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Stage-Discharge Rating Development and Discharge Measurements

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Outline

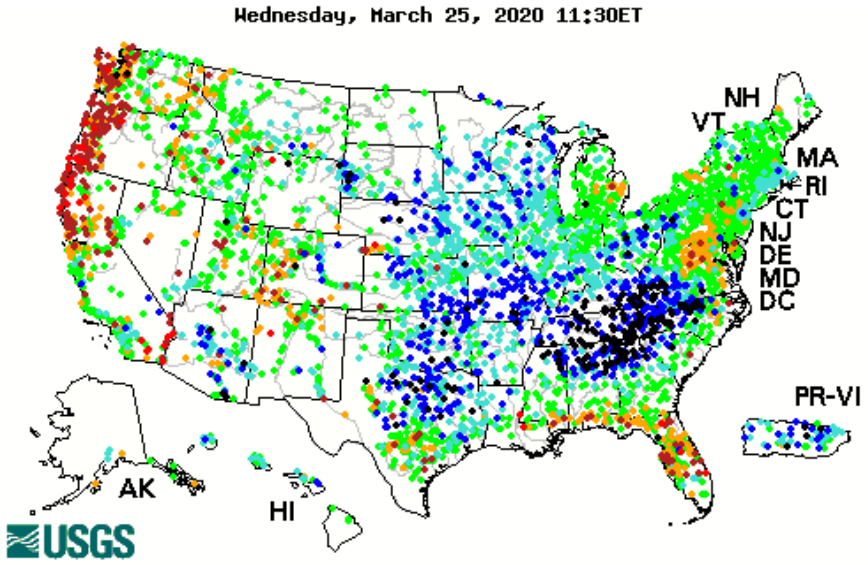
- Streamgages
- Measurement of stage
- Discharge Measurements
- Stage-Discharge Ratings
- Rating Validation
- Stage-Discharge Rating Shifts

Uinta River near Neola, UT

USGS Current Water Data for the Nation

--- Predefined displays ---
Introduction ▾ go

Daily Streamflow Conditions



Explanation

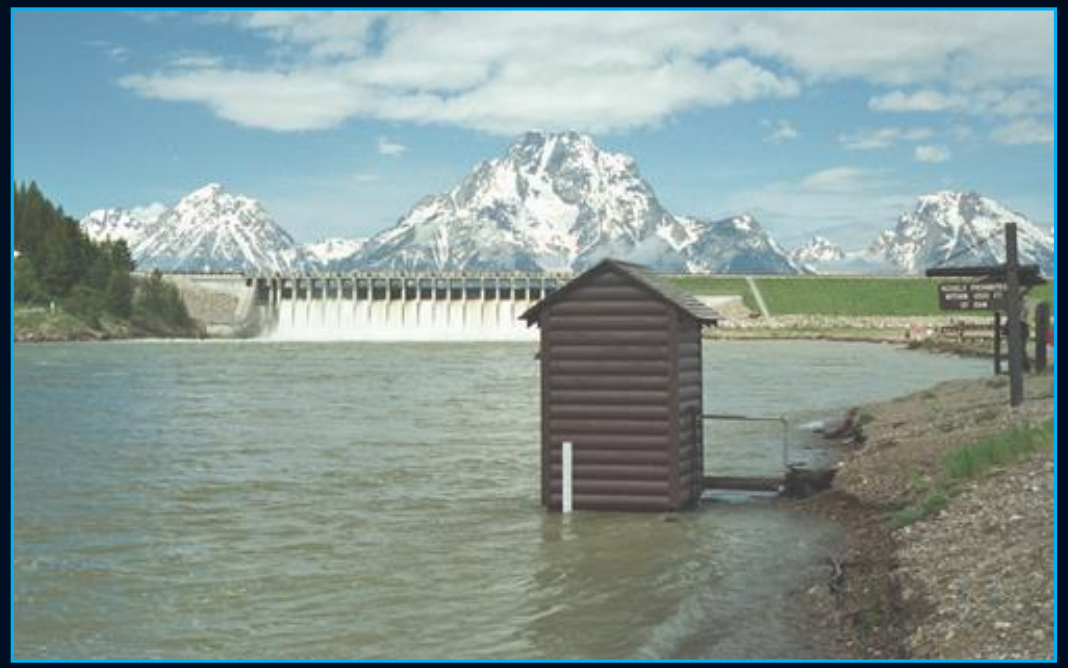
- High
- > 90th percentile
- 76th - 90th percentile
- 25th - 75th percentile
- 10th - 24th percentile
- < 10th percentile
- Low
- Not ranked

The colored dots on this map depict streamflow conditions as a percentile, which is computed from the period of record for the current day of the year. Only stations with at least 30 years of record are used.
The **gray circles** indicate other stations that were not ranked in percentiles either because they have fewer than 30 years of record or because they report parameters other than streamflow. Some stations, for example, measure stage only.

https://waterdata.usgs.gov/nwis/rt

Streamgages

- Stage also known as gage height
  - Arbitrary datum of water surface elevation at a gaging station
- Reference stage sensors (non-recording)
  - Staff gage
  - Wire-weight
- Electronic stage sensors (recording)
  - Non-submersible pressure transducers
  - Float tapes
  - Non-contact radars
- Measures stage not discharge!
- Stage transmitted using telemetry
  - GOES
  - Iridium Satellites
  - Cellular



Snake River near Moran, WY

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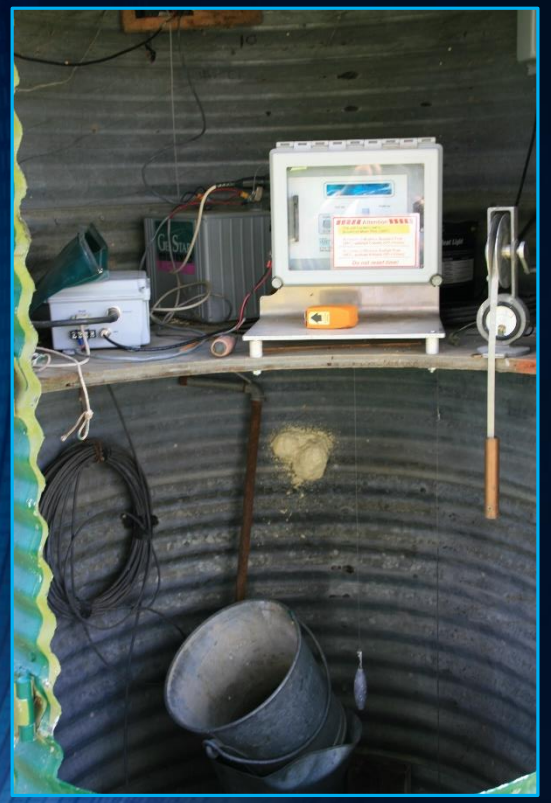
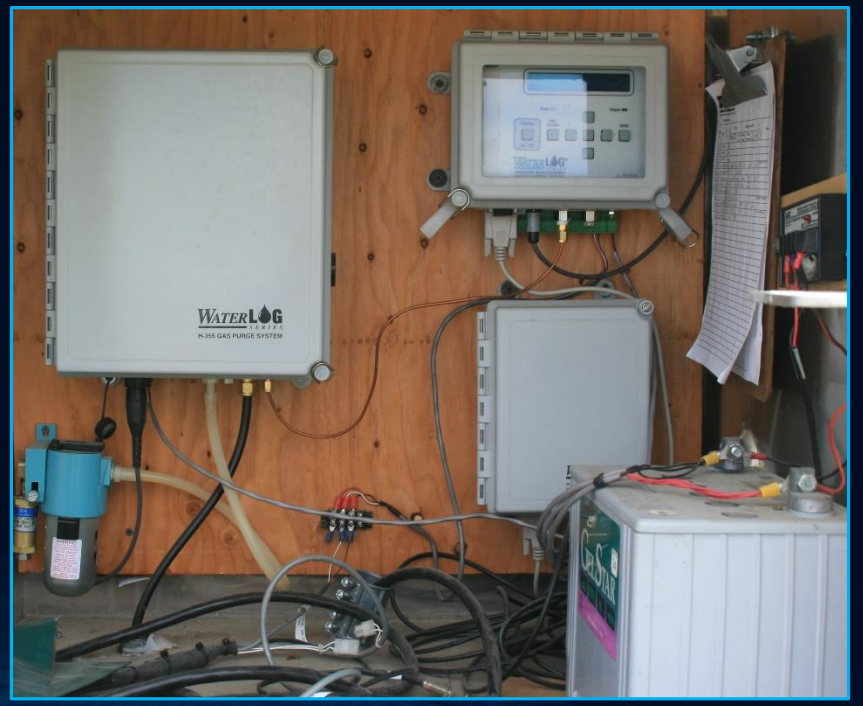
Examples of Electronic Stage Sensors



Shaft encoder

Shaft encoder

Non-submersible Pressure Transducer



Non-contact Radar

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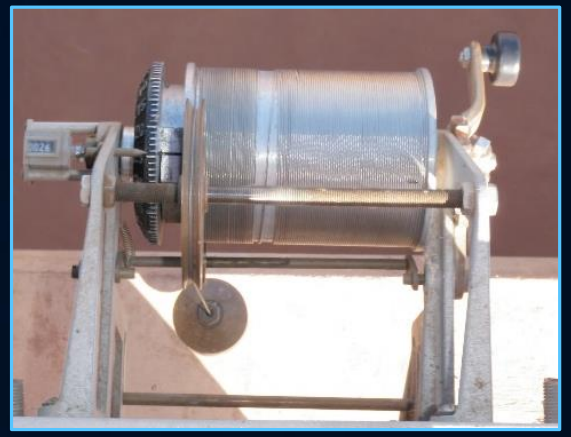
Examples of non-recording stage sensors

Staff gage



Wire Weight

Tape down from Reference Point

Wire Weight

Cantilever Wire Weight

Electric Tape gage

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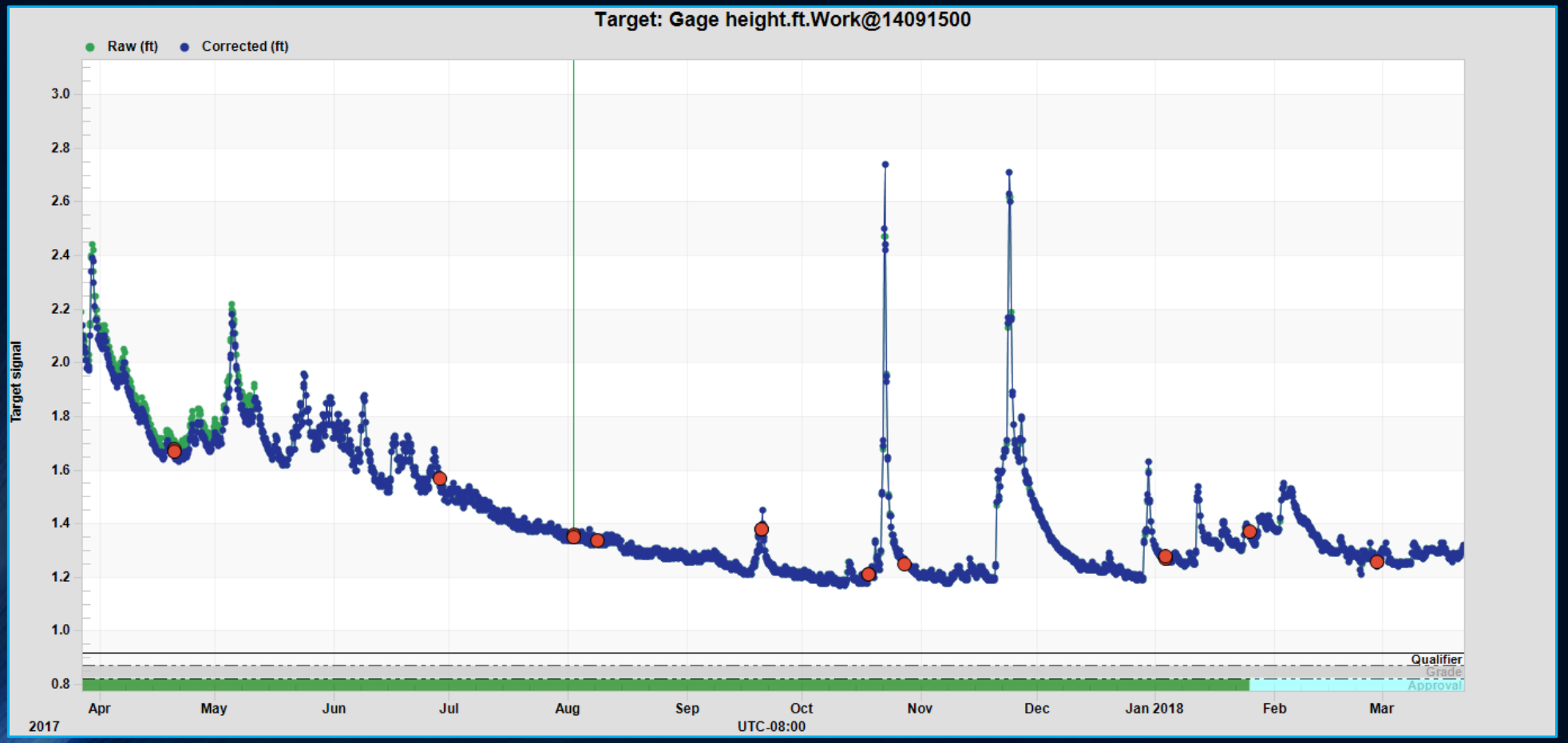
Streamgages provide a time series of instantaneous stage/gage height



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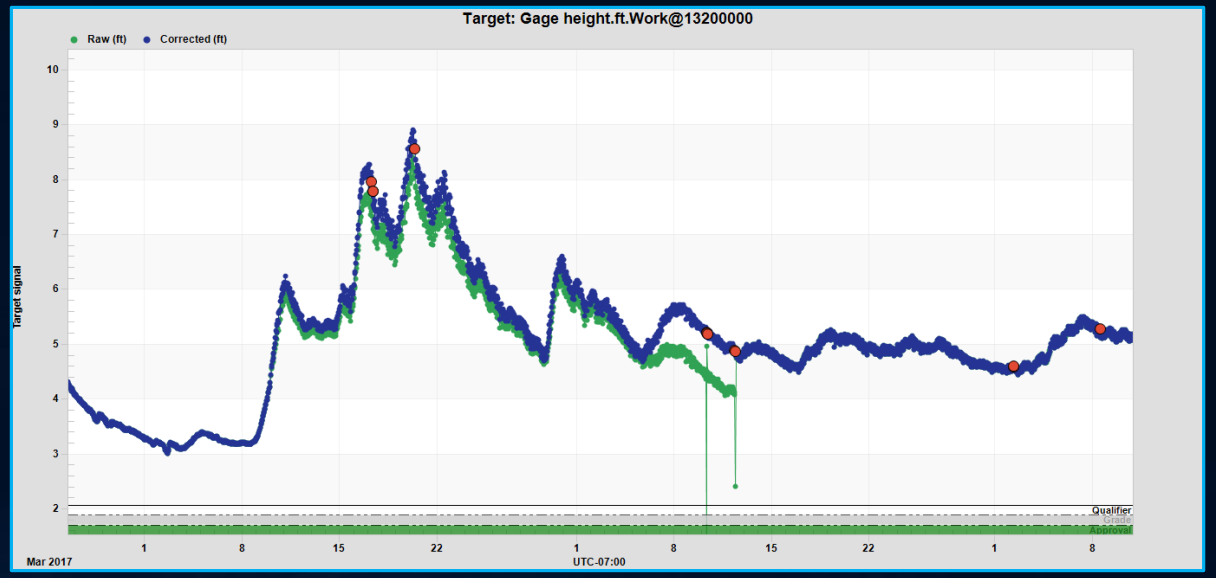
Field observations and maintenance ensure the gage height time series is accurate

- Gage height time series is edited to remove errors
  - Erroneous spikes
  - Gage height corrections (discrepancies between reference and recorder sensors)



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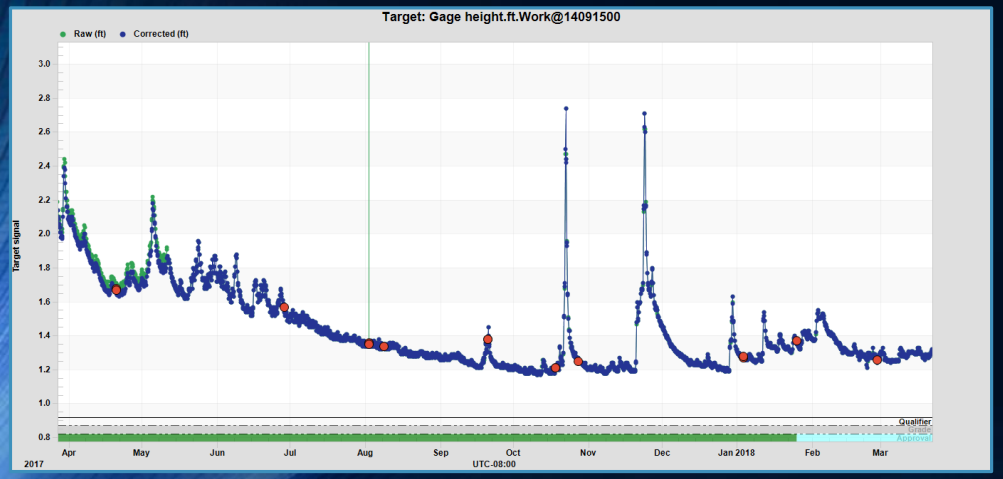
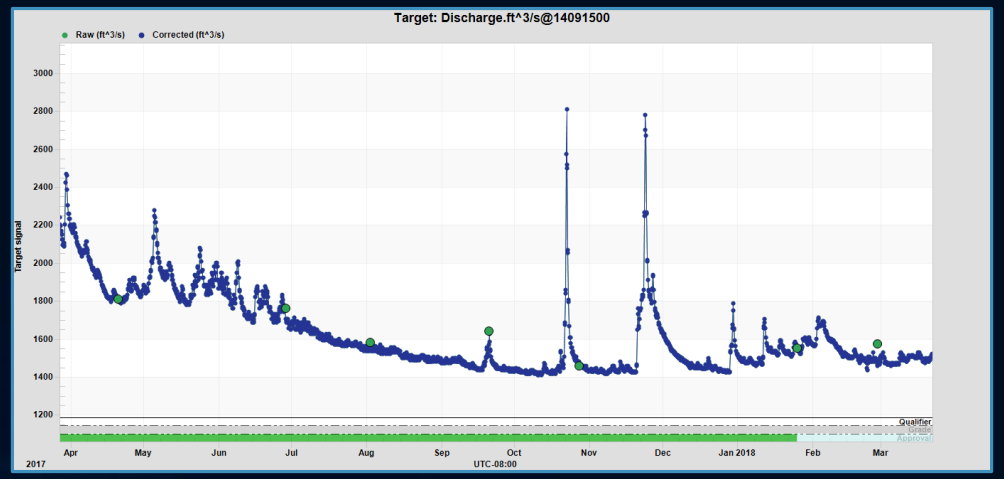
From the corrected time series of gage heights a time series of discharge can be determined using a stage-discharge rating model

- Stage is the surrogate parameter used to predict discharge
  - *"The height of the water is directly related to the amount of water flowing"*
- The fundamental assumption for applying the stage-discharge method for computing streamflow is that for every gage height value there is a unique discharge value



Gage Height



Discharge

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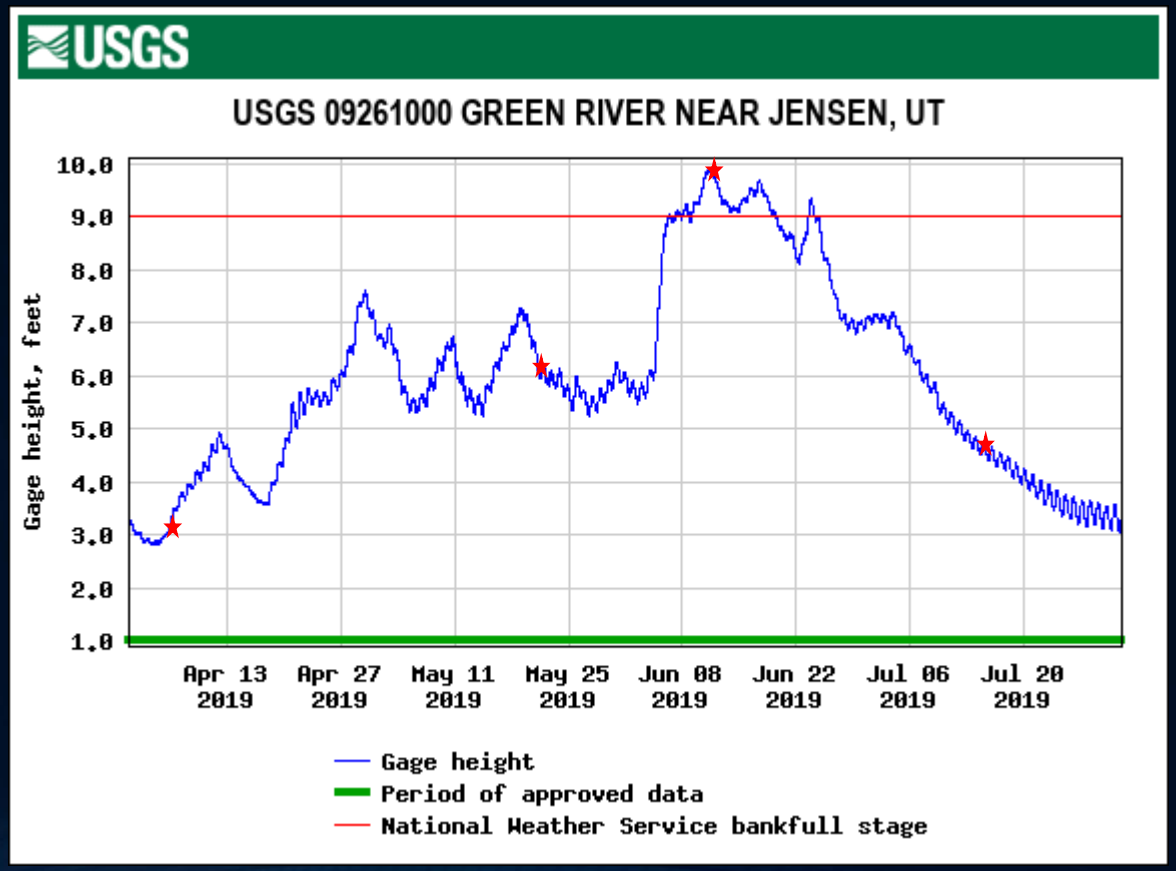
Development of Rating Curve—the basics

- Discharge measurements are made over the range of flow/gage heights experienced at a site
- A gage height is assigned to the measured discharge



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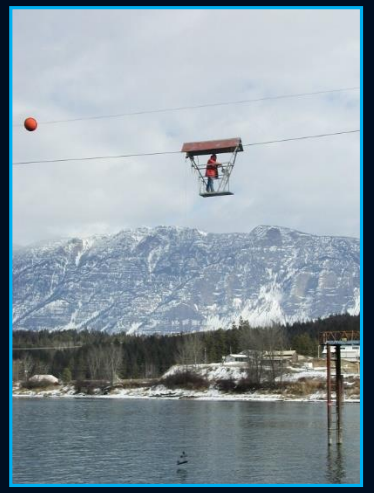
Types of Discharge Measurements

- Direct measurements
  - Volumetric measurements
  - Portable flumes / weirs
  - Mid-section method
  - Moving boat ADCP
  - Large Scale Particle Image Velocimetry (LSPIV)
  - Tracer Dilution
- Indirect measurements



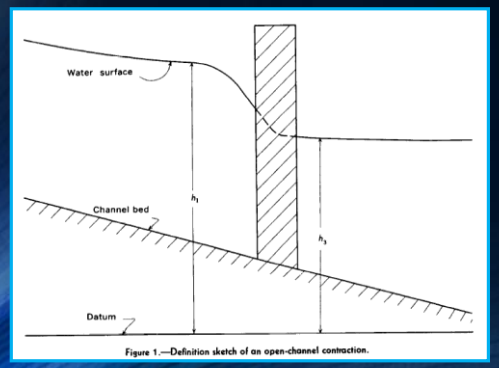


Figure 1.—Definition sketch of an open-channel contraction.

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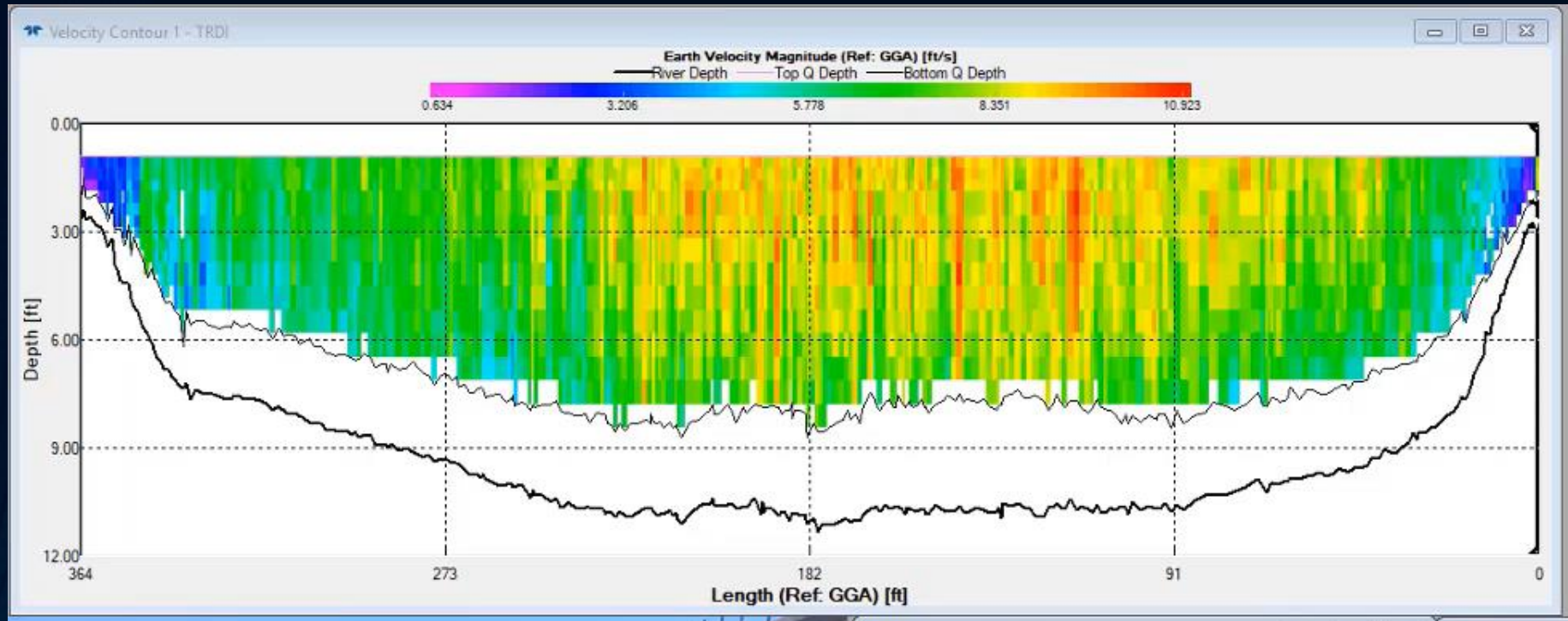
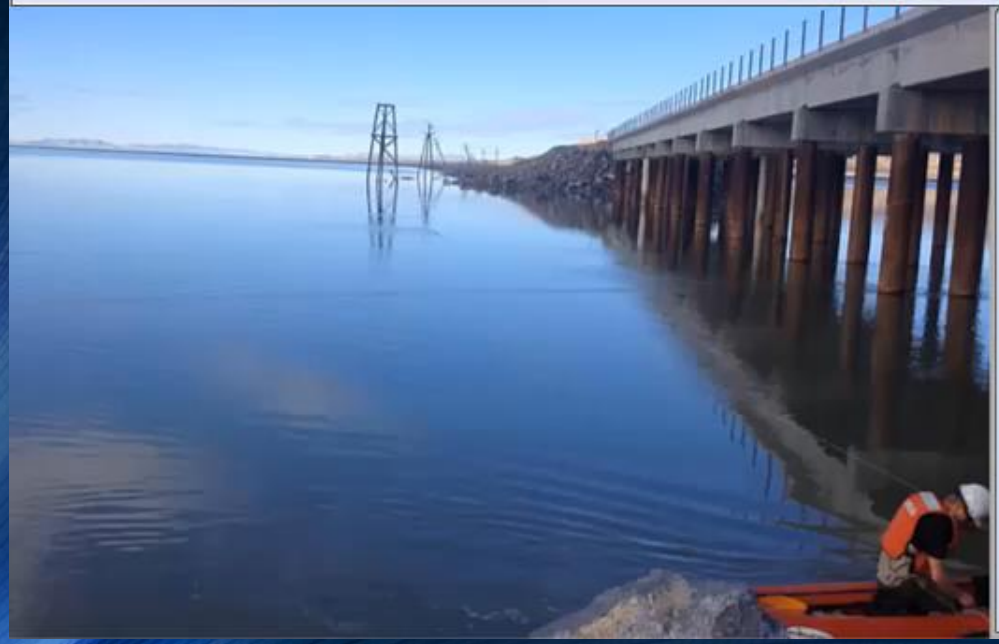
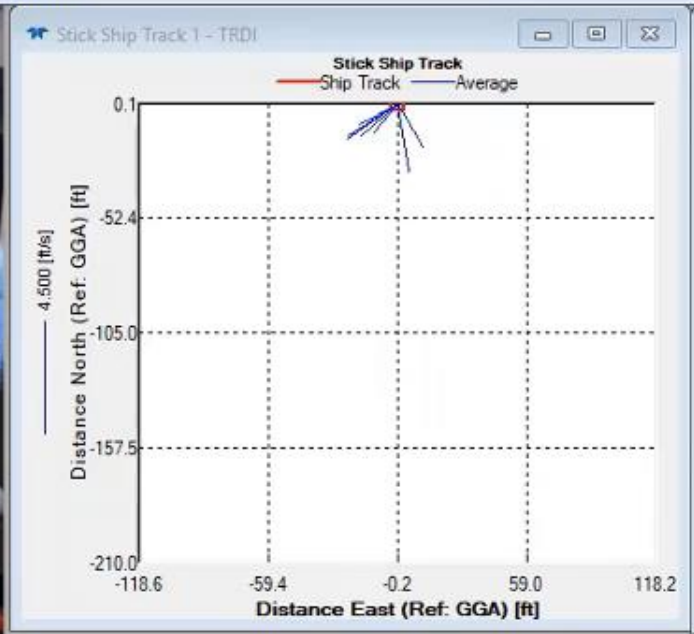






Composite Tabular 1 - TRDI

Ens. Nmb.	Nmb. of Ens.	Lost Ens.
679	8	0
Bad Ens.	%Bad Bins	Delta Time
1	0%	0.55

June 10, 2019 13:05:50.87

Pitch	Roll	Heading
-2.64°	-2.88°	25.64°
Temp.	Press.Sensor	
14.44°C	NA	

Discharge (Ref: GGA) Right to Left

Good Bins	3	
Top Q	-0.827	[ft³/s]
Measured Q	-0.819	[ft³/s]
Bottom Q	-0.537	[ft³/s]
Left Q	0.000	[ft³/s]
Right Q	0.000	[ft³/s]
Total Q	-2.183	[ft³/s]

Discharge Measurement Accuracy

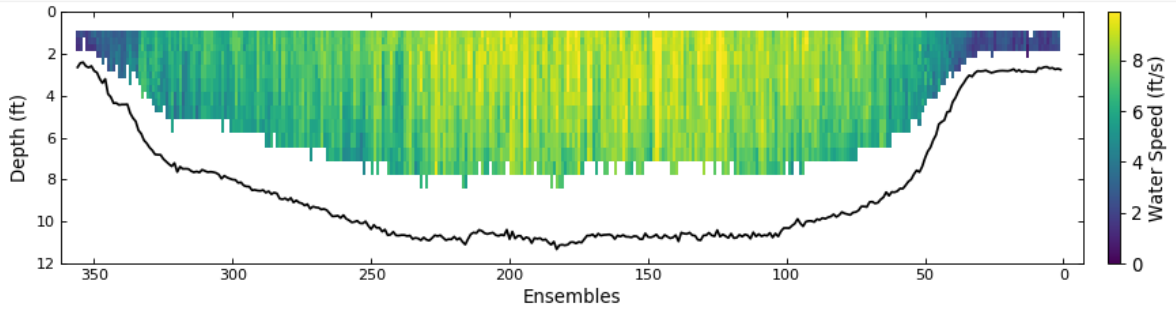
- Discharge Uncertainty
  - QRev
  - Statistical analysis
    - Velocity distribution
    - Depths

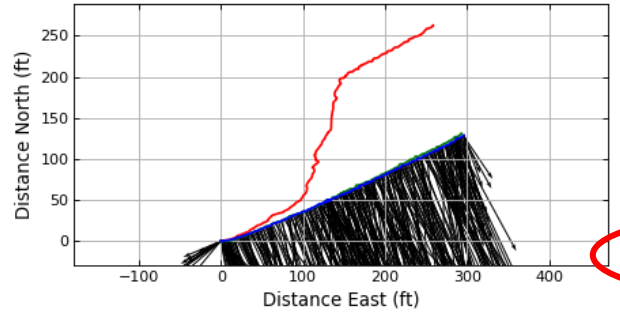
Main | SysTest | Compass/P/R | Temp/Sal | MovBedTst | BT | GPS | Depth | WT | Extrap | Edges | EDI

Summary | Details | Premeasurement | Settings | ADCP

Transect	Start	Bank	End	Duration(sec)	Total Q (ft3/s)	Top Q (ft3/s)	Meas Q (ft3/s)	Bottom Q (ft3/s)	Left Q (ft3/s)	Right Q (ft3/s)
Measurement	**13:05:47**		**13:28:48**	**1240.0**	**20154.35**	**2218.89**	**13419.41**	**4465.77**	**31.18**	**19.10**
09261000_0_000_20190610130546_643482_40.409010N_109.235151W	13:05:47	R	13:10:45	298.6	20176.01	2226.87	13335.15	4577.72	21.15	15.12
09261000_0_001_20190610131127_643482_40.409358N_109.234106W	13:11:26	L	13:17:22	355.6	19953.81	2202.01	13309.47	4389.79	34.51	18.04
09261000_0_002_20190610131841_643482_40.409010N_109.235156W	13:18:41	R	13:23:27	286.2	20081.17	2204.45	13436.15	4367.43	51.95	21.18
09261000_0_003_20190610132349_643482_40.409359N_109.234097W	13:23:49	L	13:28:48	299.7	20406.40	2242.23	13596.87	4528.15	17.10	22.05

	COV %		% Q
Q:	0.95	L/R Edge:	0.15 / 0.09
Width:	0.79	Invalid Cells:	0.10
Area:	0.72	Invalid Ens:	0.00





Uncertainty	Auto	User
Random 95%	1.5	
Invalid Data 95%	0.0	
Edge Q 95%	0.1	
Extrapolation 95%	0.6	
Moving-Bed 95%	0.0	
Systematic 68%	1.5	
Estimated 95%	**3.4**	**3.4**

Gage Height Uncertainty

- Accuracy of gage height readings assigned to discharge measurement is considered when qualifying measurement.
- Can have greater uncertainty at higher flows
  - Wave action
  - Drawdown

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Measurement Uncertainty

- Qualitative Rating
  - Excellent: +/- 2%
  - Good: +/-5%
  - Fair: +/-8%
  - Poor: +/-10%
- Example:
  - Discharge: 20,200 cfs
  - Measurement Rated: Good
  - Max: 21,210 cfs
  - Min: 19,190 cfs

USGS 09261000 GREEN RIVER NEAR JENSEN, UT

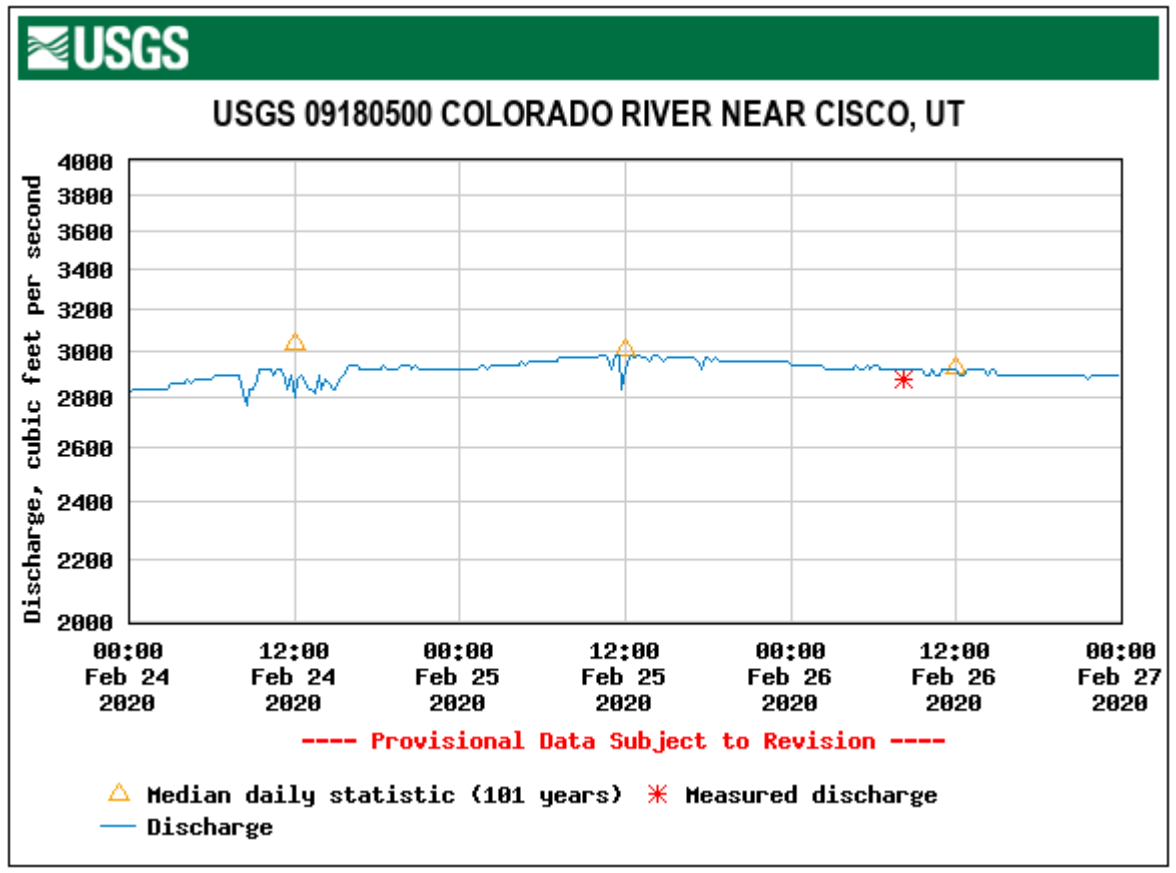
Available data for this site | Surface-water: Field measurements | GO

Uintah County, Utah
Hydrologic Unit Code 14060001
Latitude 40°24'34", Longitude 109°14'05" NAD27
Drainage area 29,660.00 square miles
Contributing drainage area 25,400.0 square miles
Gage datum 4,758.00 feet above NGVD29

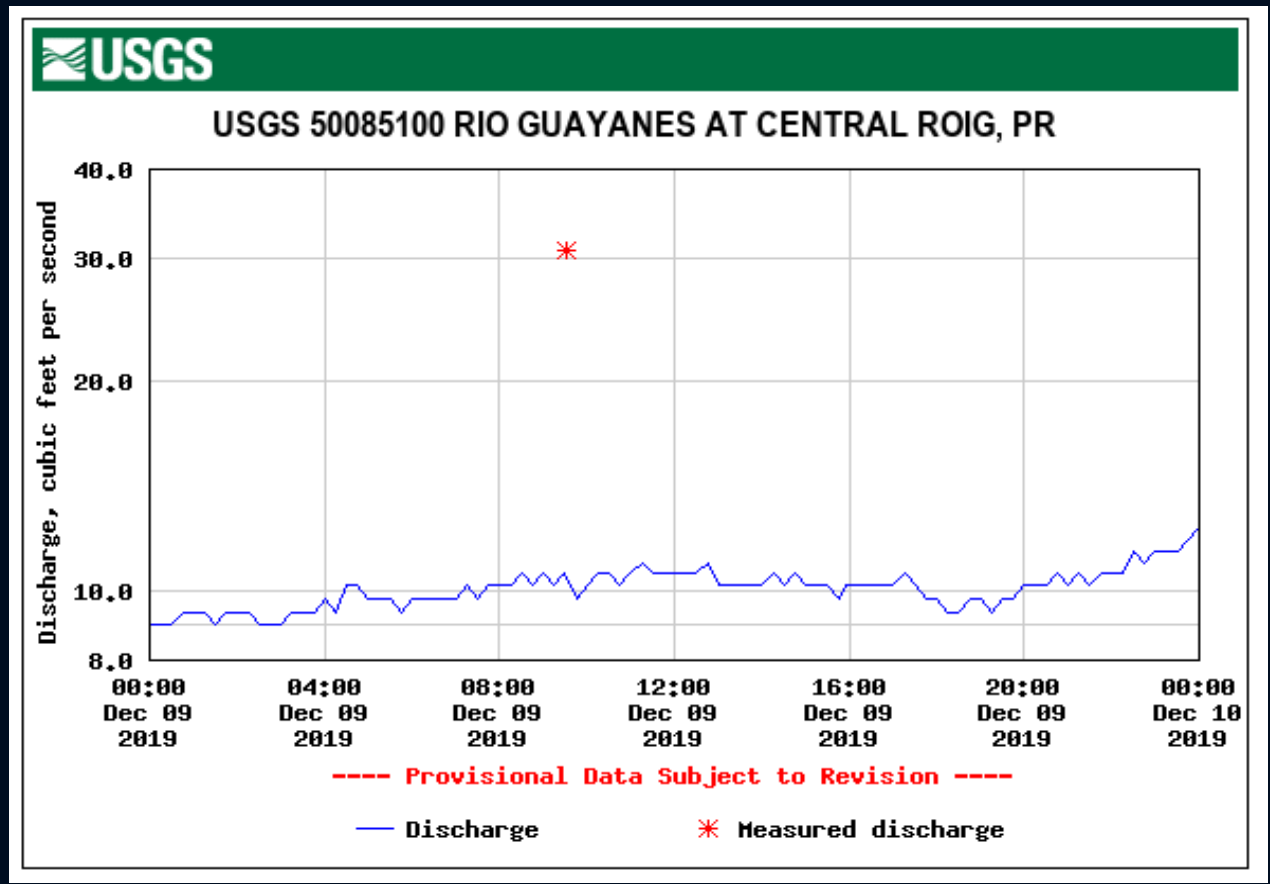
Output formats

- HTML table with channel data
- HTML table without channel data
- Tab-separated data with channel data
- Tab-separated data without channel data
- Graph of data
- Reselect output format

Meas. Number	Date Time	Time Datum	Measurement Used?	Who	Measuring Agency	Stream flow (ft^3/s)	Gage Height (ft)	GH Change (ft)	Meas. Duration (hr)	Meas. Rated	Control
1040	2020-03-04 13:54:10	MST	Yes	ELR	USGS	2330	2.99	0.01	0.20	Good	Clear
1039	2020-03-04 13:16:51	MST	Yes	ELR	USGS	2290	2.94	0.01	0.20	Good	Clear
1038	2020-01-23 11:04:32	MST	Yes	ELR	USGS	2410	2.96	0.01	0.30	Fair	Clear
1037	2019-12-17 14:48:54	MST	Yes	ELR/BTR	USGS	2530	3.09	0.06		Good	Clear
1036	2019-11-14 14:28:01	MST	Yes	ELR/BTR	USGS	1640	2.46	0.00	0.50	Good	Clear
1035	2019-10-07 13:38:17	MDT	Yes	ELR/BTR	USGS	1830	2.54	-0.02		Fair	Clear
1034	2019-08-29 09:03:05	MDT	Yes	ELR/BTR	USGS	2110	2.86	0.00	0.30	Fair	Clear
1033	2019-07-23 12:43:33	MDT	Yes	ELR/NML	USGS	3170	3.53	0.00	0.20	Fair	Clear
1032	2019-06-10 13:17:17	MDT	Yes	ELR/MLF	USGS	20200	9.60	0.01	0.40	Good	Clear



Good example! Discharge measurement (2880 cfs; Good) is 1.3% less than reported discharge (2920 cfs)

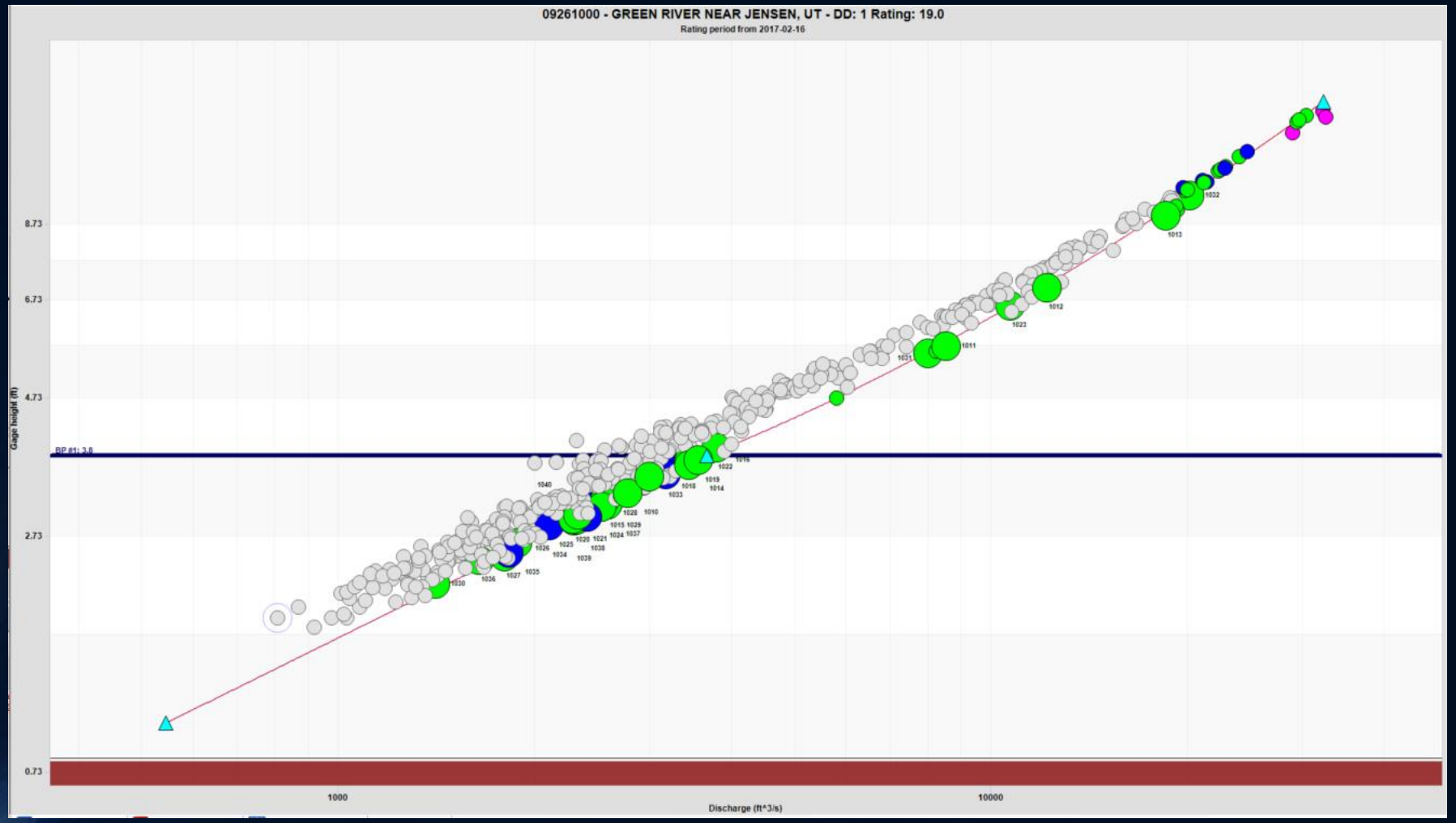


Not ok!
Discharge measurement (31 cfs; Fair) is 210% greater than reported discharge (10 cfs)

USGS Stage-Discharge Rating Curve Method

- Empirically based and rooted in open-channel hydraulics
  - not statistically developed
- Developed manually – "curve" fitting
  - Equations are not used to fit the data
- Measurements are filtered in the development of the base rating curve
  - Range of flow
  - Historic measurements in similar channel conditions

Development of Rating Curve



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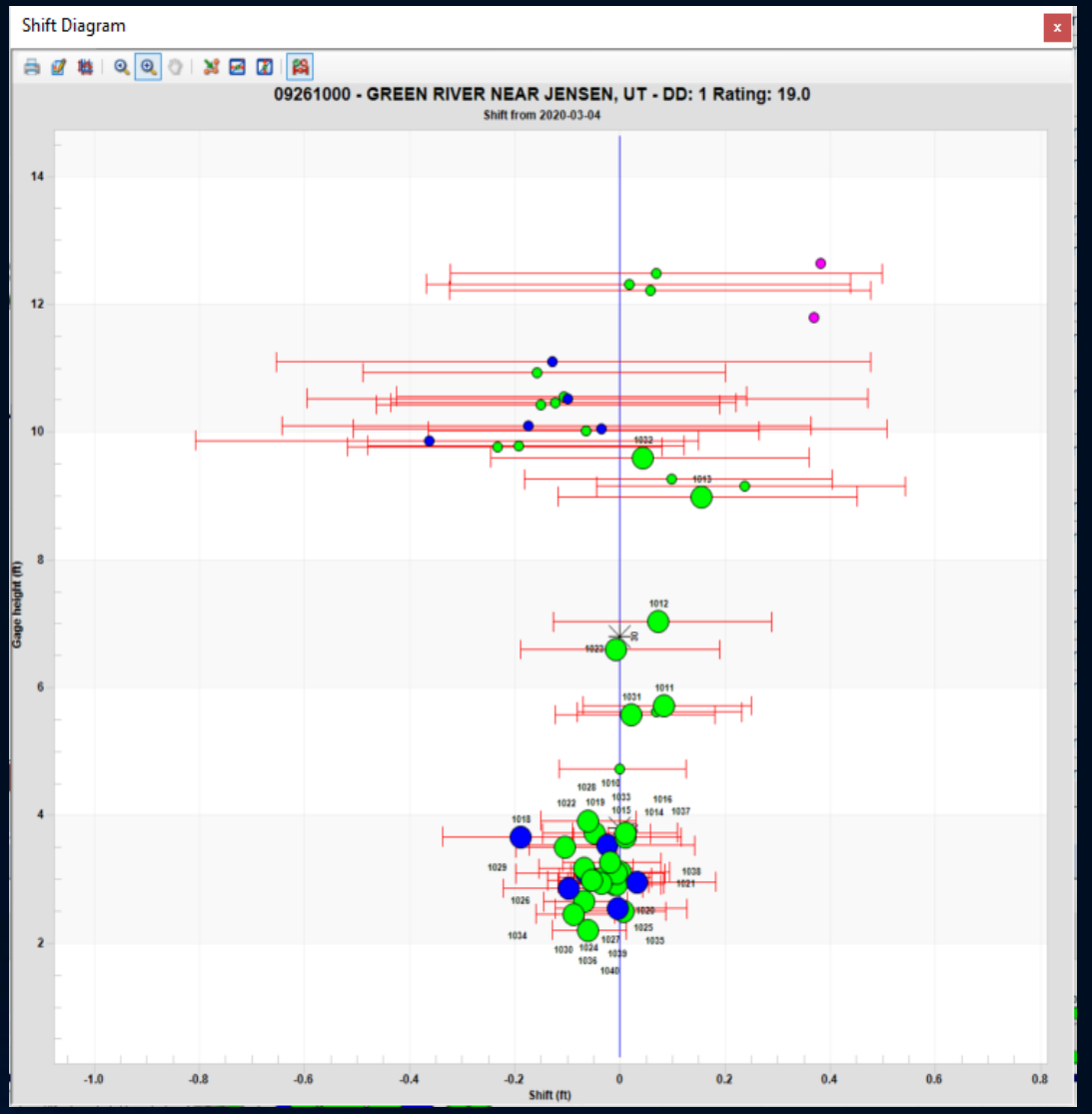
Development of Rating Curve

- "Curve fitting"
- Balance error bars of discharge measurements
- Cover range in stage
- Historic peak measurements



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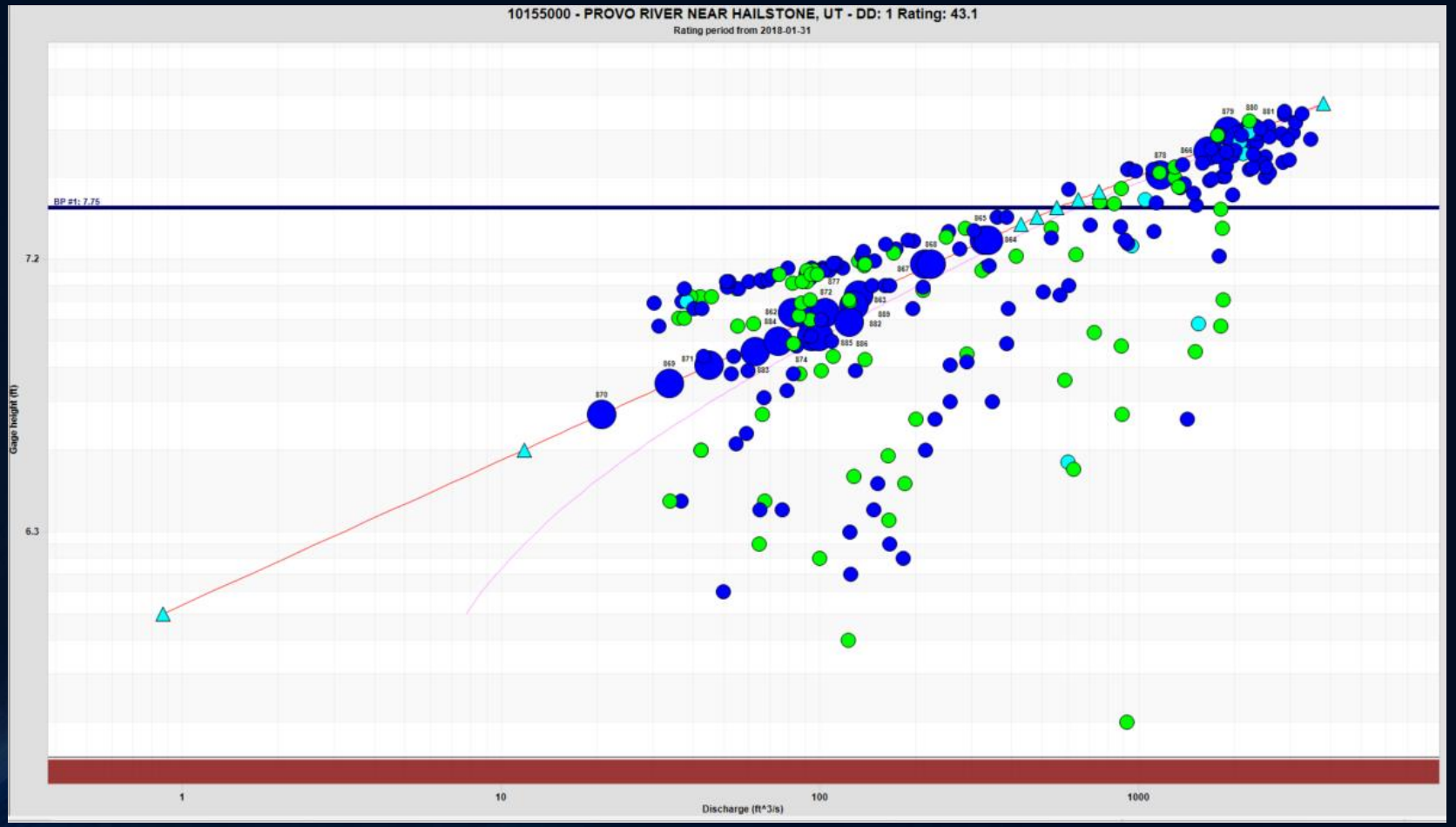
Validation of Stage-Discharge Curve

- Continue to make measurements to validate stage-discharge model
- Channels are dynamic!!
- Temporary changes in the stage-discharge relation are handled via rating shifts
- Permanent changes in the stage-discharge relation lead to development of a new base rating curve

Unstable Channels



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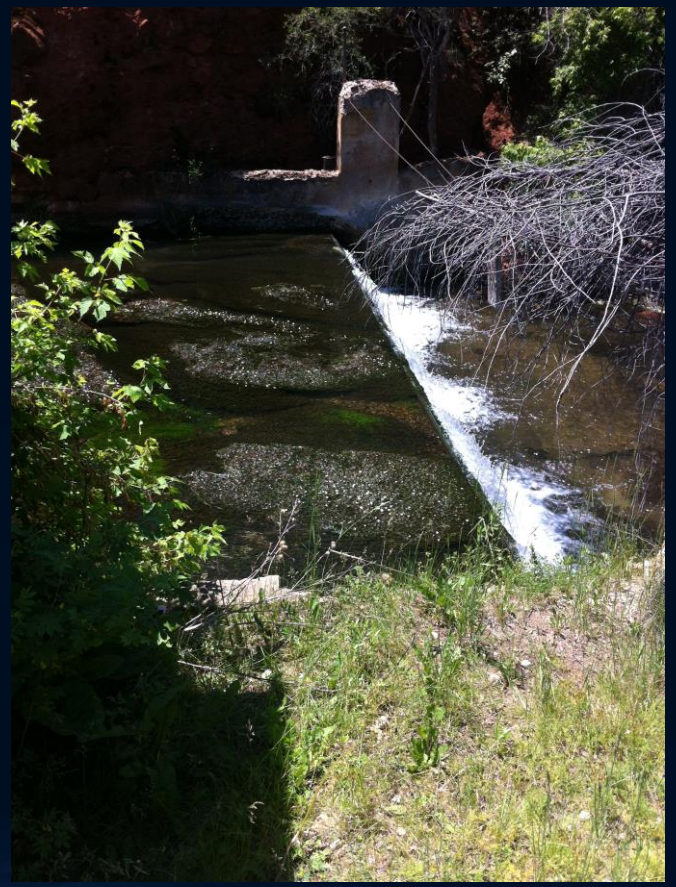
Unstable Channels

Dirty Devil River

Temporary Shifts to Stage-Discharge Rating Curve

Debris/Beaver Dams



Seasonal Algae

Scour/Fill from events

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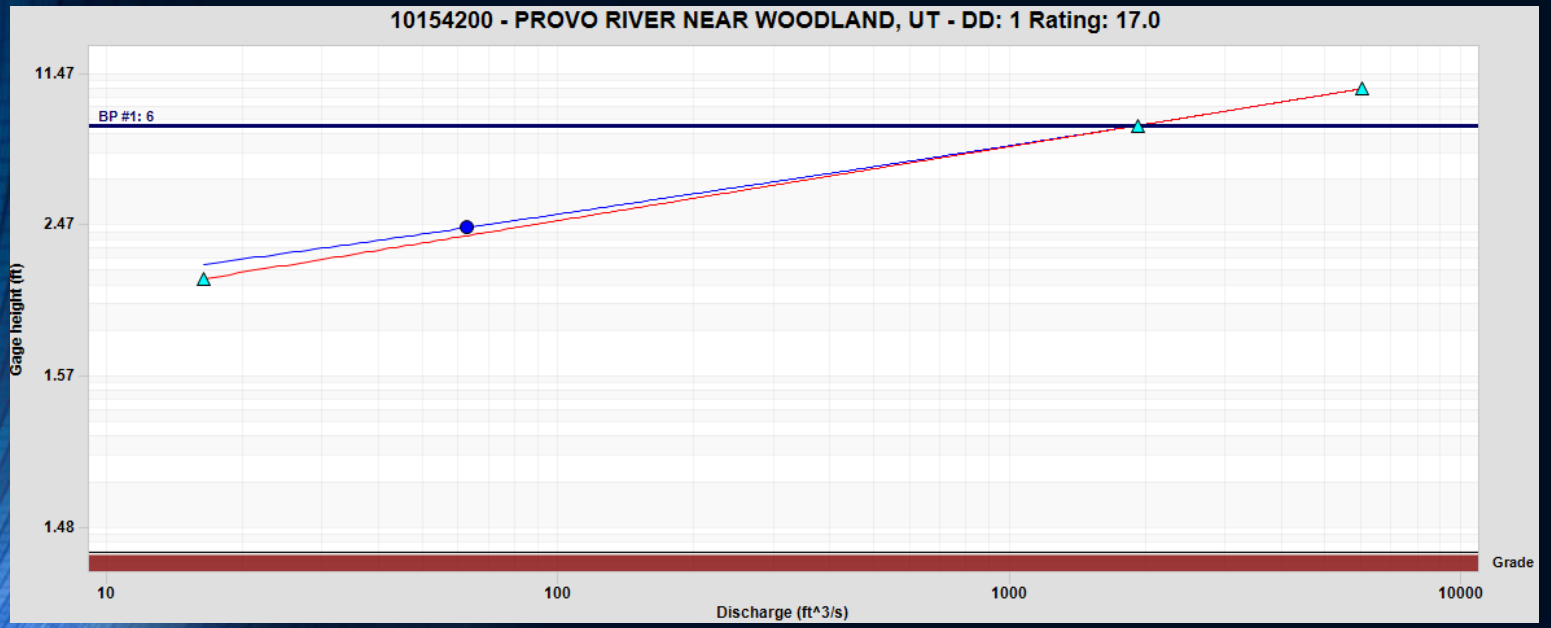
What is a Shift Curve?

- A shift curve is used to make an adjustment to the existing rating curve
- Adjustment is based upon an identified change to the hydraulic control
  - Identified by a verified discharge measurement that plots off of defined rating curve. (Exceeds measurement uncertainty)
- Discharge measurements are treated as the "truth" and we temporarily adjust our "model" (i.e. rating curve) to ensure accurate discharge is reported.

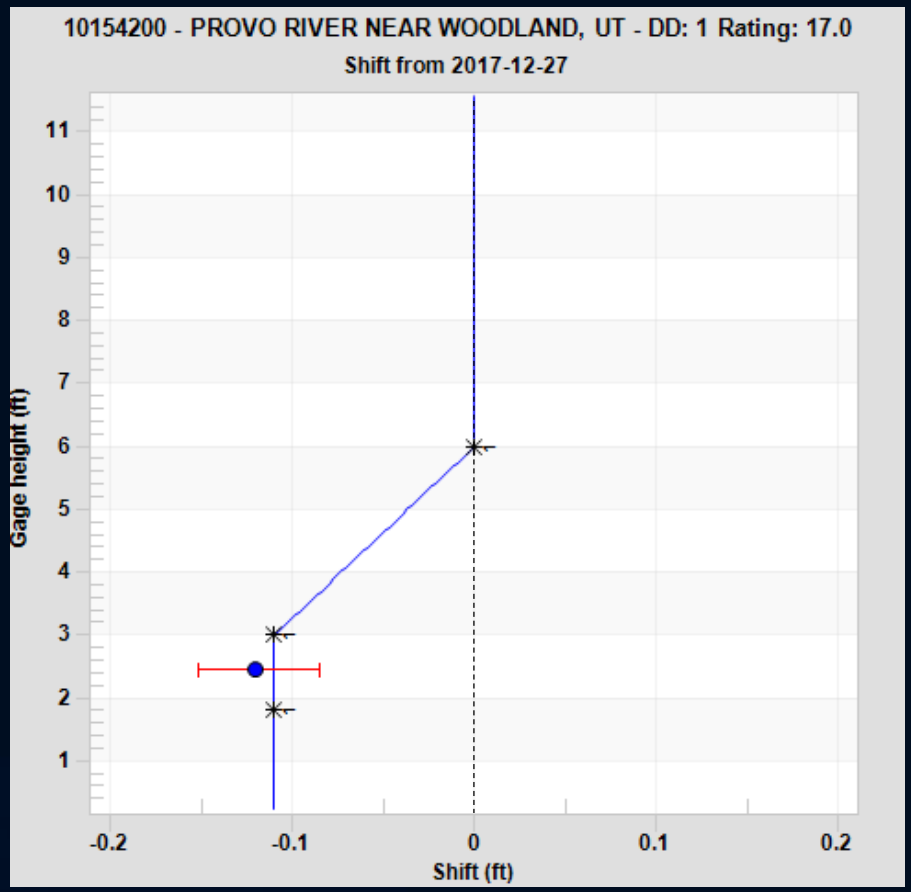
Variable Shift Diagram (a.k.a. V-Diagram)

- Shifts curves are developed using the rating curve plot and what is known as a variable shift diagram



Shift curve plotted on rating

Shift curve plotted variable shift diagram



Rating represented by the "0" shift amount

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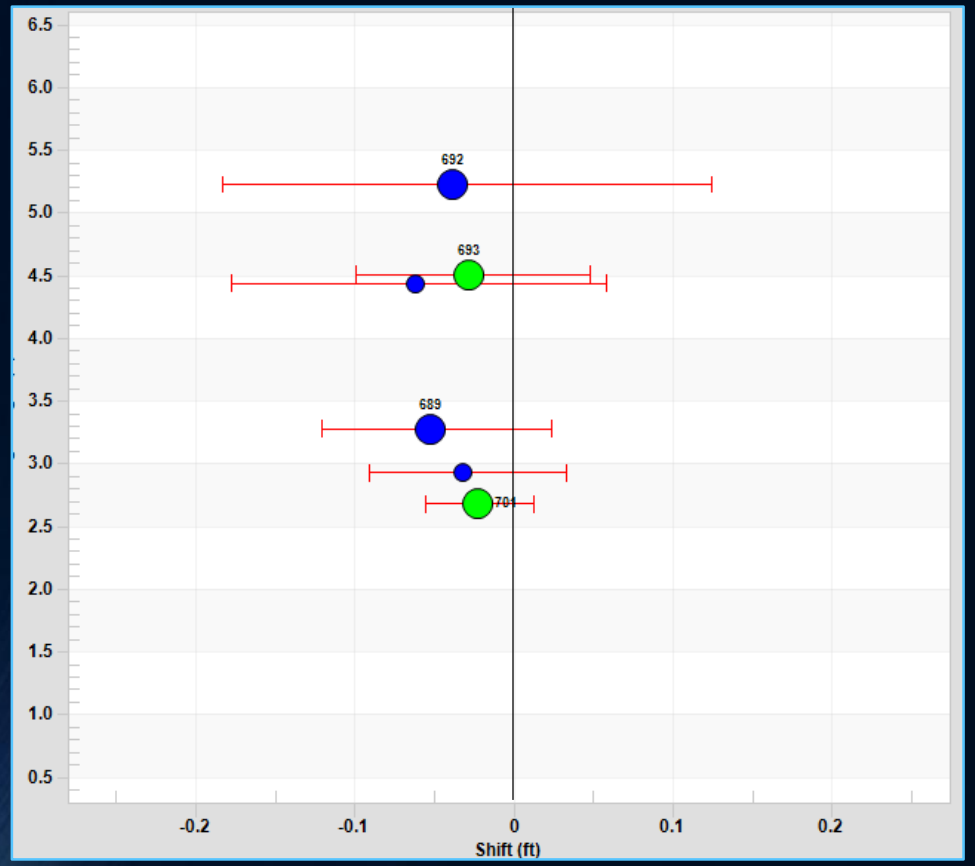
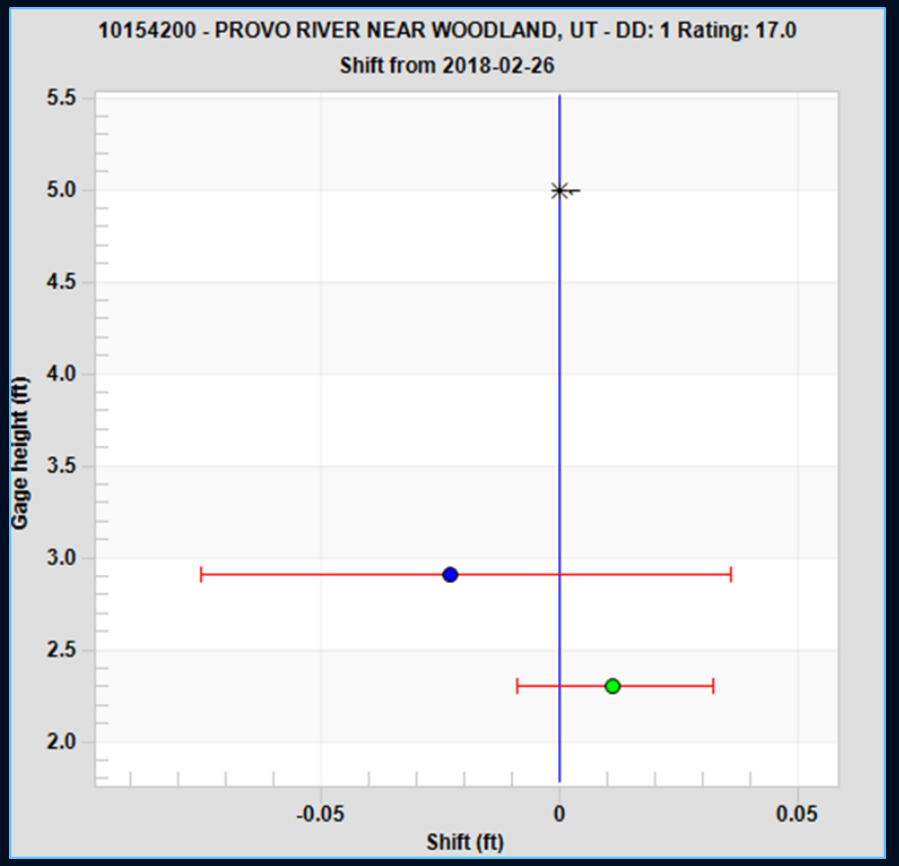
When is a Shift Curve Needed?



Trend of measurements indicates a slight change in the stage-discharge relation

- Shift could be justified or new rating
- Over/under estimating discharge



Indicates that no adjustment to base rating is needed.

- No shift applied

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Questions?

Green River near Jensen, UT