

Surface-Water Records.

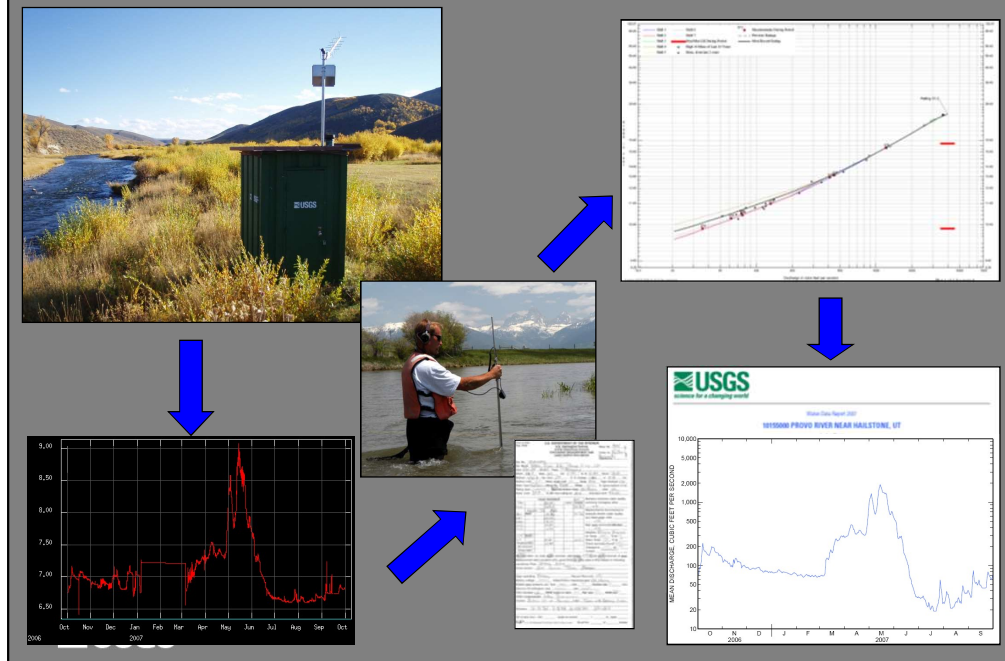


Narrated by Joe Nielsen



Streamflow-gaging stations are used to provide a continuous record of streamflow or discharge. For a variety of reasons, it is not possible to directly measure streamflow on a continuous basis. River stage, or water surface elevation, is therefore most commonly used as a surrogate for streamflow, as it can be easily measured on a continuous basis. The collection of surface-water records at most U.S. Geological Survey streamflow gaging stations is thus a computational process that relates the continuous record of river stage measured at a streamflow-gaging station to the streamflow or discharge. This module discusses the various steps in that computational process. These types of surface-water records are often referred to as stage-discharge records.

Methods for computing surface water records.



This overview describes the methods and techniques used by the U.S. Geological Survey to produce an accurate and complete record of discharge from a continuous time series of recorded stage. Starting with the continuous record of stage, you will become familiar with the processes of correcting the recorded stage using data corrections. Additionally, you will learn of the processes used to develop and maintain the relation between stage and discharge. Finally, you will be introduced to techniques used to estimate daily mean discharges for periods of missing, erroneous, or ice affected stage record. The goal of this module is a detailed introduction to the surface-water record computation process.

Slide 2

IWSC1 Terry, I think that it would be good to have a lead-in slide prior to this one to introduce the subject of the training module.

Idaho Water Science Center, 12/9/2008

Terminology to review.

- Stage: The water-surface elevation at a gaging station, usually referenced to an established datum plane.
- Gage height: The water-surface elevation at a gaging station, usually referenced to an arbitrary datum. Use of the term gage height is more appropriate when referencing a reading on a gage.
- Unit value: The instantaneous value of a parameter at a moment in time, either measured or computed. The collection frequency of unit values is dependent upon the recording equipment.
- Daily value: A statistical computation of a parameter over a single day.
- Data corrections: Corrections made to a measured parameter, such as stage.
- Stage-discharge rating: The developed relation between stage and discharge. Often simply referred to as a "rating".
- Rating shift: A temporary change to an existing rating that is entered as an adjustment, or offset, to the current rating rather than as an entirely new stage-discharge relation.



There are terms used in this overview of surface water records that would be helpful to briefly review.

Stage and gage height are often used interchangeably to refer to the water-surface elevation at a gaging station. It should be noted that stage is usually measured to an established datum, and that gage-height should really refer to the reading on a gage. Neither reading can be used to directly implied mean "depth of water".

Unit values are instantaneous values at specific moments in time. These values can be either measured at the station or computed from measured values. The frequency of unit values is dependent on the recording equipment and will often be every 15 or 60 minutes, although other frequencies are not uncommon.

A daily value is a statistical computation of a specific parameter, such as discharge, over a single day. Examples include daily mean values, daily minimum values, and daily maximum values.

Data corrections are corrections made to a measured parameter, such as stage. Data corrections can be used to account for things such as equipment drift or the physical movement of a reference gage.

The stage-discharge rating is the relation between stage and discharge, developed from direct discharge measurements made over the period of record of the station. For a detailed discussion on stage-discharge ratings see the stage-discharge relations module.

Shifts are adjustments to the stage-discharge ratings that are used to represent

temporary changes to the rating as defined by new discharge measurements. Shifts are entered as an offset to the current rating rather than as an entirely new rating.

Slide 3

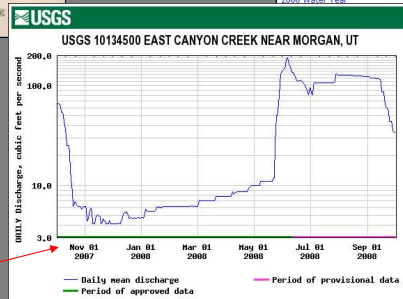
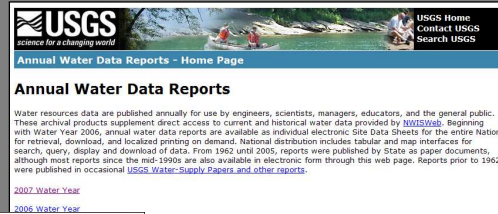
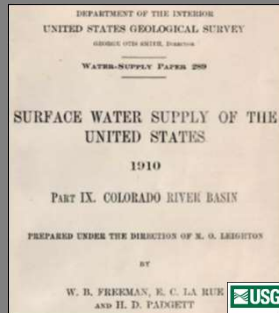
IWSC4 I moved the heading to the right to better align with the bullets.
Idaho Water Science Center, 12/9/2008

IWSC2

Surface water records are published at all continuous USGS streamflow gaging stations.

<https://sims.water.usgs.gov/SIMS/SIMSHome.aspx>

(Navigate to WSC of interest and then to station of interest)



Period of approved record is noted by green background

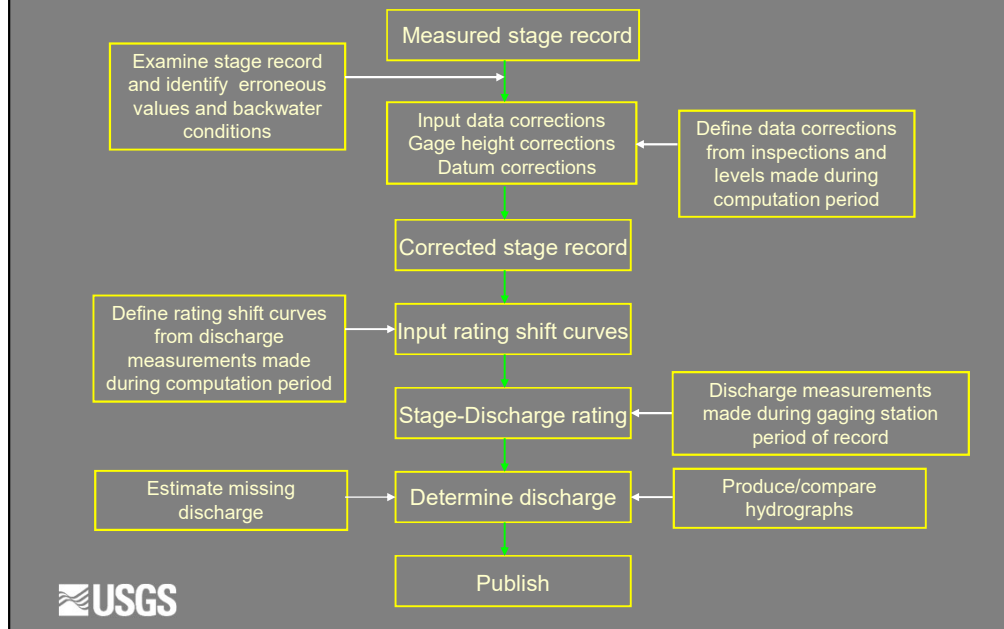
USGS — A map-based tool for locating hydrologic data
Material: Details and explanations regarding site numbering, data reported, and accuracy of
USGS — Related links to USGS data, methods (TWRs), special programs and networks, and
Systems Incorporated has information about PDFs and the visually impaired. This
make PDF files accessible. These tools convert Adobe PDF documents into HTML or ASCII
a number of common screen-reading programs that synthesize text as audible speech. In
Adobe Reader, which contains support for screen readers, is available. These tools and
are used free from Adobe at [Adobe Access](#).
Policies and Notices
U.S. Geological Survey
Water Data Report Team
8/10/08 10:48:03

Surface-water records are finalized and published at all continuous USGS streamflow gaging stations. Surface-water records can include final values of stage, velocity, and/or discharge. Publication is traditionally done by water year. Final values are usually daily values but can also include instantaneous data, or unit values, the frequency of which are dependent upon the recording interval of the gaging station. Historically, surface water data for all USGS continuous gaging stations were published in annual data reports, originally organized by river basin and later by state. Currently, surface water data are finalized and approved at more frequent intervals throughout a water year and are available online through the USGS National Water Information System: Web Interface or NWISWeb. Annual publications of these data by water year, similar to the historic format, are also available on line at <http://wdr.water.usgs.gov>.

Slide 4

IWSC2 Slide looks good, I changed NWISweb in the narration to NWISWeb. The URL is correct and works good.
Idaho Water Science Center, 12/9/2008

Stage-discharge record computation process.



For this overview we will be concentrating on a stage-discharge record for a typical USGS streamflow-gaging station. A stage-discharge record is one in which river stage is collected at a gaging station as a surrogate for discharge. This flow chart describes the basic steps used in computing such a record. The record computation starts with the raw measured stage data from the station. These data are first examined for erroneous values. If necessary, data corrections based upon field observations are applied. These initial steps are designed to produce the most accurate and representative time series of gage height for the period of interest. Using discharge measurements made during the record period together with the active stage-discharge rating, shift curves are developed. Next, unit value and daily value discharges are computed from the time series of gage height using the rating and shift curves. At this point, periods of missing, erroneous, or backwater affected record are estimated. Hydrographs for the station of interest are produced and compared with nearby stations to help in the estimation process and to aid in validating the shift curve applications. Finally, the surface water record is ready to be checked, reviewed, and published. We will generally be following this flow chart as we describe in detail the surface-water records computation process.

Slide 5

k3 I increased font and line sizes.
kmnolan, 12/1/2008

IWSC3 Idaho Water Science Center, 12/9/2008

k4

IWSC5

References.

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

Chapter A13

COMPUTATION OF CONTINUOUS RECORDS OF STREAMFLOW

By E. J. Kennedy

<http://pubs.usgs.gov/twri/twri3-a13/html/pdf.html>

Measurement and Computation of Streamflow: Volume 2. Computation of Discharge

By S. E. RANTZ and others

GEOLOGICAL SURVEY WATER-SUPPLY PAPER 2175



<http://pubs.usgs.gov/wsp/wsp2175/>



Here are a few references specific to the computation of surface water records that have been published by the USGS.

Slide 6

k4 I changed text color to make it easier to see.
kmnolan, 12/1/2008

IWSC5 I changed the font size of the heading to match the other slides.
Idaho Water Science Center, 12/9/2008

Measured stage record.



Staff plate reference gage



Wire-weight reference gage

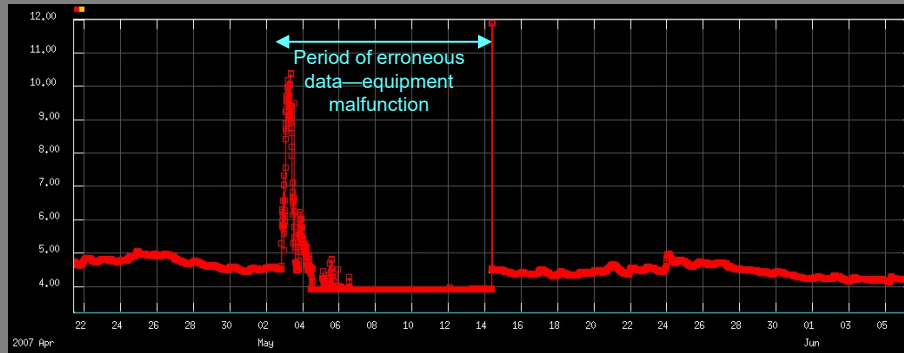


Time-series of measured stage

As described in the Stage Record module of this course, gaging stations are used to record the river stage. Gage datum is established and the data recorder is set to the stage of the reference gage, often a staff plate or a wire-weight gage. The recording interval for a typical streamgage is 15 minutes. This time series of recorded gage heights comprise the measured stage record or unit value stage record.

k16

Examination of measured stage record.



An examination of the measured stage record for erroneous values is an important first step in the record computation process. Erroneous values are those that are not representative of the actual river stage even with a correction applied. These would include erratic spikes in gage height caused by garbled data transmissions, gage heights associated with a malfunctioning measuring device or associated equipment, or gage heights measured in a pool out of communication with the stream. These values are removed, or flagged to be excluded from any further analysis, as they are not representative or related to the stage in the stream and thus cannot be used to calculate discharge. The discharge during these period will be estimated later on in the computation process.

Here are a graphical representation of measured stage record that was flagged and not used to compute the final discharge. The plot shows a period of erroneous gage height record. The equipment began to malfunction around May 3 by recording erroneously high gage heights. The equipment then flatlined until May 14 when the site was visited and the equipment repaired. These recorded stage values are not representative of the actual river stage.

Slide 8

k16 I increased font and line sizes.
kmnolan, 12/1/2008

Correcting the measured stage record.

- Identified differences between the primary reference gage and the recorder are applied to the measured stage record as “gage height corrections.”

GAGE READINGS				P.F.F.	
Time			Inside	Outside	
10:10		8210	10.78	+0.04 = 10.82	10.82
	Reset To	86			
10:11	Start		10.82	+0.00 = 10.82	10.82
10:15			10.82		
10:30			10.81		
10:45			10.80		
11:00			10.79		
11:05	Finish				
11:10			10.80		10.79
Weighted MGH			10.80		
GH correction					
Correct MGH					



The measured stage record that is not determined to be erroneous may at times still not precisely represent the actual river stage due to equipment drift, slight equipment malfunction, or physical movement of the reference gage. To obtain the most representative record of stage at such times we need to apply corrections to the measured stage record. These adjustments, known as “gage height corrections,” are determined from observed differences between the reference gage and data recorder during visits to the station.

Station inspection or measurement note sheets, like the one shown, have fields for documenting the gage height at the reference gage and the data recorder. In this example, the reference gage is the outside gage and the data recorder is noted as 8210. At the time 10:10 the recorder was reading 10.78 feet and the reference gage was reading 10.82 feet. The recorder is 0.04 feet lower than the reference gage, thus a correction to the stage record of +0.04 feet needs to be applied. Note that the recorder was reset to the reference gage one minute later at 10:11 and the correction at that time is thus zero.

Correcting the measured stage record.

- Differences found between the gage datum and reference gage are applied to the measured stage record as “datum corrections.”



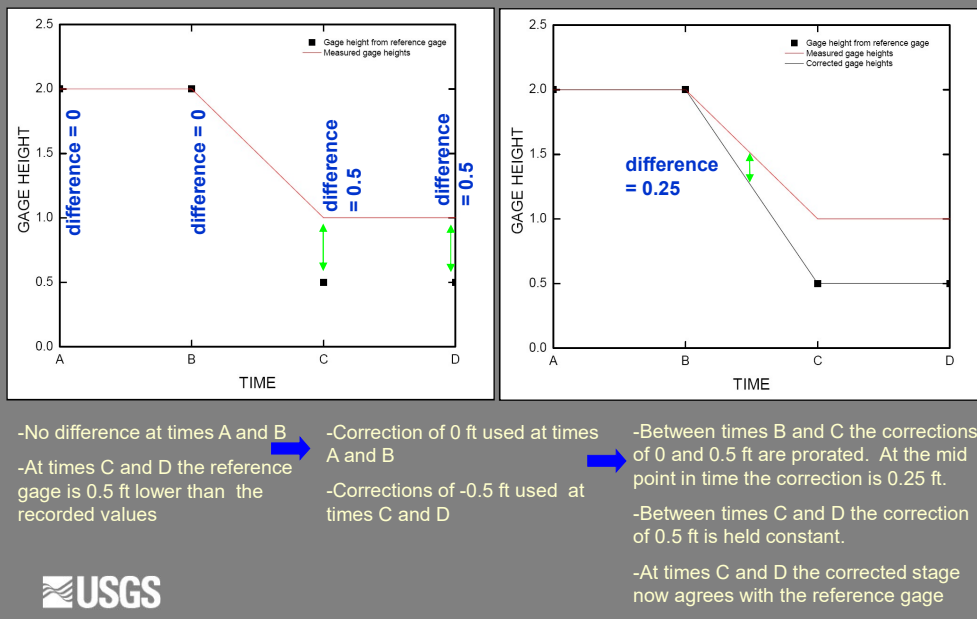
Levels are routinely run at gaging stations to ensure that the reference gage is in agreement with the established gage datum and thus reads the correct stage. The reference gage can move due to the effects of ice heave during winter months, ground settling, or the impact of flood debris. If the reference gage is found to be out of agreement with gage datum it will not read the correct stage and the recorder, while otherwise functioning normally, will have been set incorrectly because it was referenced to an incorrect reference reading.

When this occurs, what is known as a datum correction needs to be applied to the measured stage record. It is important to determine the likely cause for the difference between the gage datum and the reference gage in order to properly apply the datum correction over the affected time period. Gage height readings associated with the reference gage which are documented on inspection sheets or discharge measurement note sheets during periods affected by a datum correction need to be adjusted as well.

k6

IWSC6

Application of data corrections: Prorating a correction



Corrections to the measured stage record, whether gage height corrections or datum corrections, are generally called data corrections. Although the magnitude of a given data correction is known at the time of the site visit during which it was found, in applying the correction to the time series stage record a decision must also be made regarding the effects of the correction over time. Although sometimes a specific event can be found which is thought to have caused the needed data correction, it is often the case that the cause of the correction is believed to have occurred gradually, such as with instrument drift.

Because of this, corrections are allowed to prorate both forward and backward in time to the next observation and/or correction. Time proration allows sequential correction values of different magnitudes to be smoothed into one another through time. In this example, the plot on the left shows continuous measured gage height record from time A to time D as a red line. Visits were made at times A, B, C, and D and the gage heights associated with the reference gage are shown as black squares. The recorded value matched the reference gage value at times A and B, however the reference gage was 0.5 feet lower than the recorded values at times C and D. Data corrections were applied at the time of each visit. At times A and B, when the reference gage agreed with the recorder, a correction value of 0 was applied, and at times C and D, when the reference gage was 0.5 feet lower than the recorder, a correction value of -0.5 feet was applied. Without any direct observations of the reference gage between times B and C the applied correction was allowed to prorate over the time between the two visits. As shown in the plot on

the right, at a time halfway between B and C the measured gage height was corrected -0.25 ft, which is the mid point between the data corrections applied at times B and C. The correction values between times A and B was a constant of zero, and between times C and D was a constant of -0.5 feet. The final corrected gage height record is represented by the black line in plot on the right.

Slide 11

k6 I increased font and line sizes.
kmnolan, 12/1/2008

IWSC6 I added some wording to the description to make it more understandable.
Idaho Water Science Center, 12/9/2008

Corrected stage record.

- The corrected stage record is the best representation of river stage for the time period of interest based upon the available data.

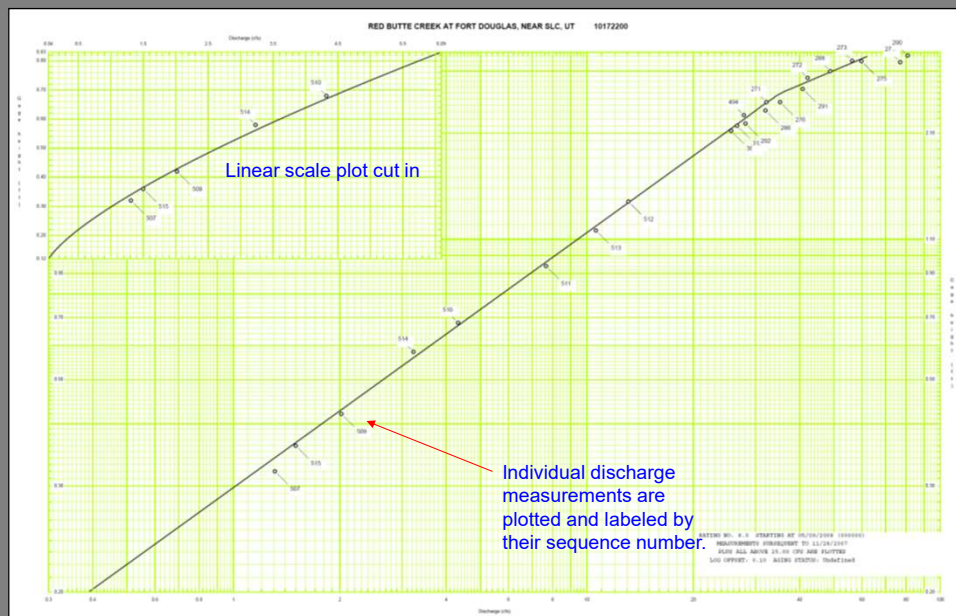


After identifying and removing from analysis erroneous data and applying the determined data corrections, the corrected stage record is produced. The corrected stage record is the best representation of river stage for the computation period based upon available data. The next step is to assign discharge values to this corrected stage record using the stage-discharge rating and any needed shift curves. We will now discuss the stage-discharge rating and the process of developing shift curves.

k7

IWSC7

Stage-discharge rating curve



Learn about the development of a stage-discharge rating see the Stage-discharge Relations module.

As you learned in the module on stage-discharge relations, a stage-discharge rating is the relation between stage and discharge developed from pairings of measurements acquired over a wide range of conditions during the period of record of the gaging station. In the next several slides we will review basic concepts about ratings and rating shifts, or shift curves, before we learn how ratings and shift curves are used in records computations.

Here is an example of a typical stage-discharge rating curve. Gage height is shown on the Y axis and discharge is shown on the X axis. In most cases rating curves are predominantly developed on a logarithmic scale because the relation is typically straight when plotted on a log scale.

Slide 13

k7 I increased font and line sizes.
kmnolan, 12/1/2008

IWSC7 I changed the heading to Arial 28 font size to match the remainder of the slides.
Idaho Water Science Center, 12/9/2008

Stage-discharge rating table

1

U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

STATION NUMBER 10172200 RED BUTTE CREEK AT FORT DOUGLAS, NEAR SLC, UT SOURCE AGENCY USGS STATE 49 COUNTY 035
 LATITUDE 404648 LONGITUDE 1114819 NAD83 DRAINAGE AREA 7.25 CONTRIBUTING DRAINAGE AREA DATUM 5400.00 NGVD25
 Date Processed: 2008-09-30 16:29 By tkennedy
 Rating for Discharge (cfs)
 Created by mjfisher on 05-06-2008 @ 13:13:27 MDT. Updated by menight on 06-11-2008 @ 14:34:13 MDT
 Remarks:

OFFSET: 0.10 BREAK, OFFSET: (2.60, 0.00)

EXPANDED RATING TABLE

Stage height, feet	Discharge (cfs)									DIFF IN Q PER .1 UNITS
	.00	.01	.02	.03	.04	.05	.06	.07	.08	.09
0.10										
0.20	0.39	0.44	0.50	0.56	0.62	0.68	0.75	0.81	0.88	0.94
0.30	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.5	1.6	1.7
0.40	1.8	1.9	1.9	2.0	2.1	2.2	2.3	2.4	2.5	2.6
0.50	2.6	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5
0.60	3.6	3.7	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5
0.70	4.6	4.7	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.6
0.80	5.7	5.9	6.0	6.1	6.2	6.3	6.4	6.6	6.7	6.8
0.90	6.9	7.0	7.2	7.3	7.4	7.5	7.6	7.8	7.9	8.0
1.00	8.1	8.3	8.4	8.5	8.6	8.8	8.9	9.0	9.2	9.3
1.10	9.4	9.5	9.7	9.8	9.9	10.1	10.2	10.3	10.5	10.6
1.20	10.7	10.9	11.0	11.1	11.3	11.4	11.6	11.7	11.8	12.0
1.30	12.1	12.2	12.4	12.5	12.7	12.8	13.0	13.1	13.2	13.4
1.40	13.5	13.7	13.8	14.0	14.1	14.3	14.4	14.5	14.7	14.8
1.50	15.0	15.1	15.3	15.4	15.6	15.7	15.9	16.0	16.2	16.3
1.60	16.5	16.6	16.8	16.9	17.1	17.3	17.4	17.6	17.7	17.9
1.70	18.0	18.2	18.3	18.5	18.7	18.8	19.0	19.1	19.3	19.4
1.80	19.6	19.8	19.9	20.1	20.2	20.4	20.6	20.7	20.9	21.1
1.90	21.2	21.4	21.5	21.7	21.9	22.0	22.2	22.4	22.5	22.7
2.00	22.9	23.0	23.2	23.4	23.5	23.7	23.9	24.0	24.2	24.4
2.10	24.5	24.7	24.9	25.1	25.2	25.4	25.6	25.7	25.9	26.1
2.20	26.3	26.4	26.6	26.8	27.0	27.1	27.3	27.5	27.7	27.8
2.30	28.0	28.2	28.4*	28.5	28.7	28.8	29.0	29.2*	29.3	29.5
2.40	29.7	29.9*	30.1	30.3	30.4	30.6	30.7*	30.9	31.1	31.3
2.50	31.5	31.6*	31.8	32.0	32.2	32.4	32.6	32.8	33.0	33.2
2.60	33.4*	33.6	33.8	33.9	34.1	34.3*	34.5	34.8	35.0	35.3*
2.70	35.5	35.8	36.0	36.3*	36.6	37.0	37.3*	37.7	38.0	38.3
2.80	38.7	39.0	39.4	39.7	40.0	40.4	40.7	41.1	41.4	41.8
2.90	42.1	42.5	42.8	43.2	43.6	43.9	44.3	44.7	45.0	45.4
3.00	45.8	46.1	46.5	46.9	47.3	47.6	48.0	48.4	48.8	49.2
3.10	49.6	50.0	50.4	50.7	51.1	51.5	51.9	52.3	52.7	53.2
3.20	53.6	54.0	54.4	54.8	55.2	55.6	56.0	56.5	56.9	57.3
3.30	57.7	58.2	58.6	59.0	59.5	59.9	60.3	60.8	61.2	61.6
3.40	62.1*									

** indicates a rating descriptor point

A rating table is developed from the rating curve to facilitate manual application. Here is the rating table for the previously shown rating curve. The gage height is shown to each tenth of a foot in the left column. The other columns headings specify the hundredths place. To determine a discharge for a specific gage height, first find the corresponding row that matches the gage height of interest to the tenth place. Then move right to the corresponding column that equals the hundredth place of the gage height of interest to get the discharge. For example, on this rating table the discharge for a gage height of 0.56 feet is 3.2 cubic feet per second.

Slide 14

k8

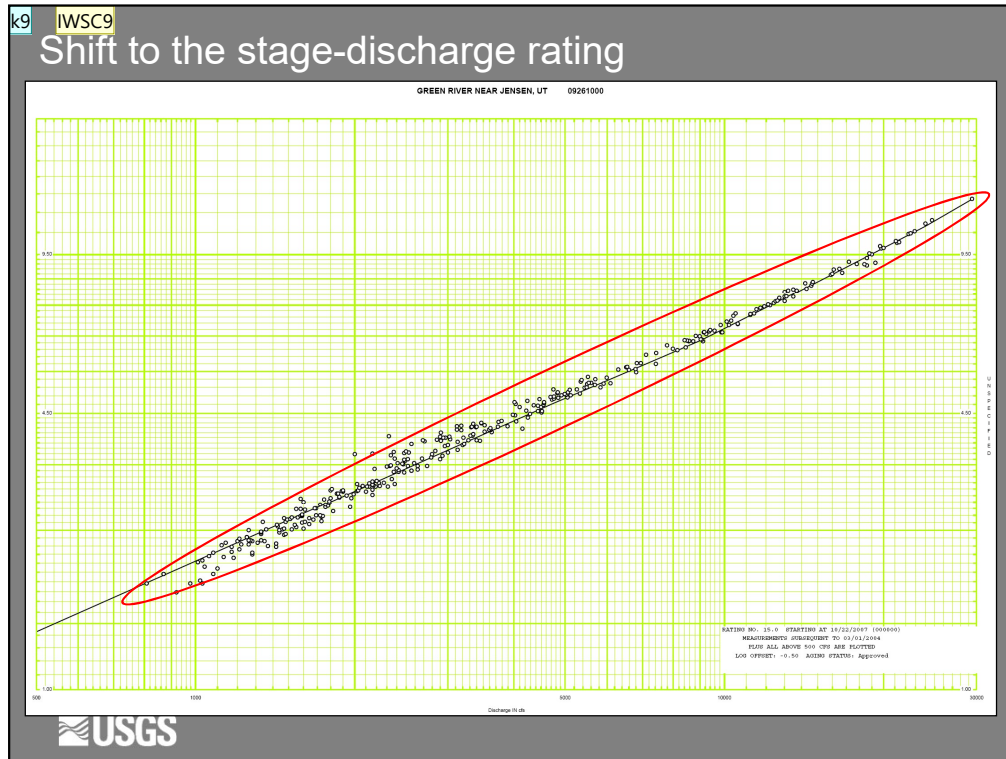
I increased line sizes.

kmnolan, 12/1/2008

IWSC8

I changed the heading size to Arial 28.

Idaho Water Science Center, 12/9/2008



Natural stream channels are not static systems but change over time. Such changes can include scour or fill during flood events, long-term stream aggregation, or shorter term effects such as algal growth or debris build up on the hydraulic control. If one plots all the available measurements for a gaging station it will typically exhibit a wide range of scatter around the rating due to these changes over time.

Changes to the stage-discharge relation that are thought to be stable and long-lasting usually require the development of an entirely new rating. However temporary conditions are accounted for in the record computation process by developing shift curves that are applied as offsets to the active stage-discharge rating. The first step in developing a shift curve begins with an examination of each individual discharge measurement made during the record computation period.

Slide 15

k9

I increased line sizes.

kmnolan, 12/1/2008

IWSC9

I increased the reduced the heading font size to Arial 28.

Idaho Water Science Center, 12/9/2008

Determination of shift from discharge measurement.

Form 9-2760
(Sep. 2000)

**U.S. DEPARTMENT OF THE INTERIOR
U.S. Geological Survey
WATER RESOURCES DIVISION
DISCHARGE MEASUREMENT AND
GAGE INSPECTION NOTES**

Mess No. _____
Comp by _____
Checked by _____

Sta. No. _____
Sta. Name _____
Date _____ 20 Party _____
Width _____ Area _____ Vel _____ G.H. change _____ Disch. _____
Method _____ No. secs. _____ G.H. change _____ in _____ hrs.
Method coef. _____ Horiz. angle coef. _____ Sup. _____ Tags checked _____
Meter type _____ Meter no. _____ Meter _____ ft. above bottom of hole
_____ ft. below bottom of hole
Rating plot _____ Spout before mess _____ after _____
Meas. plots _____ % diff from rating no _____ Indicated shift _____

GAGE READINGS			
	Inlets	Outlet	
Time			Samples collected: water quality, sediment, biological, other _____
Gage			Measurements documented on separate sheets: water quality use, base page, other _____
			Rain gage serviced/calibrated _____
Peak			Weather: Air Temp. _____ °C at _____ Water Temp. _____ °C at _____ Check bar/chair found _____ Changed to _____ at _____ Correct _____
Weighted MGH			
GH correction			
Correct MGH			
Warning: cable too loose; upstr.; downstr.; side bridge _____			ft. msl; upper/down of gauge _____
Measurement rated/excellent (2+), good (1-3), fair (0-1), poor (< 0-); based on following conditions: Flow: _____			
Cross section: _____			
Gage operating _____ Record Removed _____			
Battery voltage: _____ Intake/Crifice cleared/purged: _____			
Bubble-gage pressure, psi: Tank _____ Line _____ Bubble-rate _____ /min.			
Extreme-GH indicators: max _____ min _____			
CGG checked: _____ HWM height on rock _____ Ref. elev. _____ HW/H elev. _____			
Add'l remarks/outside: _____			
Control? _____			
Remarks: _____			
GH of zero flow = GH _____ , depth at control _____ = _____ ft., rated _____			
Sheet No. _____ of _____ sheets			

Compute percent difference from rating: $\left[\frac{Q_{\text{measured}} - Q_{\text{rating}}}{Q_{\text{rating}}} \right] \times 100$

$$\left[\frac{Q_{\text{measured}} - Q_{\text{rating}}}{Q_{\text{rating}}} \right] \times 100\%$$

Compute shift:

Example:

$$\text{GH}_{\text{Rating}} - \text{GH}_Q$$

$$Q_{\text{measured}} = 7.5 \text{ ft}^3/\text{s}$$

Gage height (GH_Q) = 0.89 ft

Gage height from rating ($\text{GH}_{\text{Rating}}$) = 0.95 ft

Computed shift = +0.06 ft

EXPANDED RATING TABLE													
Page	Discharge (cfs)												
Rating,	.00				.01				.02				
feet	.03				.04				.05				
0.10				0.04*				0.07		0.11		0.15	0.19
0.20	0.39	0.44	0.48	0.54	0.58	0.62	0.66	0.70	0.74	0.78	0.82	0.86	0.90
0.30	1.0	1.1	1.2	1.2	1.3	1.3	1.4	1.5	1.5	1.6	1.7	1.8	1.9
0.40	1.8	1.9	2.0	2.0	2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9
0.50	2.6	2.7	2.8	2.8	2.9	3.0	3.1	3.2	3.3	3.4	3.5	3.6	3.7
0.60	3.6	3.7	3.8	3.8	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7
0.70	4.6	4.7	4.8	4.8	4.9	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7
0.80	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.5	6.6	6.7	6.8	6.9
0.90	6.9	7.0	7.1	7.2	7.3	7.4	7.5	7.6	7.7	7.8	7.9	8.0	8.1
1.00	8.1	8.3	8.4	8.5	8.6	8.6	8.8	9.0	9.1	9.2	9.3	9.4	9.5
1.10	9.4	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5	10.6	10.7
1.20	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9
1.30	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3
1.40	13.4	13.5	13.6	13.7	13.8	13.9	14.0	14.1	14.2	14.3	14.4	14.5	14.6
1.50	15.0	15.1	15.3	15.4	15.6	15.7	15.8	15.9	16.0	16.2	16.3	16.4	16.5
1.60	16.5	16.6	16.8	16.9	17.1	17.3	17.4	17.6	17.7	17.9	18.0	18.1	18.2
1.70	18.0	18.2	18.4	18.5	18.7	18.9	19.0	19.1	19.2	19.3	19.4	19.5	19.6
1.80	19.6	19.8	19.9	20.1	20.2	20.4	20.6	20.7	20.9	21.0	21.1	21.2	21.3
1.90	21.4	21.5	21.6	21.7	21.8	21.9	22.0	22.1	22.2	22.3	22.4	22.5	22.6

Specific fields on a discharge measurement note are critical to the development of shift curves and should be filled out whenever a discharge measurement is made.

First, a precise gage height associated with the measured discharge must be determined, preferably a weighted mean gage height when the gage height has changed during the measuring period.

Second, the control conditions field must be used to document the type of control in effect, such as a riffle, channel, weir, or overbank, the location of the control in relation to the gage, and the condition of the control, such as clear, or affected by the presence of algae, ice, or debris.

Third, the measurement uncertainty must be rated as either Excellent, Good, Fair, or Poor based upon the conditions documented. Note that this rating is not an assessment of the skill or level of effort of the hydrographer, but rather as assessment of the uncertainty in the measured discharge based on the conditions of the measurement. An excellent hydrographer using excellent technique can still make a poor measurement when faced with very difficult conditions beyond his or her control.

Fourth, if possible a gage-height of zero flow, or GZF, should be obtained from the point of zero flow at the control. Tracking the GZF can prove very useful in the development of both shift curves and stage-discharge ratings.

Also, the percent difference from the active rating should be computed as shown.

Finally, the indicated shift should be computed by first looking up the gage height

associated with the measured discharge on the rating table and then subtracting the gage height determined for the measurement. For example, a discharge of 7.5 cubic feet per second was measured at a gage height of 0.89 feet. To compute the shift, the closest stage to a discharge of 7.5 cubic feet per second is located on the rating table, which in this case is 0.95 feet. The measurement gage height of 0.89 feet is subtracted from 0.95 feet, resulting in an indicated shift of +0.06 feet.

What this shift means is that for the rating table to properly represent the discharge in the stream at a gage height of 0.89 feet, 0.06 feet must be added to the gage height associated with the measurement. The rating table must be offset, or shifted +0.06 feet.

Slide 16

k10

I increased font sizes.

kmnolan, 12/1/2008

k11

Interpretation of a positive computed shift.



The gage height (GH_Q) = 0.89 ft.

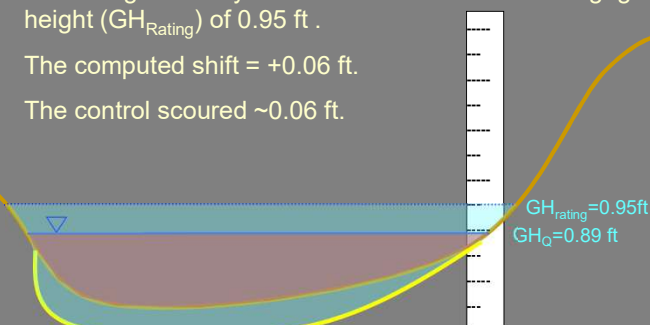
For this gage height the rating table indicates that the discharge should be 6.8 ft³/s.

Discharge measured = 7.5 ft³/s.

The rating table says 7.5 ft³/s is associated with a gage height (GH_{Rating}) of 0.95 ft.

The computed shift = +0.06 ft.

The control scoured ~0.06 ft.



If shifts are indications of changes in the conditions of the hydraulic control then they should also provide insight into the change that may have occurred. In the previous example in order for the rating table discharge to match the actual discharge in the stream we had to shift the gage height +0.06 feet. What does this tell us about the control?

Here, a cross section of a hydraulic control is shown. Using the same information from the shift computation in the previous slide we will illustrate the likely change that occurred to the hydraulic control. The gage height associated with the discharge measurement was 0.89 feet. At this gage height the rating table indicates a discharge of 6.8 cubic feet per second. The discharge actually measured was 7.5 cubic feet per second, higher than indicated by the rating. If the stage-discharge relation had not changed we would have expected a gage height of 0.95 ft at the measured discharge. Using the shift computation equation we thus computed a shift of +0.06 ft. In order for the rating table to associate the measured discharge of 7.5 cubic feet per second to the gage height of 0.89 feet we need to shift the gage height value in the rating +0.06 ft. Note that the gage height associated with the measurement was accurate, it is the stage-discharge relation that changed.

As shown here, this was likely caused by scouring of the hydraulic control by about 0.06 feet, causing a higher discharge at the gage height of 0.89 ft than the rating would indicate.

Slide 17

k11 I increased font sizes.
kmnolan, 12/1/2008

Interpretation of a negative computed shift.



The gage height (GH_Q) = 0.89 ft.

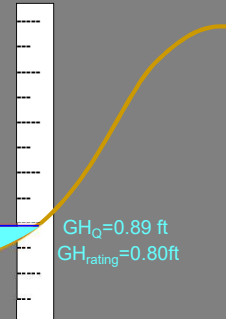
For this gage height the rating table indicates that the discharge should be 6.8 ft³/s.

Discharge measured = 5.7 ft³/s.

The rating table says 5.7 ft³/s is associated with a gage height (GH_{Rating}) of 0.80 ft.

The computed shift = -0.09 ft.

The control filled ~0.09 ft.



The interpretation of a negative shift is similar. For this example, the gage height associated with the discharge measurement was 0.89 feet. The rating table indicates a discharge of 6.8 cubic feet per second at this gage height. The discharge actually measured was 5.7 cubic feet per second lower than indicated by the rating. If the stage-discharge relation had not changed we would expect a gage height of 0.80 ft at the measured discharge. Using the shift computation equation we computed a shift of -0.09 ft. In order for the rating table to associate the measured discharge of 5.7 cubic feet per second, to the gage height of 0.89 feet we need to shift the gage height value in the rating -0.09 ft. As stated in the last example, the gage height associated with the measurement was accurate, it is the stage-discharge relation that changed.

As indicated by the computed shift and shown here the hydraulic control was raised or filled by about 0.09 feet. An occurrence of filling can be associated with sediment deposition, algal growth, or other debris being deposited on the control.

From these illustrations it is easy to see one of the values in regularly obtaining gage heights of zero flow, or GZF's, when feasible, as they can provide confirmation of scour or fill on the control.

Computed shift values and the rating curve.



From the measured discharge and associated gage height we learned how to examine the rating table to determine the indicated shift. The plotting position of a discharge measurement on a rating curve also shows the indicated shift as the difference between the gage height of the measurement and the gage height at the measured discharge. This measurement has an indicated shift of +0.10 feet, and this one a -0.14 foot shift.

The location of the plotted measurement in relation to the rating also tells us something about the change to the hydraulic control, specifically whether it plots below, or “to the right,” or above, or “to the left,” of the rating curve. Measurements plotting to the right indicate a positive shift related to scour of the control, and those plotting to the left indicate a negative shift related to fill, algae or debris on the control.

The shift as indicated by the measurement is only known to represent a single stage, but for the records computation process we must use it to help us assess a broader range of the rating. One approach to this is to remember that the shift is also a measure of the changes in the control and that the control affects a range of stages on the rating. There are two controls represented in this rating curve, a riffle at lower stages and a channel control at high stages. Lets look at this concept further on the next slide.

Slide 19

k12 I increased line sizes.

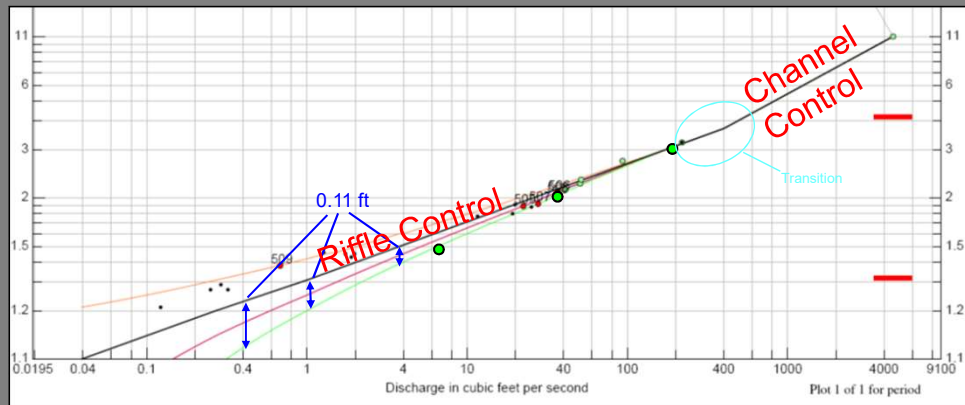
kmnolan, 12/1/2008

IWSC11 I reduced the heading font size to Arial 28.

Idaho Water Science Center, 12/9/2008

k13

Shift curves and the rating curve.



As you learned in the prior module on stage-discharge relations, the shape and slope of a rating curve is determined by the controls. Since shifts are not typically large-scale changes in the control, the shifted rating should maintain a same basic shape as the un-shifted, or base rating.

Here is an example of a rating curve, shown in black, with 3 shift curves, or shifted ratings, shown in orange, red, and green. Shift curves are defined by up to three points that consist of a gage height and a shift value at that gage height. As previously illustrated, the shift value is the amount added to the gage height to get the desired discharge on the rating. Below the lowest point on the shift curve, the applied shift is a constant amount equal to the shift of that point, and above the highest point on the shift curve the shift is a constant equal to the shift of that point. Between points the amount of the shift is interpolated based on the gage height.

For example, the green shift curve above is defined by the following 3 points: gage height 1.5 feet, shift value +0.11 feet, gage height 2.10 feet, shift value +0.11 feet, and gage height 3.00 feet, shift value 0. This shift curve was developed for measurement 507, visible in the plot, which had a computed shift of +0.11 feet using the shift computation equation shown earlier. The notes for this discharge measurement should have indicated the control that was in effect at that stage, in this case a riffle control. As we learned, a positive shift, or shift to the right, is often caused by scour to the control. It is likely that this scour condition affects the entire range of the rating affected by this riffle control. It is for this reason that the +0.11 ft shift is used for the entire range in stage below 2.10 feet. Although the

measurement was made at a stage of approximately 1.9 feet, it is reasonable to infer the scour affects the rating in a similar manner at lower stages also affected by the riffle control. Above a stage of about 2.5 feet the rating starts to transition from a riffle to CHANNEL control. The scour in the riffle will not have affected this control, therefore lacking any other information we assume the base rating still applies in this area. We thus prorate the shift from +0.11 ft to zero on the upper end of the riffle control part of the rating.

Note that it appears that the shift curves shown diverge from the base rating curve at the lower end, but this is due to the logarithmic plotting. At gage heights below the bottom input point, the shift value is the same. For example, the shift value remains at +0.11 feet from the lowest input point, gage height 1.50 feet, for the green shift curve.

All shifts should be developed by thinking about the hydraulic properties of a control. Some general rules are that:

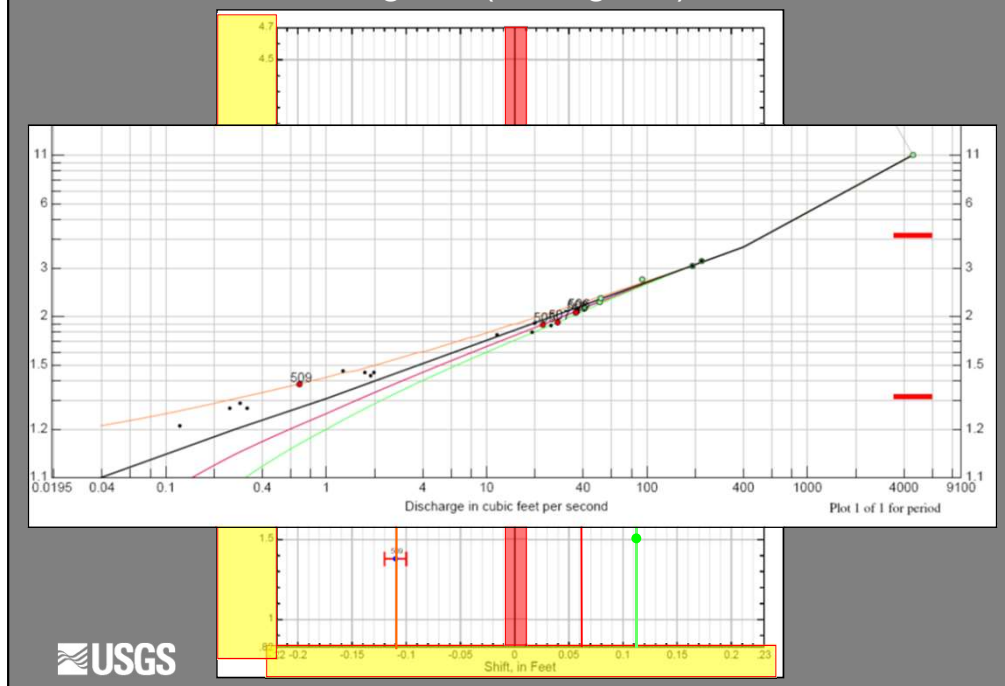
- The shape of the curve as determined by the input gage heights and shift value should agree with the general shape of the rating curve.
- A computed shift at a specific stage will not typically increase in magnitude as the stage increases, but rather stay constant or decrease to zero as the stage approaches the transition to the next control.
- Shift curves should not cross the base rating as one shift cannot be scour and fill at the same time.

Slide 20

k13 I increased font and line sizes.
kmnolan, 12/1/2008

IWSC12

Variable Shift Diagram (V-diagram).



A commonly used tool for developing shift curves, specifically the 3 input points that define them, is the variable shift diagram, or V-diagram, which is shown here. The diagram has shift values plotted on the X axis and stage plotted on the Y axis. The zero shift represents the base rating curve. Note that discharge is not represented in the diagram. Discharge measurements, plotted by gage height and shift value, are shown with error bars that correspond to the qualitative uncertainty identified by the field hydrographer in the “measurement rating” field of the discharge measurement note. The error bars indicate the range that the shift could occupy at that stage that would keep the measurement within its defined uncertainty from the shifted rating. Error bars that overlap the zero shift line thus come within their defined uncertainty from the base rating. This generally indicates a shift at that stage is not necessary.

This is a V-diagram for the same time period as the previous rating we examined that contained 3 shift curves. Recall that this rating represents riffle control below a gage height of about 3.5 feet and channel control above. When developing shift curves, it is important to examine the rating curve to determine the general shape of the shift curve in relation to the control features of the rating, specifically at what stages the shift applies and how and where the shift curve might blend back to the base rating. When developing a shift by hand it is recommended to first draw the shift curve on the rating curve and then transfer it to the V-diagram. In computerized applications like GRSAT both the rating and the V-diagram are used together in shift development. In either approach it is never appropriate to develop a

shift on the V-diagram alone without referencing the rating curve. In this way the shift curve remains true to the basic hydraulics of the channel as described by the rating.

In this example, the shift curves are already drawn on the rating curve. A gage height of 3.00 feet was selected for the point where the shift blends into the rating curve, just below the transition between riffle and channel control. We can now examine the V-diagram and transfer the drawn shift curves. As shown, the shifts on the V-Diagram take on a “half house” type of shape. Because all of these shifts affect the same riffle control, they share common points describing their transition back to the base rating despite the fact that the measurements used to define them were made at different stages. In other words any measurement made when the riffle control is in effect will define a consistent shift for the stage range up to about 2.2 feet, but any shift to the riffle control will have no effect above 3 feet where the channel control starts to take effect.

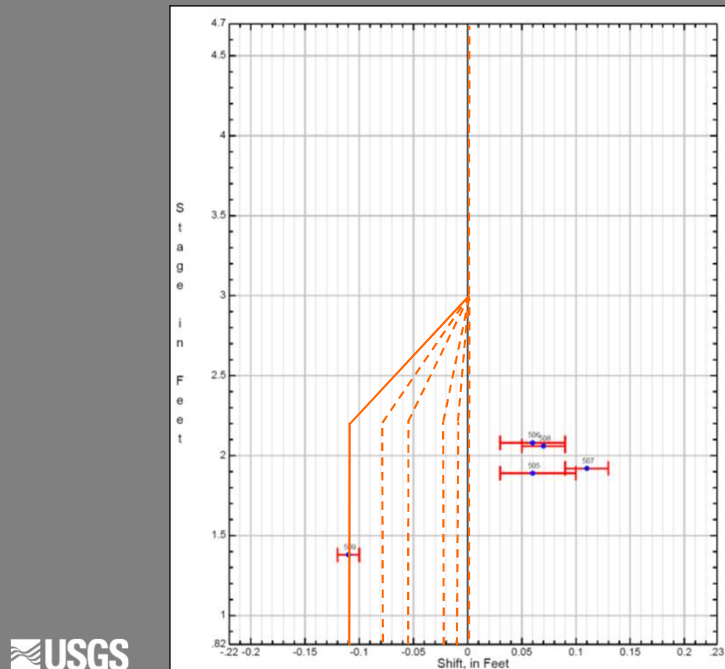
As previously discussed, shift curves are defined by 3 points that consist of a gage height and shift value. Using the previous example for the green curve, these input points are: gage height 1.5 feet, shift value +0.11, gage height 2.10 feet, shift value +0.11, and gage height 3.00 feet, shift value 0.

After determining the input points for each of the shift curves, the next step is to determine the periods of time when each shift should be applied. Note that while all shifts are temporary conditions by their very nature, in some settings a shift is stable enough that it can be measured at more than one stage, for example the red shift above has been developed using both measurements 505 and 506. Understanding the shifting characteristics of a particular station is important in selecting the proper timing of shifts, as we shall see.

Slide 21

IWSC12 I decreased the heading font size to match the rest of the slide show.
Idaho Water Science Center, 12/9/2008

Proration of shift curves.



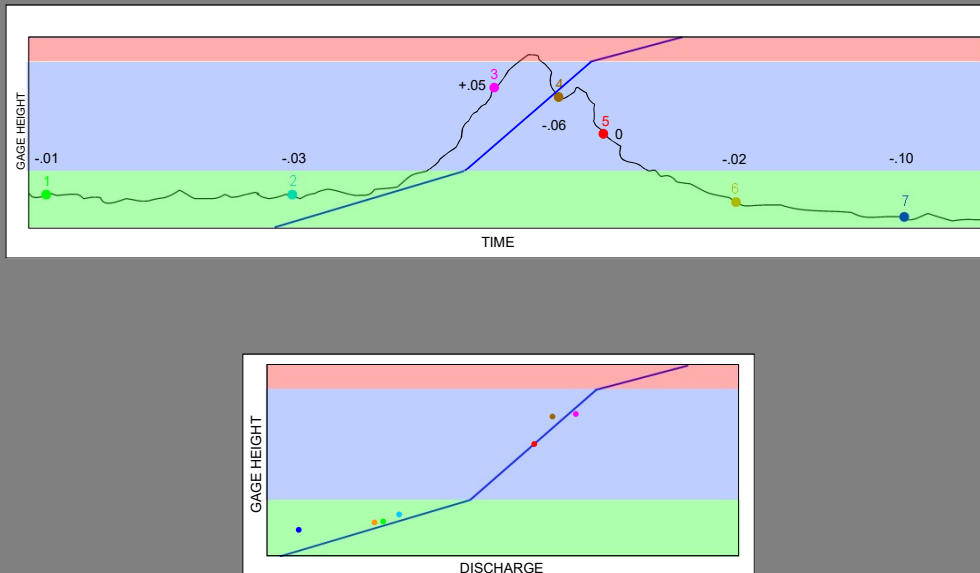
At this point we have developed shifts that are hydraulically representative of the conditions of the control and the developed stage-discharge rating. Now we will be discussing how to apply the shift curves in time with respect to hydrologic and hydraulic events that caused them.

Similar to data corrections, shift curves can be prorated forward and backward in time. As shift curves prorate between one another or to a zero shift, the amount of shift gradually varies as time passes. For example if the orange shift above prorates over time into a zero shift, representing the base rating, the prorated shift would progress through time as follows until the zero shift was active. Notice that above the point where the shift curve merges with the rating, at a gage height of 3.0 feet, the shift to the rating is 0. Halfway in time between the two shift curves the active shift would be here. The manner in which shift curves prorate into one another stresses the importance that the individual curves stay true to the general shape of the rating curve, have similar form, such as common merge points, and do not cross one another. Because a shift curve represents the applied stage-discharge relation and because a prorated shift curve is, in effect, changing constantly through time, it is possible to create a wildly hydraulically unreasonable intermediate curve when prorating between two shift curves that have not been consistently and properly defined with respect to the base rating.

Slide 22

IWSC13 I changed the heading font size to match the rest of the presentation.
Idaho Water Science Center, 12/9/2008

Shift curves, the rating, and the gage height record.



Since discharge measurements provide a snapshot in time of the control conditions and the processes that change hydraulic controls, and as we have only a limited number of measurements available, we are forced to make interpretations of how a control changes over time between measurements.

The dates of application of shift curves to the time-series record should be based on real hydrologic or hydraulic events. As we have seen, in many cases shifts are caused by scour or fill associated with the rise and fall in stage. Other shifts are caused by more gradual changes in river hydraulics from backwater from aquatic growth or accumulated debris. In either case, the application in time of shift curves should be based upon the events which are presumed to have caused them and not on the dates of the measurements themselves.

Here we have a time series of gage heights, the black line, with 7 discharge measurements plotted as the numbered and colored dots. This time series is similar to that of a snowmelt runoff stream with a single, long duration event. Here is a simplified rating curve for this station. As can be seen, the rating curve represents 3 controls; riffle shown in green, channel shown in blue, and the overbank shown in red. We can transfer the rating curve and various control segments to the gage height time series plot to provide some context to the gage height record. Here are the measurements as they plot on the rating curve. We can now see that measurements 1, 2, 6 and 7 were made under riffle control and measurements 3, 4, and 5 were made under channel control. Here are the computed shifts for the 7 measurements. As you can see measurements 1 and 2 indicate small negative

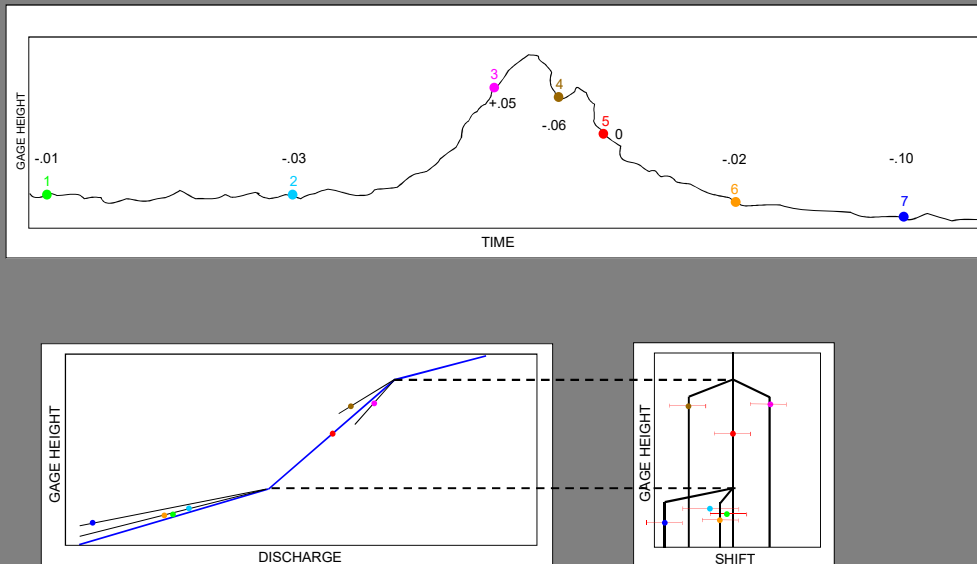
shifts. As the runoff event started and progressed some scour likely occurred, as evidenced by the +0.05 ft shift of measurement 3. Following the peak it appears some filling of the control occurred based upon the -0.06 ft shift associated with measurement 4. Measurement 5 plotted directly on the rating, following by negative shifts for measurements 6 and 7 in the long recession after the peak, during which time the field hydrographer noted the presence of aquatic growth in the control section.

Lets look at this record in more detail.

k14

IWSC14

Development of shift curves.



Before we can apply the shifts in time, we first need to develop the shift curves themselves. Here are the measurements plotted on the V-diagram. We can once again transfer the gage heights associated with the control segments over to the V-diagram. Following the previously outlined methods for developing hydraulically representative shift curves, shift curves for the 7 measurements were developed; first on the rating curve then on the V-diagram.

Lets discusses the shifts we chose to develop for this record.

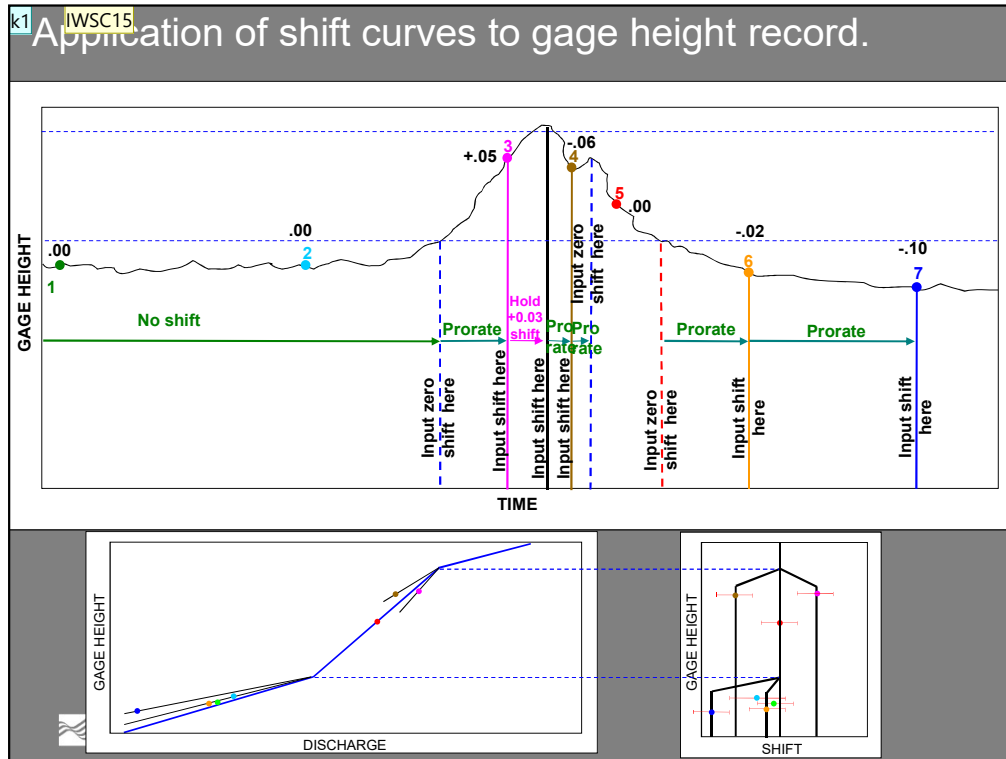
- No shift was developed for measurements 1 and 2. Although both of these measurements indicate a small negative shift, as shown by the error bars in the V-diagram both of the measurements also come within their rated uncertainty of the base rating. As was stated previously, without specific information from the field notes regarding changes to the control, it is often more appropriate to not apply a shift in such cases, and that is the decision made here.
- Shifts to measurements 3 and 4 were developed to account for the scour and fill presumed to have occurred during this event.
- Shifts to measurements 6 and 7 were developed to account for the presence of aquatic growth on the control. Note that like measurements 1 and 2, measurement 6 also comes within its rated uncertainty from the base rating. However for this measurement we have the hydrographers notes of the presence of aquatic growth. That fact, plus the further evidence given by measurement 7, gives us confidence in applying a shift for this measurement.

Now that we have developed the actual shift curves, lets take a closer look at the unit value stage record to determine how to apply the shifts in time.

Slide 24

k14 I increased line sizes.
kmnolan, 12/1/2008

IWSC14 I changed the heading font size to match the rest of the slides.
Idaho Water Science Center, 12/9/2008



As we have stated, without any obvious hydrologic event occurring between measurements 1 and 2 or any hydrographer notes, and because both measurements come within their rated uncertainty from the rating, we have elected not to apply a shift for the first part of our time-series record. Measurement number 3, however, indicated a +0.05 ft shift and we developed a shift curve to account for it, assuming that the control scoured as the flow increased. We assume that this scour occurred gradually over time as the flow rose, and thus want to prorate this shift on. To do this we must actually enter a zero shift at the start of the proration period. Although the timing of the start is somewhat conjectural, recall the point on the rating where the control changes from riffle to channel. As the shift for measurement 3 occurred to the channel control, it would not be appropriate to apply this shift to the period where the riffle control is in effect. We thus elect to start the proration at the transition point where the channel control comes into effect.

Without any measurements documenting the control conditions further up the hydrograph, we have to assume that the +0.05 ft shift curve is constant to the peak of the event. For this reason we will hold the +0.05 ft shift curve to the peak and input it at that time. Note, however, that the +0.05 ft shift curve merges into the rating at the transition from channel control to overbank control at the stage shown by the higher blue dotted line. Therefore, the peak for this event will have an actual applied shift zero. Ideally we should have field evidence such as high water marks or a crest stage gage reading to corroborate that the peak occurred in the overbank portion of the rating, and for this example we will assume this to be the case.

Measurement 4 made early on during the recession indicated a shift of -0.06 ft, suggesting some deposition in the channel as flows decreased. Like the scour on the rise, we will assume this fill occurred gradually over time and prorate from the +0.05 ft shift curve on the peak forward into the -0.06 ft shift curve of measurement number 4.

Measurement 5 indicated that no shift was needed and that the deposition seen in measurement 4 had been removed. The rise between the measurements is a reasonable cause, so the shift curve used for measurement 4 will be prorated to zero shift at the peak of the rise, and then no shift used until measurement 5.

As we learned earlier, the hydrographer noted the existence of aquatic growth on the riffle control during measurements 6 and 7. We will assume that this growth started at the point when the discharge got back down into this section of the control and then prorate it forward to the actual observed backwater for measurement 6 and 7.

As should be understood by now, the application of shift curves requires substantial hydrologic reasoning and interpretation and use of data from multiple sources, including hydrographer notes, the unit value record, and historical experience at the station. When applying such reasoning it is paramount that a detailed narrative be prepared describing the rational behind all decisions made. The station analysis document, which we will discuss later, is used to describe the reasoning behind the application of shifts, including the form of the shift curves themselves as well as the timing.

Slide 25

k1 I increased font sizes and changed colors to make everything easier to see. Make sure I did not confuse the intent of this slide.

kmnolan, 12/1/2008

IWSC15 During the animation, the pink vertical line masks the positive sign of the $+0.03$ ft shift and makes it appear to be a (-) negative sign. I also hit a shift return on the 4th green prorate to move the "r" down below the line, it makes the split of the word prorate more correct. Perhaps the black dotted line showing the shift input around the peak should be drawn at the end of the flat line before the dropoff at the peak? And I might input the shift associated with measurement 5 at the beginning of the dropoff to the right of measurement 5?

Idaho Water Science Center, 12/9/2008

Primary computations.

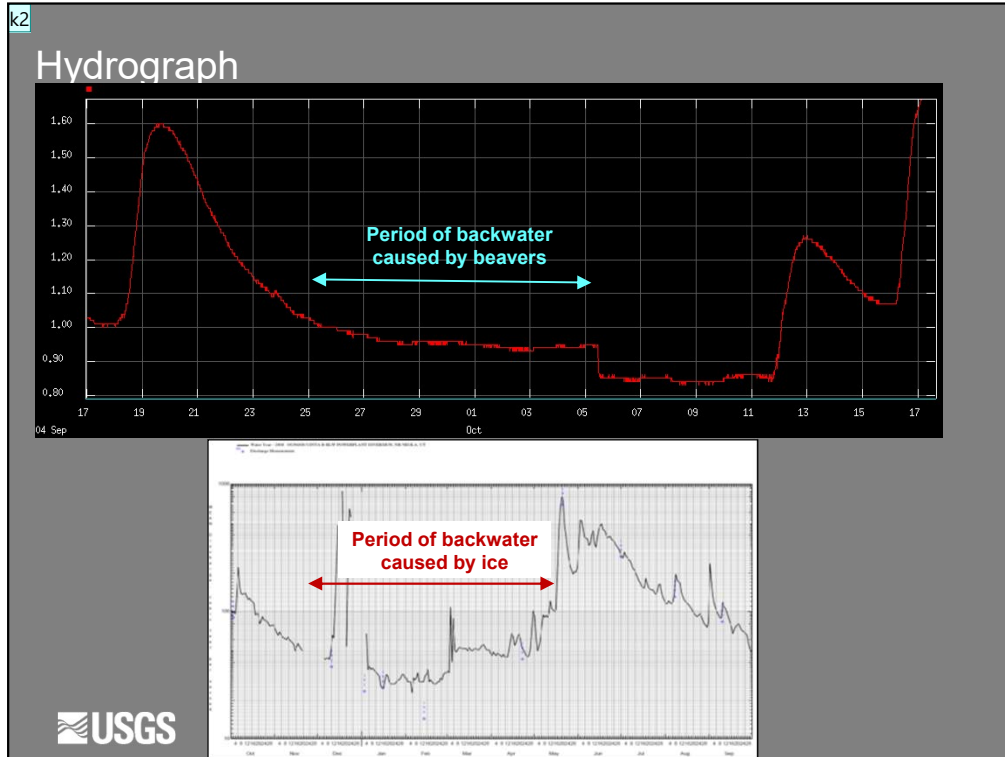
U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES														
STATION:10155000 PROVO RIVER NEAR HALLSTONE, UT TYPE:STRAIGHT AGENCY:USGS STATE:49 COUNTY:1061														
LATITUDE: 405053 LONGITUDE: 1111951 WGS84 DRAINAGE AREA:230 CONTRIBUTING DRAINAGE AREA: DATUM:6220.00 NGVD29														
Date Processed: 2008-11-21 08:40 By tkerney														
Primary computations of gage height and discharge Ratings Used														
Discharge (cfs) Time zone: MST DST used STGQ 38.0 2007/11/01 00:00:00														
Input ID: 2 (00065) Gage height (ft.) Stored statistics: Mean														
PROVISIONAL DATA FOR PERIOD 11/01/2007 to 11/30/2007 Report Only approved														
Flags	Date	(00065) INSTANTANEOUS GAGE HEIGHT, FEET						(00060) DISCHARGE, CUBIC FEET PER SECOND						Final
		Max	Corr	Time1	Min	Corr	Time1	Max	Shift	Time	Min	Shift	Time	
	11/01/07	6.97	0.00	00001	6.95	0.00	17151	6.96	118	-0.02	00001	110	-0.02	17151
	11/02/07	6.95	0.00	00001	6.91	0.00	23001	6.93	110	-0.02	00001	95	-0.02	23001
	11/03/07	6.92	0.00	10001	6.89	0.00	20151	6.91	99	-0.02	10001	88	-0.02	20151
	11/04/07	6.92	0.00	07451	6.89	0.00	00001	6.91	99	-0.02	07451	88	-0.02	00001
	11/05/07	6.92	0.00	10101	6.91	0.00	00001	6.91	99	-0.02	10101	88	-0.02	00001
	11/06/07	6.91	0.00	00001	6.88	0.00	23301	6.89	95	-0.02	00001	85	-0.02	23301
	11/07/07	6.89	0.00	08301	6.87	0.00	06451	6.88	88	-0.02	08301	82	-0.02	06451
	11/08/07	6.89	0.00	09001	6.87	0.00	00001	6.88	88	-0.02	09001	82	-0.02	00001
	11/09/07	6.89	0.00	10001	6.87	0.00	00001	6.88	88	-0.02	10001	82	-0.02	00001
	11/10/07	6.89	0.00	10301	6.87	0.00	00001	6.88	88	-0.02	10301	82	-0.02	00001
	11/11/07	6.89	0.00	00001	6.88	0.00	01301	6.88	88	-0.02	00001	85	-0.02	01301
	11/12/07	6.89	0.00	00001	6.87	0.00	20151	6.88	88	-0.02	00001	82	-0.02	20151
	11/13/07	6.89	0.00	14001	6.87	0.00	00001	6.88	88	-0.02	14001	82	-0.02	00001
	11/14/07	6.88	0.00	10301	6.87	0.00	00001	6.87	85	-0.02	10301	82	-0.02	00001
	11/15/07	6.87	0.00	00001	6.83	0.00	10001	6.85	82	-0.02	00001	69	-0.02	10001
	11/16/07	6.87	0.00	10001	6.85	0.00	00001	6.86	82	-0.02	10001	75	-0.02	00001
	11/17/07	6.87	0.00	00001	6.87	0.00	00001	6.87	82	-0.02	00001	82	-0.02	00001
	11/18/07	6.87	0.00	00001	6.87	0.00	00001	6.87	82	-0.02	00001	82	-0.02	00001
	11/19/07	6.87	0.00	00001	6.87	0.00	00001	6.87	82	-0.02	00001	82	-0.02	00001
	11/20/07	6.87	0.00	00001	6.86	0.00	02451	6.87	82	-0.02	00001	79	-0.02	02451
A	11/21/07	6.87	0.00	00001	6.82	0.00	08001	6.83	82	-0.02	00001	66	-0.02	08001
AT	11/22/07	7.17	09151	6.77	11451	6.83			216	0.00	09151	57	0.00	11451
AT	11/23/07	7.13	09451	6.78	01451	6.89			186	0.00	09451	60	0.00	01451
AT	11/24/07	7.36	09301	6.81	21001	6.99			322	0.00	09301	69	0.00	21001
AT	11/25/07	7.41	09301	6.83	17001	7.06			353	0.00	09301	75	0.00	17001
AT	11/26/07	6.96	08451	6.83	00001	6.86			121	0.00	08451	75	0.00	00001
AT	11/27/07	6.85	00001	6.85	00001	6.85			82	0.00	00001	82	0.00	00001
AT	11/28/07	7.05	09301	6.85	00001	6.92			159	-0.00	09301	82	0.00	00001
AT	11/29/07	7.06	02451	6.82	17301	6.90			163	0.00	02451	72	0.00	17301
A	11/30/07	6.86	00001	6.86	00001	6.86			85	0.00	00001	85	0.00	00001
Period 11/01/07 - 11/30/07														
Max GH: 7.41 (0930)11/25; Max Discharge: 353 (0930)11/25														
Min GH: 6.77 (1145)11/22; Min Discharge: 57 (1145)11/22														
NOTE: Symbols used above have the following meanings --														
Flags (shown in Flags column)														
A = Ice affected values exist on this day														
T = Test difference threshold was exceeded														
Remark Codes (shown beside individual unit and daily values)														
e = Estimated value														
e = Daily value computed from affected unit value														

Once the stage record is cleaned up, and data corrections, ratings, and shift curves developed and entered into the database, the next step in the record computation process is to actually compute unit value and daily value discharges from the time-series gage height record. This step is commonly termed the “primary computation.” The primary computation first applies the data corrections to the time series of measured stage record, including any prorated corrections, to develop the corrected stage record. This corrected stage record is then used as input to the rating curve with any applicable shift curve to calculate unit value discharges. Finally, daily values of discharge, such as daily mean, daily minimum, or daily maximum, are then computed from the unit value discharges.

Shown here is typical output from a primary computation. Each row represents a single day. Maximum, minimum, and mean gage heights are shown on the left half of the page along with associated data corrections. Note that the gage heights are shown with the correction applied. Similarly, on the right half of the page maximum, minimum, and mean discharges are shown along with associated shift values. The final 2 columns on the right contain the computed daily mean discharge along with the final daily mean discharge value which could be different if the day was estimated. This is the case for November 21 through November 30 where the final values are coded with an “e”. The computed daily mean values are coded with an “&” symbol which indicates that they were computed from affected unit values. In the flags column on the left you can see that these days were initially flagged with an “A” indicating that the gage heights were affected by ice. The description of flags

and remark codes are contained at the bottom of the page.

The flagging and estimation of data is covered in the next section of this module.



Following the primary computation, the record must be reanalyzed for periods when the stage-discharge rating does not apply due to backwater effects that cannot be corrected with shifts because they are too variable over time. The most common example is backwater from ice in the channel or on the control, but other examples can include variable backwater from active debris pileup or beaver activity.

It is important to note, however, that unlike erroneous data the recorded stage in these cases still represents the true stream elevation. It is simply that the backwater condition makes the rating no longer usable to calculate discharge. In effect the stage is no longer a valid surrogate for discharge. For this reason we do not mark or delete the stage data as erroneous, rather we flag it as “affected.”

In most cases we still need to produce a discharge for these periods because a complete period of record is required for statistical and other reasons. We thus need to estimate the discharge during these periods when the stage-discharge rating cannot be used, as well as for periods identified earlier where the stage data are completely missing or erroneous. A variety of techniques are used in this process.

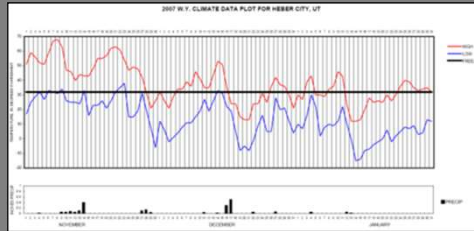
Slide 27

k2

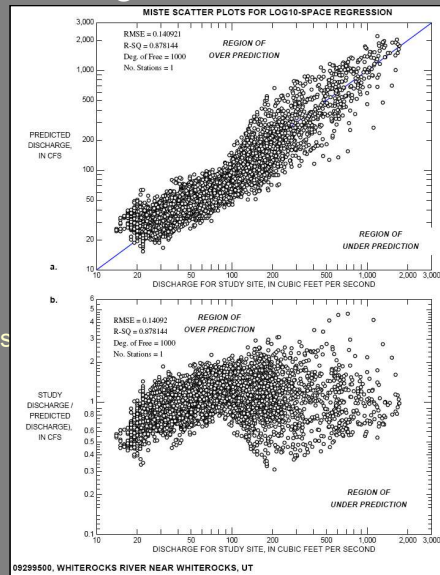
I increased font and line sizes.

kmnolan, 12/1/2008

Estimate missing daily value discharges.



Time series of daily high and low temperatures along with daily precipitation totals



Linear regression technique using period of record daily values for study site and index site(s).

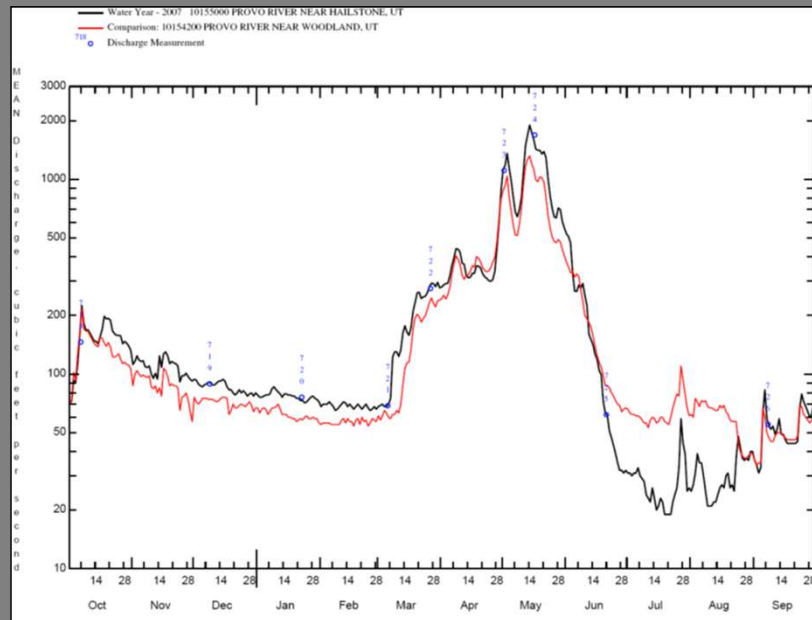
When estimating discharges it is important to assemble all available data to develop the most accurate estimates possible. Data most commonly used include days of adjoining computed discharges, intermittent recorded stage values for incomplete days, maximum or minimum gage heights from secondary gages, discharge measurements, control inspections and other notes made during the period requiring estimates, precipitation records, reservoir releases, temperature records for ice affected periods, discharges from upstream or downstream stations, and discharges from nearby stations that compare favorably with the site.

Techniques used in estimating discharges range from simple examinations of adjoining periods of discharge, to interpretation of precipitation and temperature records, to developing predictive statistical models based on discharge at other correlated stations. The data and techniques used in developing estimates are dependent on the reason estimates are required, and the length of the period that needs to be estimated. For some short duration events the unit values may be estimated and new daily values calculated by rerunning a primary computation. However in most cases the daily values are estimated directly.

Slide 28

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Idaho Water Science Center, 12/9/2008

Hydrographic comparison.



Comparing hydrographs of stations located on the same stream or other nearby stations is an important means of validating estimated record as well as the shift application methodology. A plot should be developed containing the hydrograph for the station in which record is being computed as well as any comparison stations. The plots should be reviewed to ensure that the relation between the stations makes hydrologic sense and is consistent with previous history.

The plot shown here contains daily mean discharges for two stations located on the same stream with a water diversion in between. The stations compare favorably until irrigation season begins in May.

Slide 29

IWSC17 I changed the heading font size to Arial 28.
Idaho Water Science Center, 12/9/2008

Station analysis.

Station Analysis

10155000 Provo River Near Hailstone, UT

Analysis Period: 10/1/2005 to 12/8/2006

Analysis Notes

Station Analysis

LOCATION—Lat 40°30'37", long 111°19'51" referenced to North American Datum of 1927, in SW 1/4 NE 1/4 SW 1/4 sec 36, T.2 S., R.5 E., Wasatch County, UT. Hydrologic Unit 16020203, on left bank 0.25 mi downstream of bridge on State Highway 32, 4.5 mi upstream from Ross Creek and Hailstone.

EQUIPMENT—Gage equipment consists of a Sutron 8210 DCP connected to float driven incremental shift recorder. The reference gage consists of an electric tape gage attached to the equipment shelf. Equipment is housed in a 64x16x4in prefabricated metal shelter mounted over an 6-foot deep 42-inch diameter well.

GAGE HEIGHT RECORD—The Sutron 8210 provided a nearly complete record of gage height for the 2006 water year and into the 2007 water year. On November 28, 2005 the failsafe tripped on the Sutron 8210. A new battery was installed on December 1, 2005. Daily mean discharges for November 28–December 1, 2005 were estimated using MISTE. The stage-discharge relationship was determined to be ice affected from December 2, 2005 through March 22, 2006. Daily mean discharges were estimated using MISTE. On July 30, 2006 the float counter weight rusted off the float tape. A new weight was installed on August 1, and July 30–August 1, were estimated using the adjoining days of computed daily mean discharges. The stage-discharge relationship was determined to be ice affected from November 28, 2006 through the end of this record period, December 8, 2006. MISTE was used to estimate daily mean discharges.

DATUM CORRECTIONS—Last levels were run on November 2nd, 2004, by Vince Walzorn and Paul Dowdhouse.

On May 10 the Sutron 8210 was found to be in disagreement with the electric tape reference gage by -0.05 feet. The float hanger attached to the float tape was hung up on the float. Upon adjusting the hanger, the Sutron came into agreement with the reference gage. An inspection of the unit-value gage height record prior to May 10, it appeared that this hang-up likely occurred on April 13. On April 13 the recorded stage values remained flat at 7.33 feet until April 17. A +0.05 foot dial correction was applied on May 10 at 10:00 and was held constant until April 17 at 19:15 when it was allowed to prorate back to 0 feet on April 13 at 20:45. Following this correction the maximum recorded gage height during this period was 7.86 feet on May 5. The Datason indicator reading from May 10 was 7.85 feet. The -0.01 foot correction found on July 14, 2005 was held constant to July 30 at 08:30, the

time the float counter weight rusted off of the float tape. A new counter weight was installed and the dial was reset on August 1.

RATING—The channel is fairly straight and well defined upstream of the gage, while downstream of the riffle-control a series of channels exist. Channel gradient would be characterized as steep. Bed material ranges from small cobbles to well rounded boulders and is fairly mobile at large discharges. A cobble riffle acts as the control for low to medium stages while channel control is in effect for higher discharges.

Measurements made in the period of October 1, 2005 through December 8, 2006 ranged in stage from 6.64 ft to 8.60 ft, and in flow from 43.1 cfs to 1,980 cfs.

Prior to the highwater period of water year 2006, only one shift to the stage discharge relation was required. On March 22, measurement 712 defined a +0.03 ft shift to rating 37.0. It is likely that this minor shift was due to slight adjustments to the cobble control caused by ice cover. This +0.03 ft shift was allowed to prorate into the 0.0 ft shift defined by measurement 713, made during the initial snowmelt runoff rise. Measurement 714, the highest measurement made in water year 2006, indicated scor occurring during the rising limb of the snowmelt hydrograph with a +0.21 ft shift. The associated shift curve was brought back into rating 37.0 at 10:00 ft. This shift curve was held until the peak of the runoff on June 6. The next measurement, 715, made during the runoff recession, defined a -0.12 ft shift, indicative of fill processes occurring to the channel. The scor shift was prorate into the fill shift from the event peak. Although measurement 715 was made under channel control and measurement 716 was made under riffle control, the -0.12 ft shift was allowed to prorate forward into the -0.05 ft shift defined by measurement 716. The associated shift curve for the -0.05 ft shift was brought back into the rating a gage height of 7.32 ft. The remaining measurements for water year 2006 and the first measurement in water year 2007 plotted on this shift curve. The shift was held until the ice affected period of water year 2007, November 28, 2006.

DISCHARGE RECORDS—Discharge is computed by applying hourly gage heights, with applied shifts, to Rating No. 37.0.

SPECIAL COMPUTATIONS—The ADAPS HYDRA MISTE tool was used to estimate the ice affected periods, and for the November 28–December 1, 2005 period. The equation used, saved as equation 1, was developed during a previous record computation using upstream gaging station 10154200 Provo River near Woodland, Utah. The predicted trend in daily mean discharges was preserved, however, most predicted daily values were adjusted to match adjoining days of record and instantaneous discharge measurements made during ice affected conditions.

REMARKS (SANDL)—Records are good, except for estimated days, which are fair to poor. Hydrographic comparisons should be made with upstream USGS streamflow gaging station 10154200, Provo River near Woodland, Utah. During irrigation season, the upstream station, Provo River near Woodland, Utah, will typically have more streamflow than this station which is



A critical part of the records computation process is the station analysis, which is an internal document that specifically describes how the streamflow record was worked. This narrative contains elements to describe the gage height record, data corrections, rating(s), shift curves, and estimated record. A detailed account of how each of these critical elements were processed, applied, determined, and/or utilized by the hydrographer in computing discharge from the measured stage record should be contained. This is the place to describe missing record, estimation techniques used, the accuracy of the computed values, any interpretations made in applying data corrections or shifts, and the status of the stage discharge rating for the computation period. A well prepared analysis provides a summation of the conditions experienced over the computation period in context with the thought processes of the hydrographer who worked up the record.

As much as possible the station analysis should be written along with the records work and not at the end of the process. This ensures that the decisions and methods used by the hydrographer are still fresh when documented and helps make the analysis that much more detailed and complete.

Slide 30

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Idaho Water Science Center, 12/9/2008

Check and review the record.

Station Number	Station Name	Worker	Checker	Reviewer	Site Type
09230300	BIRCH SPRING DRAW AT FGNRA BOU...	sigerner	rjeacret	dallen	Discharge
09230300	BIRCH SPRING DRAW AT FGNRA BOU...	sigerner	mrfisher	downhour	Water Quality, Spec...
09230300	BIRCH SPRING DRAW AT FGNRA BOU...	sigerner	downhour	mrfisher	Water Quality, Tempe...
09277500	DUCHESNE RIVER NEAR TABONA, U...	rjeacret	rjeacret	menright	Discharge
09277500	DUCHESNE RIVER NEAR TABONA, U...	rjeacret	dallen	menright	Precipitation
09279000	ROCK CREEK NEAR MOUNTAIN HOME...	rjeacret	anielson	mrfisher	Discharge
09285900	STRAWBERRY RIVER AT PINNACLES ...	rjeacret	rjeacret	menright	Discharge
09288000	CURRENT CREEK NEAR FRUITLAND, ...	rjeacret	downhour	menright	Discharge
09288180	STRAWBERRY RIVER NEAR DUCHESNE...	rjeacret	downhour	blanney	Discharge
09289500	LAKE FORK RIVER AB MOON LAKE, ...	rjeacret	downhour	rowland	Discharge
09290500	MOON LAKE RESERVOIR NEAR MOUNT...	rjeacret	mfreeman	menright	Lake



USGS
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United States Department of the Interior
Geological Survey

UTAH WATER SCIENCE CENTER
2329 West Orton Circle
West Valley City, Utah 84119

March 13, 2006

To: David V. Allen
Hydrologic Technician, Salt Lake City, Utah

From: Terry A. Kenney
Hydrologist, Surface Water Specialist, Salt Lake City, Utah

Subject: SURFACE WATER RECORD COMPUTATION: Review of Water Year
2005 streamflow record for U.S. Geological Survey streamflow gaging
station 10172800 South Willow Creek near Grantsville, Utah

I have reviewed the subject surface water record and my comments are below.

Following the completion of the record working process, USGS procedures require that the record be checked and reviewed prior to final approval and publication. All data, including corrections, ratings, shifts, and estimates must be checked for technical accuracy and correct data entry. The hydrologic and hydraulic decisions made and documented in the station analysis must also be reviewed and assessed, and the data must be checked for continuity with the same periods at other stations and other periods at the same station. At any time in the process parts of the record may be reworked to address issues raised during the check or review.

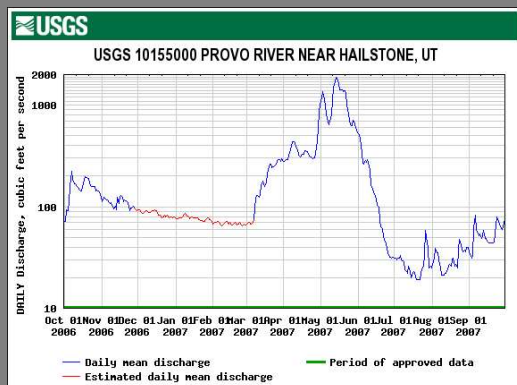
The exact form of the checking and review stage varies from one office to another depending on the availability and experience level of available personnel, but it must include at least one, and ideally two, other hydrographers than the person who originally worked the record.

The entire checking and reviewing process must be documented as part of the final record.

Slide 31

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Idaho Water Science Center, 12/9/2008

Final published daily values.



Water Data Report 2007
10155000 PROVO RIVER NEAR HAILSTONE, UT—Continued

DISCHARGE, CUBIC FEET PER SECOND
WATER YEAR OCTOBER 2006 TO SEPTEMBER 2007
DAILY MEAN VALUES
(c, estimated)

Day	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1	72	112	c94	c78	c68	c68	280	1,120	528	31	25	36
2	72	116	c93	c76	c70	c69	287	1,180	508	31	27	34
3	93	124	c89	c76	c70	c70	292	1,360	472	30	31	31
4	91	118	c87	c77	c70	c68	292	1,140	333	31	39	33
5	113	116	c86	c78	c72	c68	319	980	267	31	35	62
6	158	117	c88	c78	c70	c70	362	807	265	33	35	83
7	225	109	c89	c79	c68	c75	396	678	286	30	30	96
8	182	108	c91	c84	c65	122	440	642	276	29	25	54
9	168	110	c90	c86	c66	130	438	702	292	28	21	52
10	169	100	c88	c83	c68	130	421	808	254	24	21	54
11	162	95	c88	c81	c70	123	371	1,110	225	23	21	49
12	155	101	c90	c79	c72	133	366	1,500	160	22	22	52
13	148	94	c92	c76	c71	162	321	1,600	150	26	22	59
14	147	124	c92	c79	c68	177	312	1,900	141	23	24	49
15	143	108	c94	c79	c70	164	314	1,740	126	20	26	49
16	156	127	c92	c78	c68	158	329	1,600	119	21	27	c46
17	170	130	c96	c78	c66	173	329	1,430	104	23	26	44
18	198	124	c83	c77	c68	210	360	1,410	99	22	30	44
19	192	113	c83	c77	c70	233	358	1,410	72	19	31	44
20	193	116	c80	c75	c68	261	351	1,350	63	19	26	44
21	189	114	c78	c75	c66	263	328	1,290	61	19	27	44
22	167	113	c80	c73	c68	244	316	1,290	51	19	25	45
23	161	110	c83	c73	c70	249	310	1,010	47	22	37	66
24	158	91	c80	c71	c67	251	302	824	43	24	40	79
25	158	98	c82	c72	c65	262	299	711	39	26	42	72
26	157	98	c80	c74	c66	281	306	642	35	33	37	68
27	143	101	c77	c76	c68	293	318	634	32	39	36	64
28	147	c97	c79	c77	c66	291	442	713	32	44	37	60
29	144	c94	c80	c75	—	261	597	698	31	39	36	62
30	139	c92	c77	c74	—	296	872	606	32	25	40	72
31	132	—	c80	c72	—	277	—	561	—	26	49	—
Total	4,702	3,270	2,611	2,186	1,914	5,652	11,048	33,536	5,140	832	949	1,610
Mean	152	109	85.5	77.0	68.4	182	368	1,085	171	27.5	30.6	53.7
Max	225	130	94	86	72	296	872	1,900	525	99	40	83
Min	72	91	77	71	65	68	280	561	31	19	21	31
Ar-R	9,330	6,490	5,260	4,750	3,800	11,210	23,910	66,720	10,300	1,690	1,880	3,190

STATISTICS OF MONTHLY MEAN DATA FOR WATER YEARS 1959–2007, BY WATER YEAR (WY)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Mean	87.1	96.8	91.2	86.3	91.0	119	313	1,069	928	241	91.7	77.8
Max	191	170	156	135	128	311	824	1,835	2,026	855	265	203
(WY)	(1983)	(1973)	(1956)	(1971)	(1962)	(1986)	(1962)	(1993)	(1977)	(1965)	(1965)	(1983)
Min	41.9	50.0	55.4	54.7	55.5	65.4	113	131	302	25.3	20.9	22.2
(WY)	(2002)	(1977)	(1977)	(1977)	(2002)	(1977)	(1961)	(1977)	(1992)	(1961)	(1992)	(1960)

SUMMARY STATISTICS

	Calendar Year 2006	Water Year 2007	Water Years 1959–2007
Annual total	114,948	73,810	—
Annual mean	315	202	275
Highest annual mean	—	—	445
Lowest annual mean	—	—	80.2
Highest daily mean	2,340	Jun 6	1,900
Lowest daily mean	37	Jul 27	19
Annual extreme-day minimum	39	Jul 23	26
Annual mean (ar-R)	228,000	146,490	199,200
50 percent exceeds	860	474	796
50 percent exceeds	194	83	102
50 percent exceeds	51	30	55

Following the checking and reviewing processes, the data for the record computation period are flagged as approved, locked down in the database, and published.

Slide 32

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Idaho Water Science Center, 12/9/2008

The Class Assessment Follows.

- The assessment that follows contains five questions.
- Once you have successfully completed tests for all modules you will be given instructions on how to print out a certificate that documents successful completion of the Surface Water Procedures Training Class



Gage heights affected by ice should be used to compute discharge.

- A. True
- B. False

Lesson Assessment

Quiz - 5 questions

Last modified: Sunday, July 23, 2017 at 9:48:18 PM

Properties

On passing, 'Finish' button: [Goes to next slide](#)

On failing, 'Finish' button: [Goes to slide](#)

Allow user to leave quiz: [At any time](#)

User may view slides after quiz: [After passing quiz](#)

Show quiz in menu as: [Single Item](#)

 Edit in Quizmaker

 Edit Properties

Lesson Assessment

End of class module

- Please close this window and take the next module, if needed.

