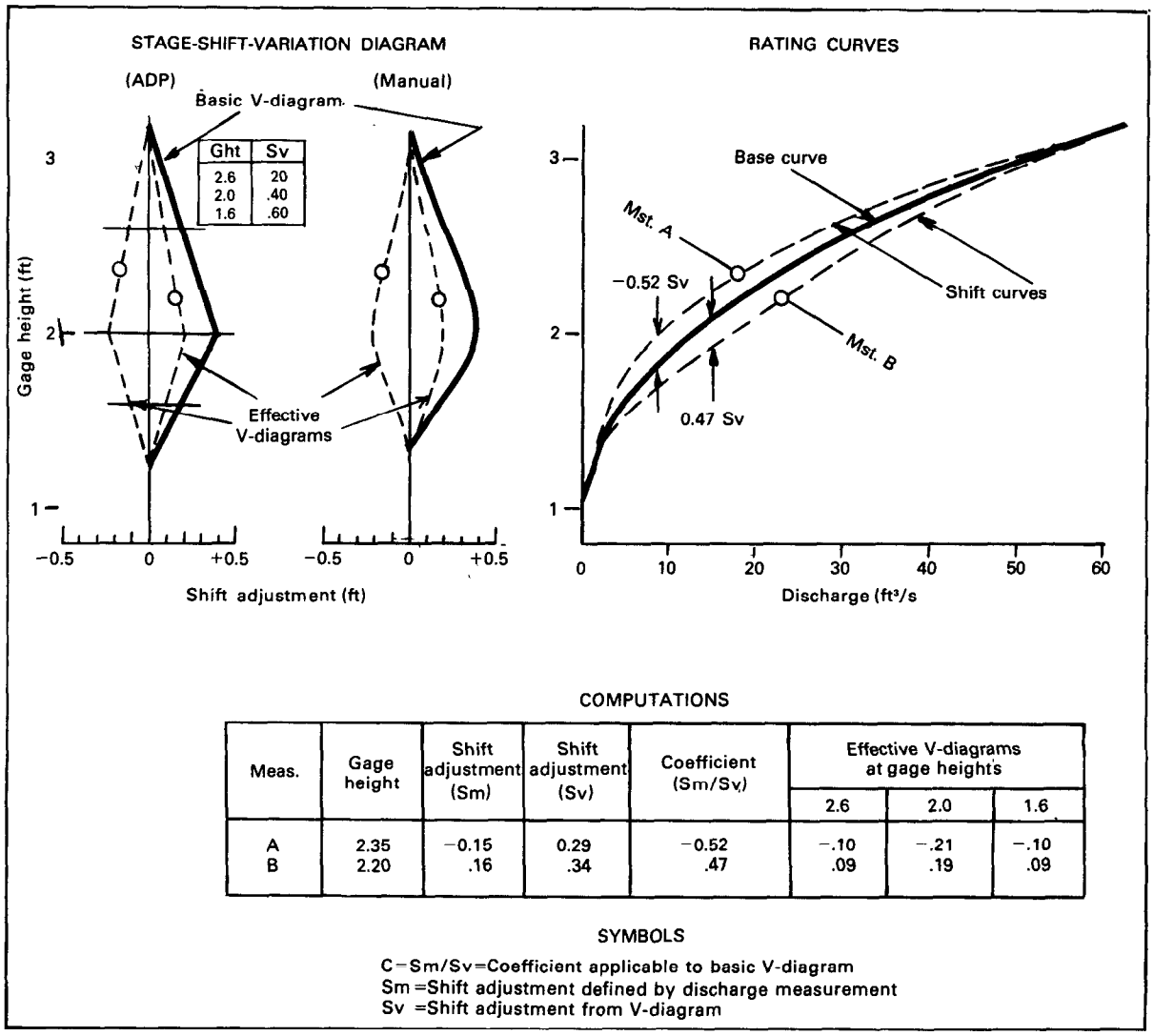
Primary computation

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

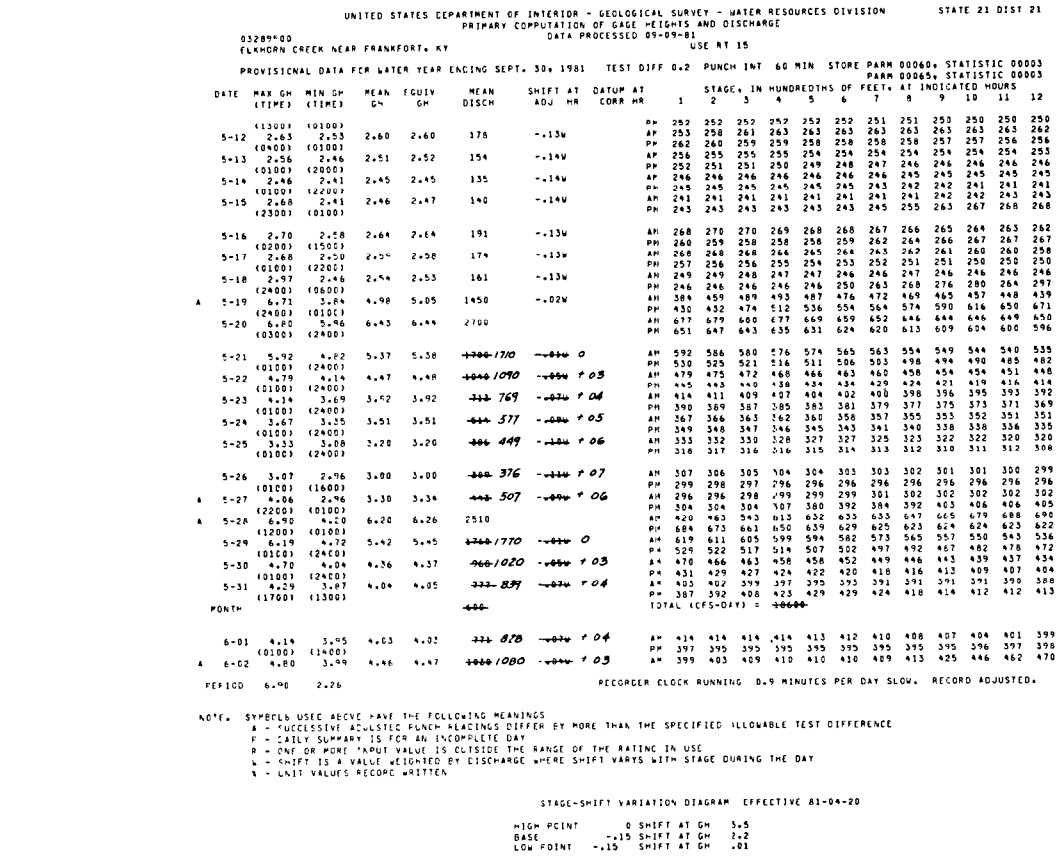


Meas.	Gage height	Shift adjustment (Sm)	Shift adjustment (Sv)	Coefficient (Sm/Sv)	Effective V-diagrams at gage heights		
					2.6	2.0	1.6
A	2.35	−0.15	0.29	−0.52	−.10	−.21	−.10
B	2.20	.16	.34	.47	.09	.19	.09

FIGURE 27.—Use of stage-shift-variation diagram coefficients to fit shift curves to discharge measurements.

rating and a time-varied V diagram as illustrated in figure 26. Change the shift pattern only during the highest rise between discharge measurements, the most logical time for a change in low-water shifts. Some ratings shift erratically at all stages. The shifting is usually more rapid during rises than during low-water periods. Interpolation of shifts with time and stage is practical for the primary computation of some such stations where weekly or more frequent measurements are made. Otherwise, the records for very unstable channels are most easily processed by using the latest rating without any shift adjusments. Then a hydrograph of the resulting discharge records, undistorted by incorrect shifts, will be used as a guide when the updating is done with final shift adjustments based on additional data (gage heights, records for other stations, hydrograph appearance, and so forth) as shown in figure 22.

The primary computation sheet, edited as will be described in the section on "updating," contains most of the information for an ADP record that form 9-192a (fig. 21) and recorder charts (fig. 15) show for a graphic-recorder station. It should be treated and preserved accordingly.



UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SURVEY - WATER RESOURCES DIVISION STATE 21 DIST 21
PRIMARY COMPUTATION OF GAGE HEIGHTS AND DISCHARGE
03289700 DATA PROCESSED 09-09-81
ELKHORN CREEK NEAR FRANKFORT, KY USE RT 15

PROVISIONAL DATA FOR WATER YEAR ENDING SEPT. 30, 1981 TEST DIFF 0.2 PUNCH INT 60 MIN STORE PARM 00060, STATISTIC 00003
PARM 00065, STATISTIC 00003

	DATE	MAX GH (TIME)	MIN GH (TIME)	MEAN GH	EQUIV GH	MEAN DISCH	SHIFT AT ADJ HR	DATUM AT CORR HR		STAGE, IN HUNDREDTHS OF FEET, AT INDICATED HOURS 1	2	3	4	5	6	7	8	9	10	11	12
		(1300)	(0100)						PM	252	252	252	252	252	252	251	251	250	250	250	250
	5-12	2.63	2.53	2.60	2.60	178	-.13W		AM	253	258	261	263	263	263	263	263	263	263	263	262
		(0400)	(0100)						PM	262	260	259	259	258	258	258	258	257	257	256	256
	5-13	2.56	2.46	2.51	2.52	154	-.14W		AM	256	255	255	255	254	254	254	254	254	254	254	253
		(0100)	(2000)						PM	252	251	251	250	249	248	247	246	246	246	246	246
	5-14	2.46	2.41	2.45	2.45	135	-.14W		AM	246	246	246	246	246	246	246	245	245	245	245	245
		(0100)	(2200)						PM	245	245	245	245	245	245	243	242	242	241	241	241
	5-15	2.68	2.41	2.46	2.47	140	-.14W		AM	241	241	241	241	241	241	241	241	242	242	243	243
		(2300)	(0100)						PM	243	243	243	243	243	243	245	255	263	267	268	268
	5-16	2.70	2.58	2.64	2.64	191	-.13W		AM	268	270	270	269	268	268	267	266	265	264	263	262
		(0200)	(1500)						PM	260	259	258	258	258	259	262	264	266	267	267	267
	5-17	2.66	2.50	2.58	2.58	174	-.13W		AM	268	268	268	266	265	264	263	262	261	260	260	258
		(0100)	(2200)						PM	257	256	256	255	254	253	252	251	251	250	250	250
	5-18	2.97	2.46	2.54	2.53	161	-.13W		AM	249	249	248	247	247	246	246	247	246	246	246	246
		(2400)	(0600)						PM	246	246	246	246	246	250	263	268	276	280	284	297
A	5-19	6.71	3.84	4.98	5.05	1450	-.02W		AM	384	459	489	493	487	476	472	469	465	457	448	439
		(2400)	(0100)						PM	430	432	474	512	536	554	564	574	590	616	650	671
	5-20	6.80	5.96	6.43	6.44	2700			AM	677	679	680	677	669	659	652	646	644	646	649	650
		(0300)	(2400)						PM	651	647	643	635	631	624	620	613	609	604	600	596
	5-21	5.92	4.82	5.37	5.38	~~1700~~ 1710	~~-.01W~~	0	AM	592	586	580	576	574	565	563	554	549	544	540	535
		(0100)	(2400)						PM	530	525	521	516	511	506	503	498	494	490	485	482
	5-22	4.79	4.14	4.47	4.48	~~1040~~ 1090	~~-.05W~~	* 03	AM	479	475	472	468	466	463	460	458	454	454	451	448
		(0100)	(2400)						PM	445	443	440	438	434	434	429	424	421	419	416	414
	5-23	4.14	3.69	3.92	3.92	~~733~~ 769	~~-.03W~~	* 04	AM	414	411	409	407	404	402	400	398	396	395	393	392
		(0100)	(2400)						PM	390	389	387	385	383	381	379	377	375	373	371	369
	5-24	3.67	3.35	3.51	3.51	~~511~~ 577	~~-.08W~~	* 05	AM	367	366	363	362	360	358	357	355	353	352	351	351
		(0100)	(2400)						PM	349	348	347	346	345	343	341	340	338	338	336	335
	5-25	3.33	3.08	3.20	3.20	~~386~~ 449	~~-.12W~~	* 06	AM	333	332	330	328	327	327	325	323	322	322	320	320
		(0100)	(2400)						PM	318	317	316	316	315	314	313	312	310	311	312	308
	5-26	3.07	2.96	3.00	3.00	~~300~~ 376	~~-.11W~~	* 07	AM	307	306	305	304	304	303	303	302	301	301	300	299
		(0100)	(1600)						PM	299	298	297	296	296	296	296	296	296	296	296	296
A	5-27	4.06	2.96	3.30	3.34	~~445~~ 507	~~-.09W~~	* 06	AM	296	296	298	299	299	299	301	302	302	302	302	302
		(2200)	(0100)						PM	304	304	304	307	380	392	384	392	403	406	406	405
A	5-28	6.90	4.20	6.20	6.26	2510			AM	420	462	543	613	632	635	633	647	665	679	688	690
		(1200)	(0100)						PM	684	673	661	650	639	629	625	623	624	624	623	622
	5-29	6.19	4.72	5.42	5.45	~~1260~~ 1770	~~-.05W~~	0	AM	619	611	605	599	594	582	573	565	557	550	543	536
		(0100)	(2400)						PM	529	522	517	514	507	502	497	492	487	482	478	472
	5-30	4.70	4.04	4.36	4.37	~~960~~ 1020	~~-.05W~~	* 03	AM	470	466	463	458	458	452	449	446	443	439	437	434
		(0100)	(2400)						PM	431	429	427	424	422	420	418	416	413	409	407	404
	5-31	4.29	3.87	4.04	4.05	~~733~~ 839	~~-.03W~~	* 04	AM	403	402	399	397	395	393	391	391	391	391	390	388
		(1700)	(1300)						PM	387	392	408	423	429	429	424	418	414	412	412	413
	MONTH					~~686~~			TOTAL (CFS-DAY) =		~~38688~~										
	6-01	4.14	3.95	4.03	4.02	~~731~~ 878	~~-.03W~~	* 04	AM	414	414	414	414	413	412	410	408	407	404	401	399
		(0100)	(1400)						PM	397	395	395	395	395	395	395	395	395	396	397	398
A	6-02	4.80	3.99	4.46	4.47	~~1000~~ 1080	~~-.03W~~	* 03	AM	399	403	409	410	410	410	409	413	425	446	462	470
	PERIOD	6.90	2.26						RECORDER CLOCK RUNNING 0.9 MINUTES PER DAY SLOW. RECORD ADJUSTED.												

NOTE. SYMBOLS USED ABOVE HAVE THE FOLLOWING MEANINGS
A - SUCCESSIVE ADJUSTED PUNCH READINGS DIFFER BY MORE THAN THE SPECIFIED ALLOWABLE TEST DIFFERENCE
E - DAILY SUMMARY IS FOR AN INCOMPLETE DAY
R - ONE OR MORE INPUT VALUE IS OUTSIDE THE RANGE OF THE RATING IN USE
S - SHIFT IS A VALUE WEIGHTED BY DISCHARGE WHERE SHIFT VARYS WITH STAGE DURING THE DAY
* - UNIT VALUES RECORD WRITTEN

STAGE-SHIFT VARIATION DIAGRAM EFFECTIVE 81-04-20

HIGH POINT	0	SHIFT AT GH	5.5
BASE	-.15	SHIFT AT GH	2.2
LOW POINT	-.15	SHIFT AT GH	.01

FIGURE 28.—Primary computation sheet.

Notes for station analysis

Notes to be included in the "station analysis," described in a subsequent section, should be written when each primary computation sheet is received. The datum correction paragraph notes are updated to reflect the corrections included in each set of primary computation supplementary data. Any changes in location or equipment should be described in the paragraph headed "Equipment." All irregularities in the gage-height record, such as timer failure or faulty-intake action, should be discussed and listed by dates in the "Gage-height record" paragraph. The ratings used for the primary work should be listed in the "Rating" paragraph and their adequacy described. Shift distribution and V-diagram use should be explained in the "Discharge" paragraph. The notes will be consolidated when the final update is made.

Updating

The update is a procedure that follows the primary computation and uses one or more subsequent passes of daily data through the computer to correct errors in the primary computation caused by faulty gage-height record, ice effect, erroneous shift adjustments, or datum corrections. Updated discharges can be computed manually and substituted for the primary discharges, or, for some periods, computed entirely by ADP. Preparation of data for updating is described in the WATSTORE User's Guide.

Before starting to update a period of record, which may be as short as a month or as long as a year, retrieve a hydrograph similar to the one in figure 30 from the WATSTORE Daily Values File (hydrograph details are discussed in a subsequent section) or plot one from the primary computation sheet discharges. Plot the dis-

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1977 TO SEPTEMBER 1978
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	12	14	54	35	30	52	263	165	166	134	40	27
2	11	26	592	25	30	49	233	172	188	144	39	26
3	11	15	343	28	30	47	203	176	210	134	38	27
4	11	14	201	30	30	47	186	166	240	122	37	27
5	11	14	146	35	33	46	168	154	265	114	36	29
6	11	14	136	38	35	44	156	147	273	107	36	33
7	12	13	119	38	38	51	146	149	252	104	35	28
8	11	11	101	40	38	60	138	165	245	98	33	27
9	11	13	92	40	42	62	133	186	237	92	33	42
10	11	14	90	41	39	74	144	199	210	86	33	39
11	11	15	114	42	36	84	159	184	186	82	33	31
12	11	14	108	43	42	84	156	170	176	77	33	29
13	11	14	330	41	38	84	151	178	170	74	33	28
14	10	15	528	41	37	82	144	199	163	70	31	27
15	10	17	406	42	35	82	139	186	151	68	33	26
16	10	16	290	40	33	86	144	176	144	76	32	25
17	9.9	11	230	39	33	107	131	174	146	66	31	25
18	10	9.9	184	37	33	147	128	176	151	63	31	25
19	9.9	7.0	154	37	34	166	128	192	156	61	31	25
20	9.9	4.0	133	36	36	184	128	226	152	59	31	25
21	9.9	3.0	122	36	39	221	122	242	152	56	32	25
22	10	3.0	112	35	43	258	118	235	149	53	33	24
23	11	5.0	101	33	49	295	114	205	144	51	29	25
24	11	8.0	93	32	57	276	109	184	142	50	36	25
25	12	15	85	33	59	260	112	170	133	48	35	24
26	11	25	80	32	58	265	138	161	128	50	31	23
27	11	33	75	31	57	265	161	158	127	49	30	22
28	11	35	70	31	55	281	168	166	127	46	28	22
29	13	52	65	30	---	304	172	163	139	44	28	22
30	14	39	60	30	---	318	172	158	136	43	28	22
31	12	---	55	30	---	298	---	159	---	41	28	---
TOTAL	340.6	488.9	5269	1101	1119	4679	4564	5541	5258	2362	1017	805
MEAN	11.0	16.3	170	35.5	40.0	151	152	179	175	76.2	32.8	26.8
MAX	14	52	592	43	59	318	263	242	273	144	40	42
MIN	9.9	3.0	54	25	30	44	109	147	127	41	28	22
CFSM	.16	.24	2.47	.52	.58	2.19	2.21	2.60	2.54	1.11	.48	.39
IN.	.18	.26	2.84	.59	.60	2.53	2.46	2.99	2.84	1.28	.55	.43
AC-FT	676	970	10450	2180	2220	9280	9050	10990	10430	4690	2020	1600

CAL YR 1977 TOTAL 10643.3 MEAN 29.2 MAX 592 MIN 3.0 CFSM .42 IN 5.75 AC-FT 21110
WTR YR 1978 TOTAL 32544.5 MEAN 89.2 MAX 592 MIN 3.0 CFSM 1.30 IN 17.57 AC-FT 64550

FIGURE 29.—Final discharge record printout.

charge measurements as colored circles on the appropriate days. The hydrograph will indicate any periods that may need attention and provide clues about the dates of rating shifts.

Assemble the primary computation sheets for the period to be updated. Check the starting and ending days against the prior and subsequent sheets for continuity or agreement with discharge-measurement notes when changes were made to the control. Scrutinize the hourly gage-height lists, especially those for days labeled "A" or "R," (fig. 28) for mispunches or incorrectly read punches. Look for sudden changes in stage or long periods of no change that could indicate recorder failure or plugged intakes. Check the discharge hydrograph for odd-looking periods (recession curve lower after a rise than before, recession faster than rise, and similar inconsistencies), and if any questionable periods are found, study the corresponding gage heights and shift adjustments to find the reason. Check the datum corrections listed on the primary computation sheet against the station analysis paragraph. See that each change (resetting) to the principal gage is reflected by a change in continuity of the punched-gage heights and that the applied correction restores the continuity and agrees with the station analysis. Resolve any minor differences by accepting the primary computation to avoid unnecessary rerunning of the tapes for the affected periods.

Decide whether the ratings and shift adjustments used for the primary computation are adequate or if updating is needed for all or part of the record. Check the shift-adjustment computations for all periods whose discharge records are acceptable. Those for other periods will not be used and need not be checked. Prepare new ratings and V diagrams (if used) for

periods that will be recomputed and have them checked by another hydrographer. Try the new rating or shift adjustments by making a manual computation every 10th day or so and for about 2 days immediately before and after any periods that will be estimated.

Fill in the discharges for periods of ice effect or no gage-height record (more about these special computations later). Treat periods of particularly erratic shift-adjustment distribution as periods of no gage-height record.

When the data for the updating process (ratings, shift distributions, and substituted discharges) are ready to prepare for computer input, the final hydrograph position should be sketched in, on the basis of manually computed values for occasional days, so there will be no surprises in the final record.

Have all computations for ratings, percent differences, shift adjustments, and substituted values checked before running the update. Obtain a new hydrograph from the WATSTORE Daily Values File after the update results have been stored. Plot the discharge measurements on the new hydrograph and scan it for any mistakes that may have survived the previous checking.

After the update is complete and all figures are final, update the primary computation sheet neatly in ink as shown in figure 28. The entries should include all of the discharges changed by recomputation or substitution, the revised shift adjustments, and the gage heights from backup recorders or graphs. If any datum corrections were revised after the primary computation, rerunning the tapes is normally more convenient than manual entry of all the related changes. The edited primary computation sheet should represent the final record as published, and any figures that are formally revised in the future will be shown on this sheet.

Records from graphic recorders

During previously described operations, the form 9-192a (fig. 21) was partially completed by listing the daily mean gage heights. The subdivided-day gage heights were computed and checked on the recorder charts. The shift adjustments, if used, must be distributed and listed on form 9-192a and on the chart's subdivision tabulations. Discharge for all but the specially computed periods (ice effect, missing record, and so forth) can then be computed from the rating table and entered on form 9-192a. Discharges likely to be changed (winter months and tentative shift adjustments, for instance) may be entered in pencil, and the others may be entered directly in ink.

Discharge-measurement numbers are usually written on form 9-192a in the space for the day on which they were made, and shift adjustments may be written as shown in figure 21. The symbol "v" indicates that the shift varied during the day. Tentative figures previously penciled in are inked after they are checked and accepted as final.

Distribution of small shift adjustments, with time and stage, can be made by inspection directly on form 9-192a. Large or complex shift-adjustment distribution is best done with V diagrams and coefficients. If a new rating is started in use on October 1, a smooth transition between discharge records for the end of the previous year and the start of the current year must be maintained. One useful transition method is to treat the previous September 30 gage height and discharge as a discharge measurement. Compute the applicable shift adjustment for that day and distribute the adjustment between September 30 and the first discharge measurement of the current year.

All computations including shift-adjustment distribution, shift curves, and the subdivided days must be checked by a second hydrographer who initials and dates form 9-192a in the appropriate space. The monthly figures, except daily discharge totals, are left blank. They will be computed by ADP when the final update is made and may be copied onto form 9-192a at that time if the district considers them necessary.

Records from nonrecording gages

The process used to compute and check the discharge computations for nonrecording gages is identical to that for graphic recorders.

Discharge hydrographs

A semilogarithmic plot of daily discharges, similar to that in figure 30, depicts the day-to-day variations in discharge in an easy-to-see form, revealing some of the errors in basic data, computations, or shift distribution. It is one of the most valuable tools available for quick assessment of record consistency and is indispensable for estimating discharges for periods of ice effect or missing gage-height record. The records for several stations in an area can be compared by placing their hydrographs on a light table and shifting the individual sheets to obtain the best fit. The discharge hydrograph for a manually computed record can be plotted while the discharge figures are being computed. In this way, the effects of the shift distribution can be studied as the discharge points are plotted. An automatically plotted hydrograph of the discharge figures in the WATSTORE Daily Values File at any time can be retrieved (see WATSTORE User's Guide). Interim hydrographs, automatically plotted, of primary computation figures are particularly useful in the update process, and an automatically plotted final hydrograph is always preferable to a manually plotted version for use as the permanent file copy. Show normally computed records as a black line, estimates in color, and discharge measurements as colored circles on the final hydrograph.

National Weather Service records of daily maximum and minimum temperatures and daily precipitation are used in the discharge computations for periods of ice effect. Figure 31 illustrates one convenient format for weather records. Prints of the form provide worksheets for stations in the area of the weather station, with space to plot the winter hydrograph on a rectangular grid which is convenient for some applications.

Periods of no gage-height record

Discharge for periods of equipment malfunction or unusual stream conditions (backwater from leaves, debris, or tributaries) where the gage-height record cannot be used directly must be estimated, usually by one of the methods described in Water-Supply Paper 2175 (Rantz and others, 1982). These methods involve the use of some combination of interpolation, reconstruction of missing gage-height records, and the use of records for other stations, power plant generation records, reservoir records, and weather records. The estimated figures are entered on form 9-192a or into the ADP update process by substitution.

Periods of ice effect

The presence of ice at a stream's control causes the gage height to indicate flow greater than the actual discharge. The computation of discharge for a period when the stream was frozen is a complex and highly subjective process, different for each section of the country. Water-Supply Paper 2175 describes the freezing phenomenon in detail and explains the discharge computation methods that apply under many conditions. The figures so computed are substituted for those previously entered on form 9-192a or are included in the updating of digital recorder records.

Station Analysis

The station analysis, illustrated in figure 32, is a complete and formal discussion of the data collected for the current year. It details the amount and kind of data, its probable accuracy, and the method used for processing it. Notes for inclusion in each section should be written, by the hydrographers who actually analyzed that part of the record, when the work is done. For example, the gage-height record section notes will generally be prepared by the individuals who made the primary computations or copied the gage heights on form 9-192b, the rating section by the individuals who analyzed the rating, and so forth. The hydrographer who prepares the final update for the water year reviews these notes and writes the station analysis. The checker should always review the entire analysis carefully. It should be written clearly and concisely. Additional sections may be added to suit local needs, but the analysis must include the following six general headings:

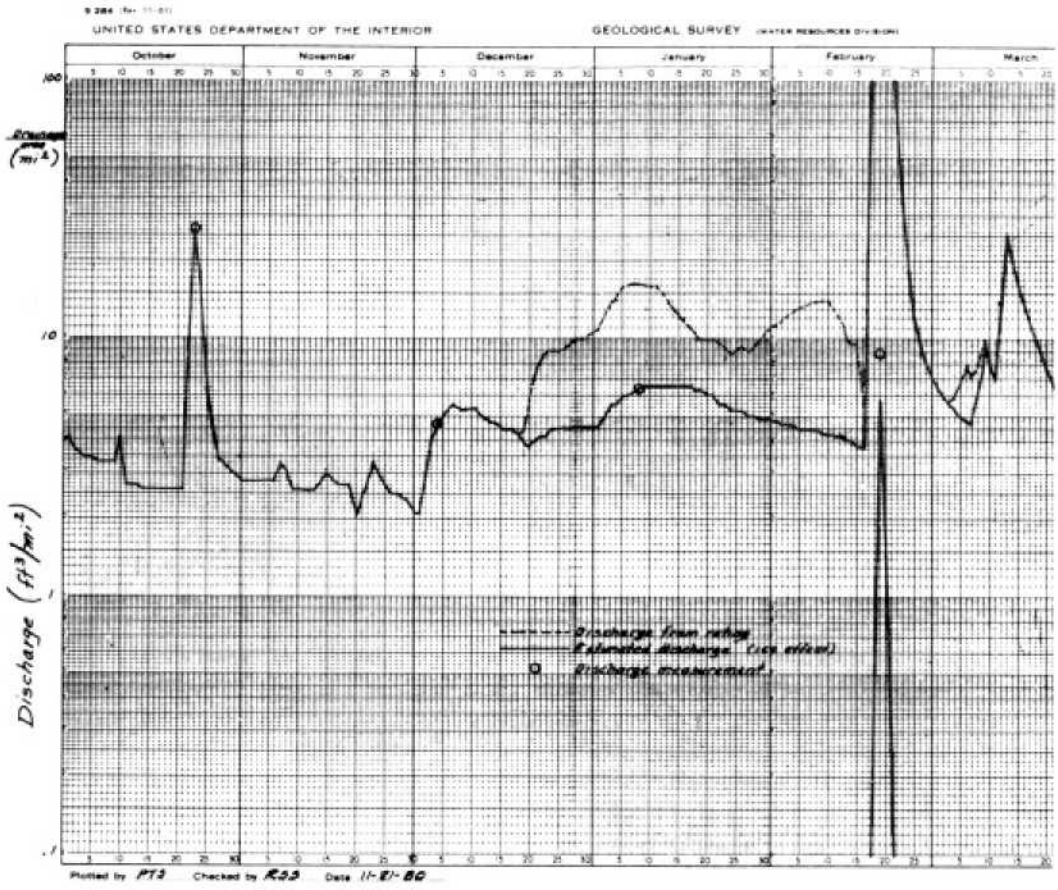


FIGURE 30.—Semilogarithmic hydrograph.

Equipment.—Start with a short statement telling the type of recorder, principal gage, and shelter. List the permanent structures outside the gage, such as outside gages, cableways and concrete controls that affect the record quality. Mention all changes in equipment and the dates.

Gage-height record.—Make a general statement about the accuracy and continuity of the gage-height record, listing all periods of missing record and the reasons for them. For a period of clock stoppage, tell if a range in stage was available or if a graph was drawn based on the observer's gage readings. List the dates for which daily gage readings are available. Mention any periods for which the record is doubtful or poor because of lagging intakes, plugged orifice, insensitive manometer, or other causes and whether the doubtful record was used. If there is more than one recorder at a station, tell which recorder was used for what period to compute the discharge record.

Datum and gage-height corrections.—Insert the gage-height correction material prepared as previously described if necessary.

Rating.—Give a brief description of the control and channel as they pertain to the current year's record. Next give the total number of measurements made during the year, their serial numbers, and the range in discharge of the measurements made during the year. Tell which were affected by ice or other unusual conditions. Explain the rest of the measurements, either individually or in groups, in terms of how they plotted with respect to the rating or ratings used during the year and why. If a new rating is drawn, state the basis for doing so. Give the reason for not drawing a new rating when one seems warranted. Explain anything out of the ordinary to help someone unfamiliar with the station to understand the situation.

Discharge.—For a digital recorder station, use a separate paragraph for a brief description of the primary computations, giving the ratings

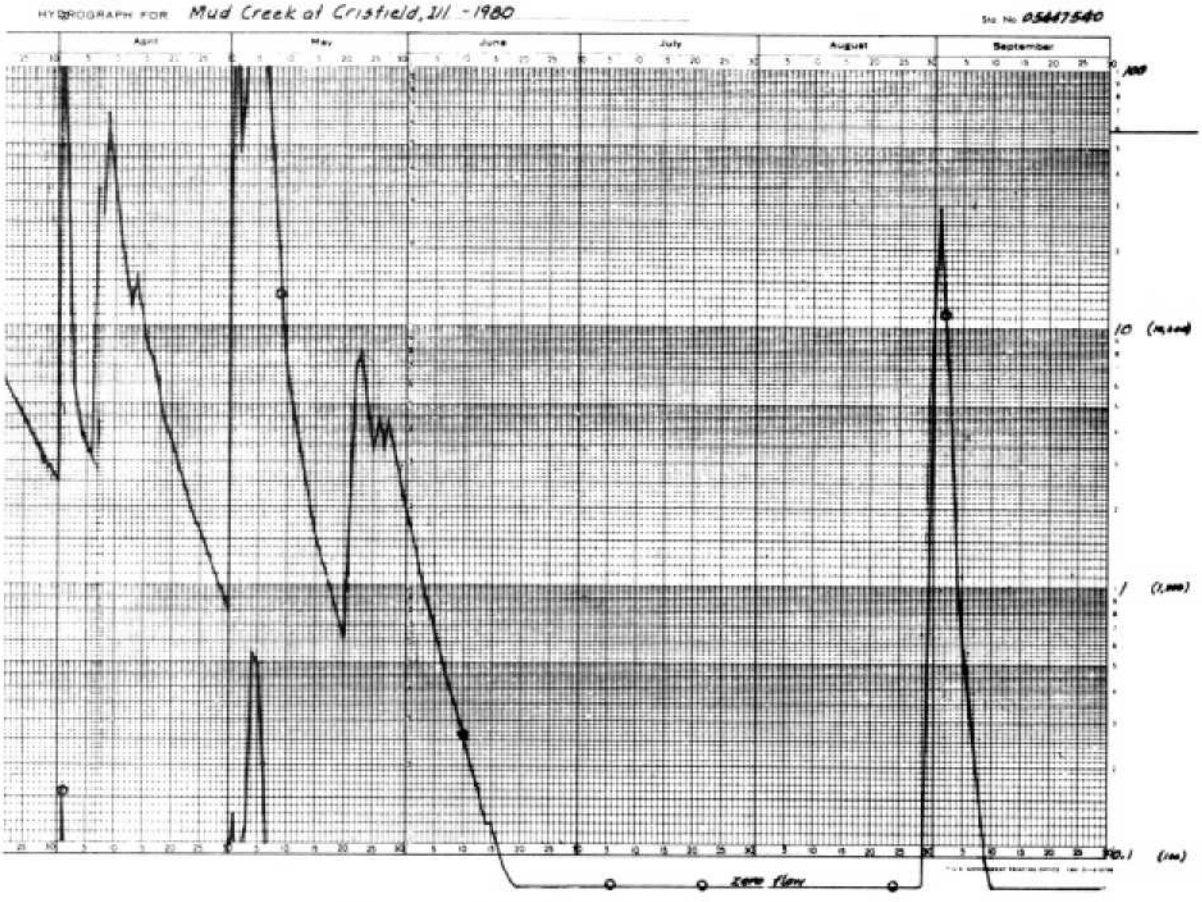


FIGURE 30.—Semilogarithmic hydrograph—Continued.

and types of shift adjustments used. Discuss the adequacy of the primary discharge records and the reasons for accepting or rejecting them as final records. In the opening sentence of the update paragraph (first paragraph for graphic recorder and nonrecording stations) state which ratings were used for the final discharge figures and their periods of use. Give the coordinates of the V diagrams used unless that information is shown elsewhere, such as on an ADP printout. List the periods for which special discharge computations (ice, missing record, or backwater) were used and give the basis for the computations. Explain all unusual features of the discharge record.

Remarks.—Give the general accuracy of the record. A rating of excellent means that about 95 percent of the daily discharges are correct within 5 percent; good, within 10 percent; and fair, within 15 percent. Poor means that daily discharges have less than fair accuracy. If some period is considerably below the rest in overall accuracy because of a lack of supporting data or because of a special method of computation, that period should be noted and rated lower in accuracy. The accuracy rating assigned in the station analysis must agree with the accuracy rating in the station manuscript.

Progress Documentation

Use some type of form to indicate the completion of each step in the record computation by a check mark, initials, or shading of an area and to ensure that the work is being done systematically and completely. The format of the sheet used depends on the type of gage and the procedures adopted by the field office to collect the data and compute the record. Figure 33 illustrates one type of progress form that can be

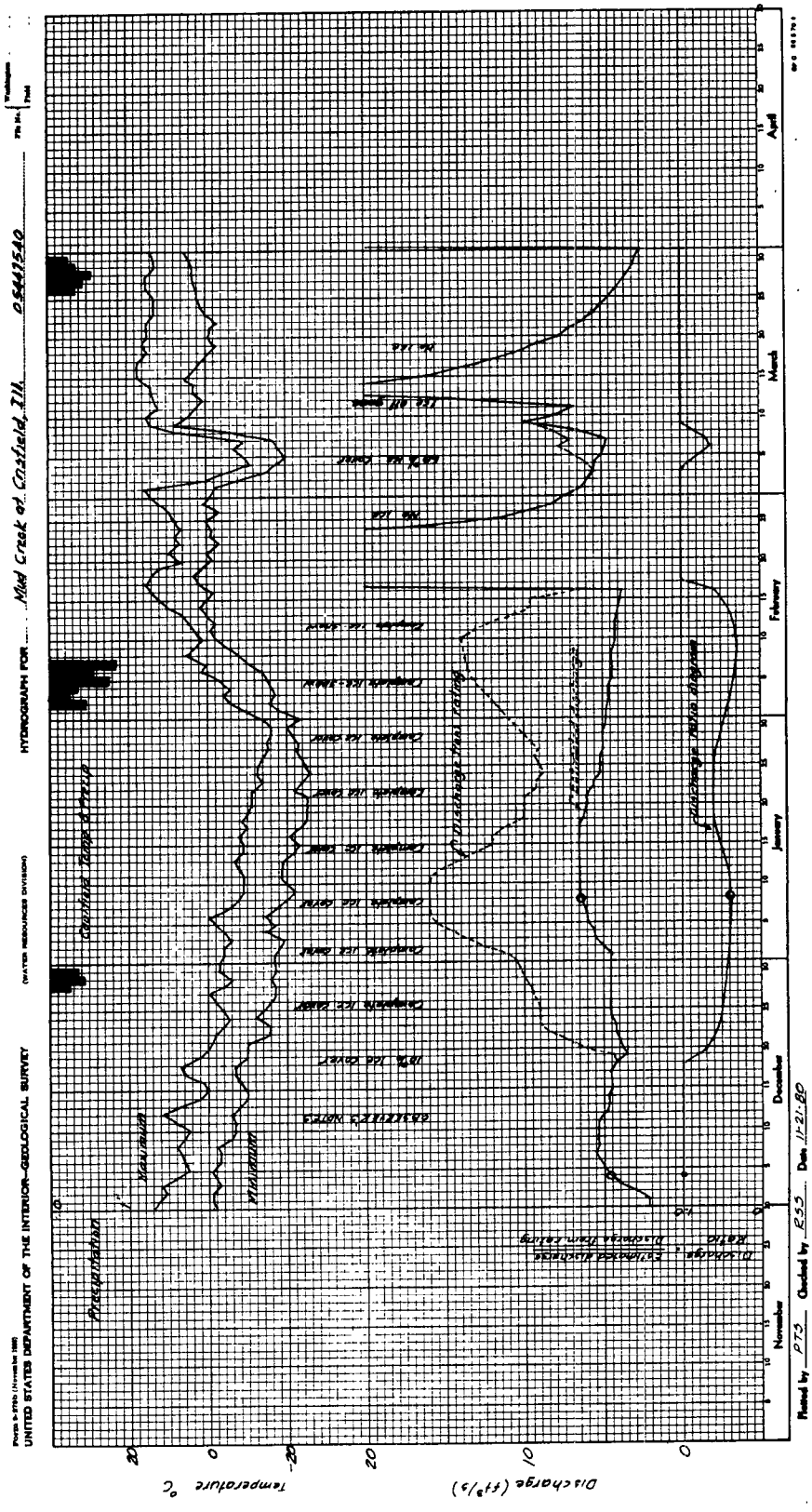


FIGURE 31.—Rectangular hydrograph and weather-record plot.

Mud Creek at Crisfield, Illinois 05447540

STATION ANALYSIS

1979-80

Equipment.--Digital recorder in 5'-4" concrete block house and well with a cableway 300 ft upstream. Local observer inspects gage weekly. No changes to equipment.

Gage-height record.--Fisher-Porter digital recorder (principal gage), checked by an electric tape (reference gage), furnished an excellent record for the entire year except for December 9-20, when the recorder was stopped by battery failure. The observer made daily electric tape readings December 14-19 and the resulting graph was satisfactory gage-height record.

Datum and gage-height corrections.--Results of levels are summarized on an attached sheet. Based on these levels, the datum correction used on September 30, 1979, notes made when a surge chain at the recorder float was untangled, and gage-height record evidence of the most likely time that the chain became tangled, the following corrections were applied to digital recorder readings:

October 1, 1979	(0000 hrs)	-.02	
November 6, 1979	(1430 hrs)	0	Levels--gage reset
December 11, 1979	(0330 hrs)	-.05	Surge--most likely time of tangle
January 3, 1980	(1415 hrs)	0	Chain untangled; Ght dropped .05 ft
September 30, 1980	(2400 hrs)		

No corrections were applied to other gages.

Rating.--The channel, about 20 ft wide at low flow, 120 ft wide at bankfull stage (12 ft), and 600 ft wide during floods, has stable wooded banks and a loose rock and gravel bed. The rocky gravel riffle collects debris and supports algae growth but is otherwise stable for long periods. Seven current-meter measurements (nos. 132-134, 136-139), a slope-area measurement (no. 135), and one observation of no flow were made during the year. Six additional observations of no flow were made by the observer. The measurements cover the entire range of flow during the water year.

The discharge measurements indicate that a low-water shift from last year's rating (no. 8) occurred during the September 3, 1979, rise and that the high-water portion of that rating needs minor revision in order to fit the recent slope-area measurement. Rating no. 9 was developed on the basis of the current data and is identical to rating no. 8 between 2.2 and 18 ft stages. The new rating is well defined throughout and reasonably consistent with all prior high-water ratings, so revisions to past records are unnecesary. The 1979 records for September, with the shift adjustments used agree closely with rating no. 9.

Discharge.--(Primary computations). Primary computations were run using rating no. 8, extended to 27 ft to cover the February 19 peak, with the V-diagrams shown on the primary computation sheets. All gage heights listed are final values. Most of the discharge figures were recomputed from the equivalent gage heights in the updating.

(Update). Rating no. 9 was used for the entire year. A V-diagram (2.0, -0.05; 6.0, -0.05; 8.0, 0) was used from February 19 to May 9 for stage-only distribution and from June 1 to September 30 for stage and time distribution of shift adjustments. Primary computation discharges for days whose gage heights were all between 8 and 18 ft are equivalent to those from rating no. 9 and were used without revision.

Discharge for the periods of ice effect (December 19 to February 16) was computed on the basis of one discharge measurement, gage heights, weather records and records for nearby stations.

Discharge for periods of no gage-height record (December 10-13) was estimated on the basis of weather records and records for nearby stations.

Remarks.--Records are good except those for December and January, which are poor.

Prepared	P. T. Spalding	12-1-80
Checked	R. S. Sands	12-4-80

FIGURE 32.—Station analysis.

Sta. No. _____

PROGRESS CHECKLIST

COMPUTATION OF DIGITAL RECORDER RECORDS

Station_____ Water Year_____

PRIMARY COMPUTATIONS

- Review disch. msts. - check ghts with tape
- Review tape for continuity with previous tape
- Update datum correction and apply to tape headers and meas.
- List discharge msts. and remarks on 9-207
- Plot disch. msts. (worksheet) - if rating is OK, skip a line
- Prepare discriptors for new rating - obtain RATLIST
- Compute shift adjustments and percent diff.
- Prepare or update V-diagram - distribute shifts
- Update station analysis notes
- Transmit tapes and supplemental data - obtain hydrograph

UPDATE

- Plot disch. msts. on prim. comp. hydrograph
- Review levels data. Update datum correct. Rerun P.C. if necess.
- Review P.C. sheets (continuity and agreement with meas.)
- Review rating. If P.C. rating is satisfactory, skip three lines
- Prepare new work curve sheet
- Prepare descriptors for new rating - obtain RATLIST
- Recompute shifts and % for update period msts.
- Update old or prepare new V-diagram
- Distribute shift adjustments
- Rough in final hydrograph position on P.C. hydrograph
- Compute ice, missing, and other special computation records
- Update station analysis notes
- Check the above work
- Prepare station analysis final copy (typed)
- Check final station analysis
- Prepare master curve sheet
- Transmit update material - request hydrograph
- Plot meas. on new hydrograph

FINAL ASSEMBLY

- Compute and list peak disch., min. disch., and aver. disch.
- Prepare manuscript and annual report page copy
- Check above work

QUALITY CONTROL

- Prepare basin comparison (monthly records)
- Check comparison

By_____Date_____ Broad review (all records)

Intensive review with memorandum (selected records)

FIGURE 33.—Typical progress form.

used for digital recorder stations whose primary computations are run currently and updated monthly, quarterly, or annually. Equivalent forms for graphic-recorder stations are simpler, and more elaborate forms can be designed to indicate the percent completion of each record at any time.

Quality Assurance

The quality of a station record depends to a large extent on natural conditions at the site and the management practices used to obtain the best records with the available manpower

and equipment. The adequacy of a record can be gaged to some extent by having an experienced hydrographer review the process used to obtain the data and compute the record. The reviewer ensures that approved methods were used throughout or that locally devised procedures were proper. All records should receive a brief review by a hydrographer not involved in the computations. A few records (5–10 percent of the total) should be thoroughly reviewed, and a memorandum of review prepared by a supervisor each year. An outside (regional, other district, or headquarters) assessment of technical operations is provided about every other year and includes a thorough review of a sampling of the gaging-station records.

Parts of most discharge computations depend on subjective judgment, especially for rating extensions, shift distribution, and estimates. Substantial errors are usually apparent from hydrographic comparison of each station record with others from the same general area. A basin comparison of monthly and annual discharges may provide a good check for major errors. Figure 34 illustrates the simplest type of basin comparison, one that can be used in a relatively humid area where the runoff from gaged areas is comparable to that from ungaged areas. A table of monthly discharges for all stations in a basin is arranged in downstream order. The monthly discharges must be adjusted for travel time between adjacent stations by advancing the downstream station period by an estimated number of days. The runoff figures (in cubic feet per second per square mile) for tributary stations are listed and those for ungaged areas are computed, listed, and underlined. If the gaging station records are free from gross errors, the underlined runoff figures will ordinarily be comparable to the other figures in the column.

The discharge of streams in arid areas does not increase uniformly downstream and may decrease in certain reaches. The gains or losses in monthly flow between stations do not indicate the reliability of records for this type of stream, and other assessments based on knowledge of the hydrology of the region must be made.

If the assessment procedure identifies the records for a very poor site as dubious, alternatives to collecting daily discharge records there should be considered.

References Cited

Carter, R. W., and Anderson, I. E., 1963, Accuracy of current-meter measurements: American Society of Civil Engineers Journal, v. 89, no. HY4, p. 105-115.

Follansbee, R., 1938, A history of the Water Resources Branch of the United States Geological Survey to June 30, 1919: Washington, D.C., privately printed, 459 p.

Hutchinson, N. E., and others, 1975 (v. 1), WATSTORE User's Guide: U.S. Geological Survey Open-File Report 75-426, Reston, Va., 523 p.

Hutchinson, N. E., and others, 1980 (v. 5), WATSTORE User's Guide: U.S. Geological Survey Open-File Report 77-729-I, Reston, Va., 357 p.

BASIN COMPARISON
(Portion of Ohio River Basin in Illinois - 1977-78 Water Year)

	Ohio River Basin	Dr. Area	Time Advance (days)	Oct. cfs	Oct. csm	Nov. cfs	Nov. csm	Water Year cfs	Water Year csm
1	Wabash River Basin (continued)								
2	Little Wabash - Effingham	240	0	62.4	.26	34.5	.14	237	.99
3	Ungaged [4 - 2]	505		94.6	.19	142	.28	531	1.05
4	Little Wabash - Louisville	745	+1	157		177		768	
5	Ungaged [6 - 4]	386		108	.28	50	.13	277	.72
6	Little Wabash - Clay City	1131	+1	265		227		1045	
7									
8	Skillet Fk. - Iuka	208	+1	28.4	.14	87.3		181	.87
9	Horse Cr. - Keene	97.2	+1	8.1	.09	26.5		83.9	.86
10	Ungaged [11-(8 + 9)]	159		20.1	.13	56.2	.35	126	.79
11	Skillet Fk. - Wayne City	464	+2	56.6		170		391	
12	Ungaged [13 -(6 + 11)]	1507		391	.26	570	.38	1286	.85
13	Little Wabash - Carmi	3102	+4	713		967		2722	
14	Little Wabash - Carmi	3102	0	821	.27	584	.19	2722	.88
15	(continued)								

FIGURE 34.—Basin comparison of monthly and annual runoff.

Kennedy, E. J., 1982, Discharge ratings at gaging stations: U.S. Geological Survey Techniques of Water Resources Investigations, book 3, Chap. A-10 (in press).

Rantz, S. E., and others, 1982, Computation of discharge: U.S. Geological Survey Water-Supply Paper 2175 (2 vol.,) 631 p.

Thomas, N. O., and Jackson, N. M., Jr., 1981, Manual for leveling at gaging stations in North Carolina: U.S. Geological Survey Open-File Report 81-1104, Raleigh, N. C., 36 p.

Glossary

ADP	Automatic data processing used to compute the discharge records for digital recorder stations
Discharge hydrograph	A semilogarithmic plot of daily mean discharges for a water year, used as a visual check of the continuity of computed discharges and a means of comparing discharges for different stations
Primary computation	The ADP process normally used for the first pass of streamflow data through the computer. The recorder tape, rating, shift-adjustment-distribution instructions, and datum corrections are input. A tentative daily discharge and hourly gage-height printout are output and a discharge hydrograph is optional.
Scalloping	An undesirable discharge-rating characteristic in which the straight-line segments of a logarithmic rating curve, when plotted using rectangular coordinates, billow upward between nodes at the descriptor points. The corresponding rating table has erratic discharge differences per tenth foot of gage-height difference.
Shape curve	A previous rating curve, or one based on a special study, whose shape is similar to the rating curve being developed
Shift adjustment	An adjustment, usually varying with time and stage, applied to gage heights in order to compensate for a change in the rating shape or position
Shifting-control method	The systematic use of shift adjustments as a substitute for revised ratings
Station analysis	A narrative description, in a standard format, of the gaging-station equipment, its performance, and the methods used to compute the discharge record
Update	The ADP process by which discharges from the primary computation are revised by using a different discharge rating, different shift adjustments, or substituted manually computed values to compile the final discharge record.
WATSTORE User's Guide	Volume 5 (record processing) and volume 1 (data files) of a set of instruction manuals regarding the format of data input to the ADP system used for discharge-record computation.