AGU PUBLICATIONS

Water Resources Research

Supporting Information for

Yosemite Hydroclimate Network: Distributed Stream and Atmospheric Data for the Tuolumne River Watershed and Surroundings

Jessica D. Lundquist[1], James W. Roche[2], Harrison Forrester[2], Courtney Moore[3], Eric Keenan[1], Gwyneth Perry[1], Nicoleta Cristea[1], Brian Henn[1], Karl Lapo[1], Bruce McGurk[4], Daniel R. Cayan[5,6], and Michael D. Dettinger[6]

[1]Department of Civil and Environmental Engineering, University of Washington, Seattle, WA
[2]National Park Service, Yosemite, CA
[3]Northwest Hydraulic Consultants, Seattle, WA
[4]McGurk Hydrologic, Orinda, CA
[5]Scripps Institution of Oceanography, La Jolla, California
[6]United States Geological Survey, Reno, Nevada

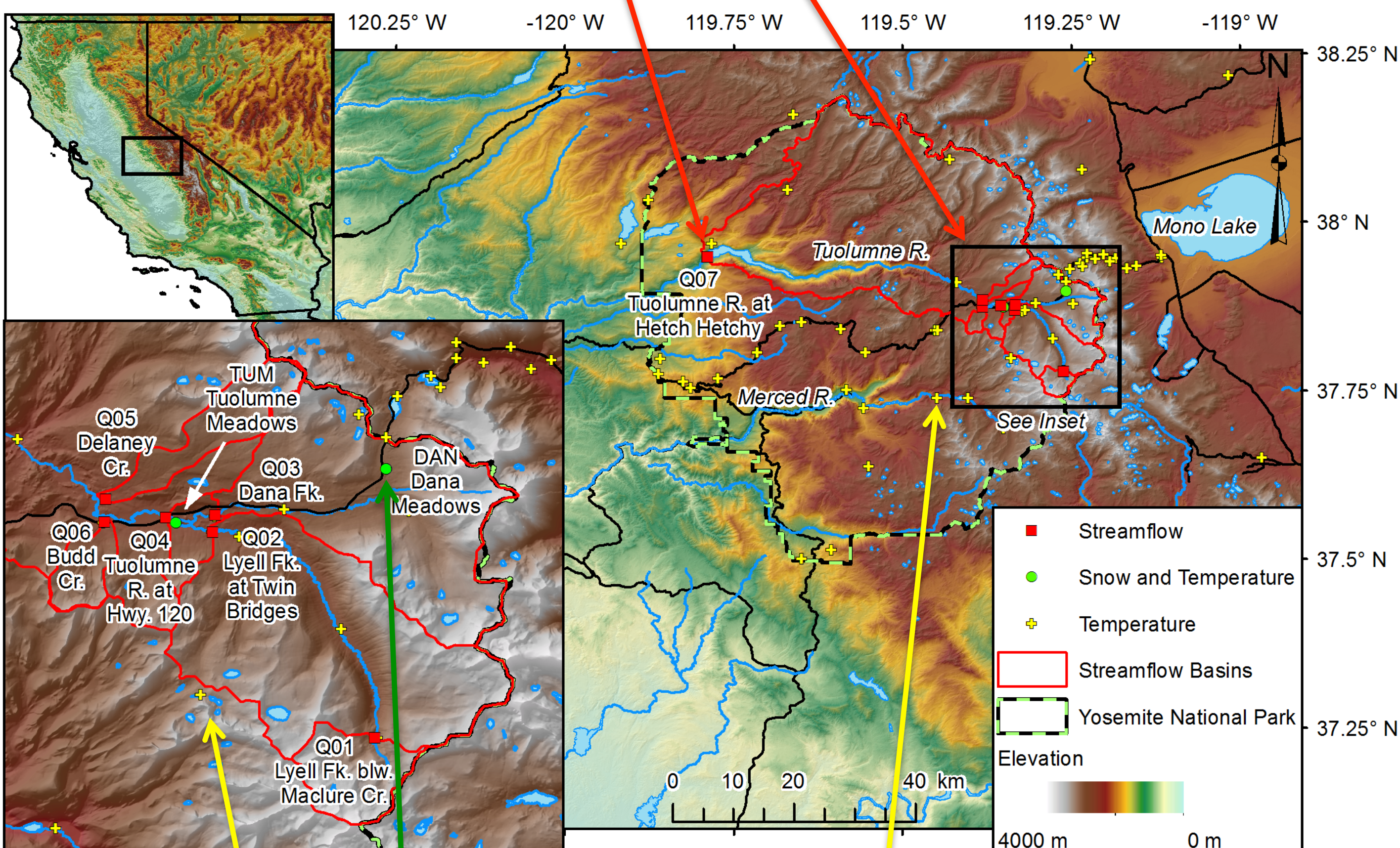
Introduction

This PDF includes graphics, maps, photographs and text to explain the different data sources provided, including how the stage data were collected, processed, and transformed into rating curves for each site, as well as how the reconstructed reservoir inflows and atmospheric data were developed. This is meant to guide users of the data to best understand the data's strengths and caveats, including the environment in which each measurement was made.

Table of Contents

Overview of the Yosemite Hydroclimate Dataset

Nested streamflow data for the Tuolumne River Above Hetch Hetchy



Full meteorological data to force a hydrologic model

Distributed air temperature data

Quick Guide to Datafiles

For users interested in quickly getting started with the data, we recommend the following files and associated README files:

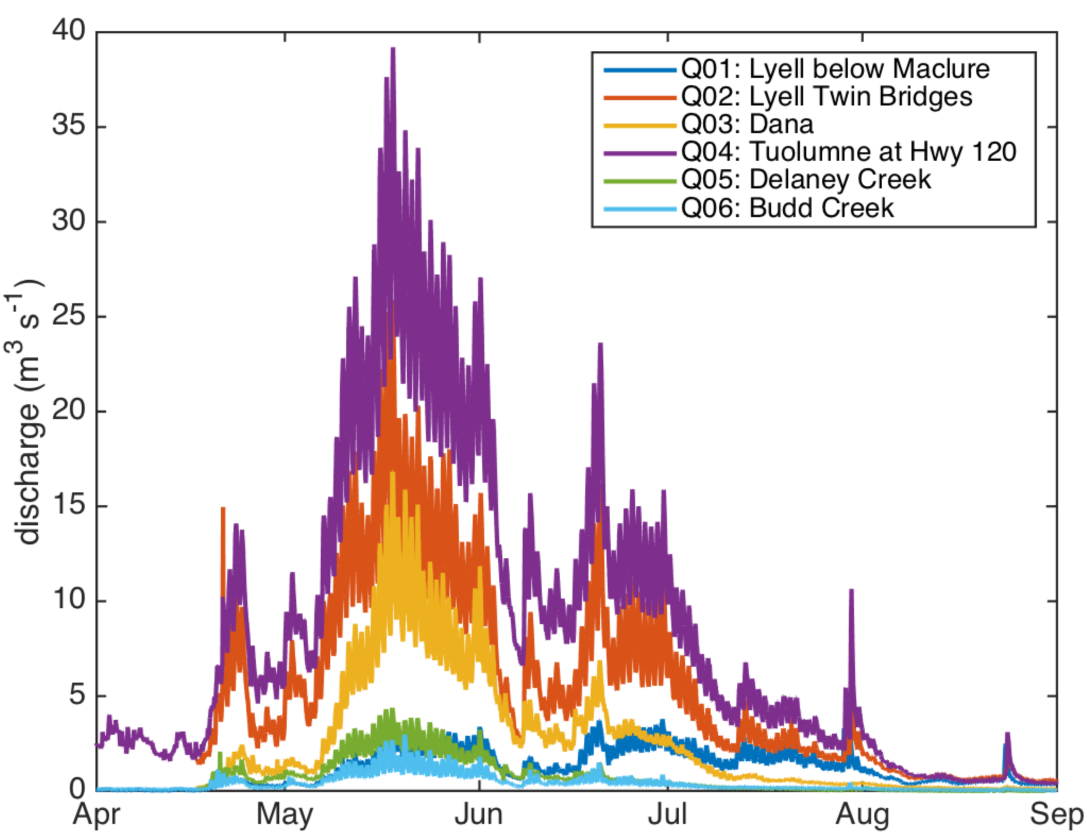
Tuolumne_combined_timeseries_Q_2002_2015.csv half-hourly time-step
Our best estimate of discharge for each of the six stream locations in the upper basin (Q01 to Q06, see graph below) using the better choice when two adjacent records were available, replacing all times with ice jams with NaN. For raw data, water temperature, and 95% confidence intervals, see the detailed stream data files.

HetchHetchy_unimpaired_timeseries_Q_1970_2015.csv daily time-step
Our best estimate of inflow to the Hetch Hetchy Reservoir each day.

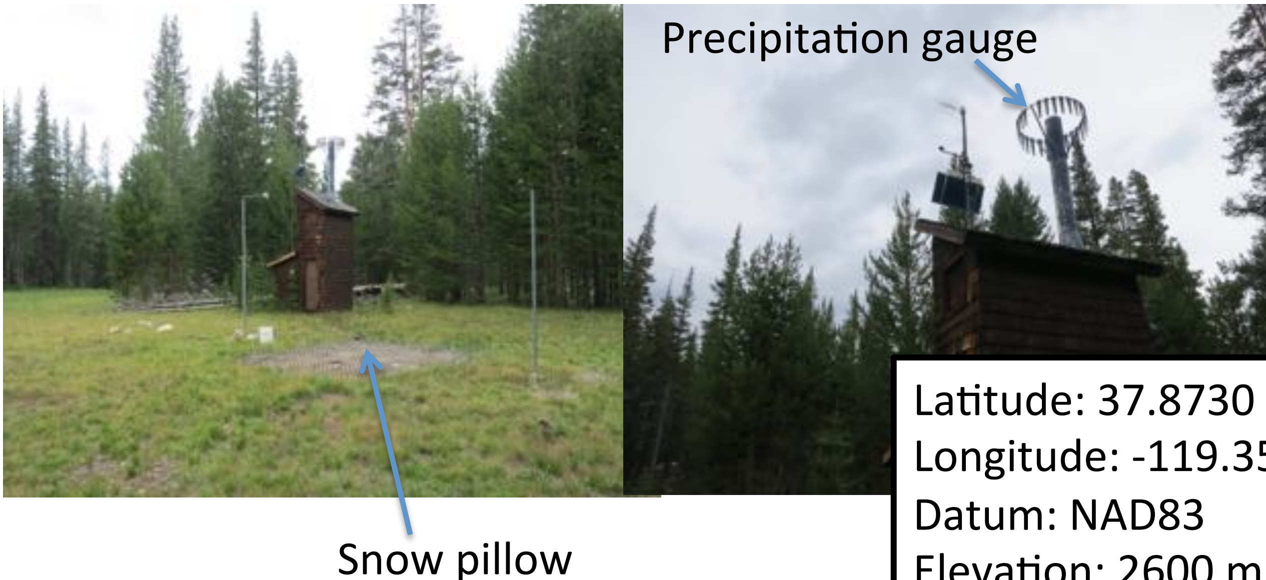
TUM-DAN_Pillow_SWE.csv daily time-step
Automated weighing observations of snow water equivalent from 1980 to 2015.

TUM_Course_SWE.csv, & DAN_Course_SWE.csv monthly time-step
Manual observations of snow water equivalent from 1970 to 2015.

Dana_Meadows_model_forcing_dataset.csv hourly time-step
Our best estimate of air temperature, wind speed, relative humidity, solar irradiance, longwave irradiance, and precipitation for 2003 to 2015, with all gaps filled.

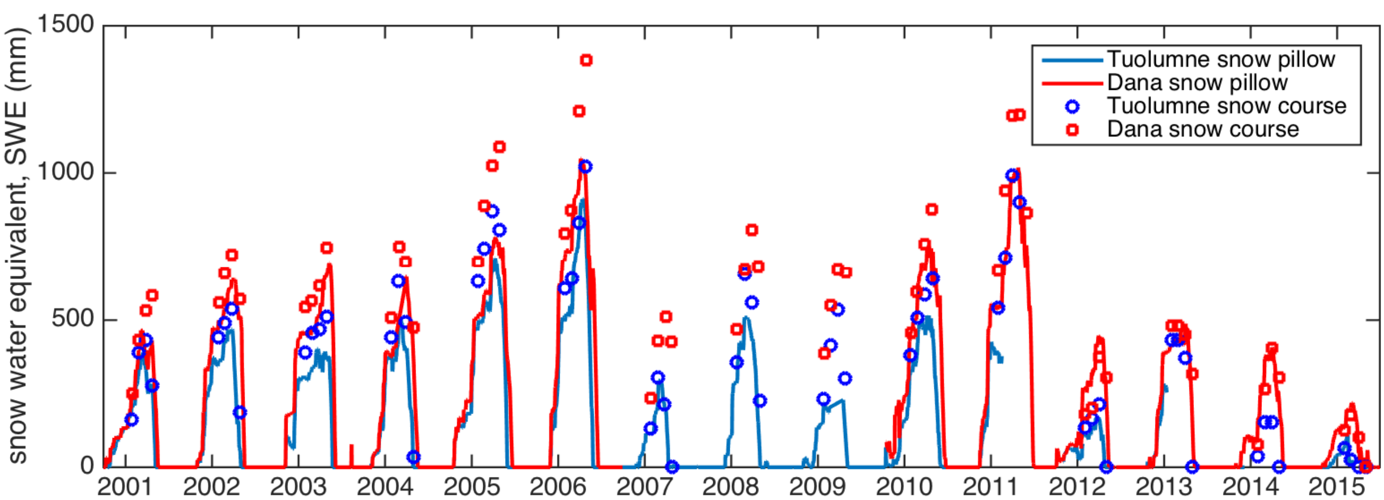


TUM: Tuolumne Meadows Precip Gauge, Snow Pillow, and Course

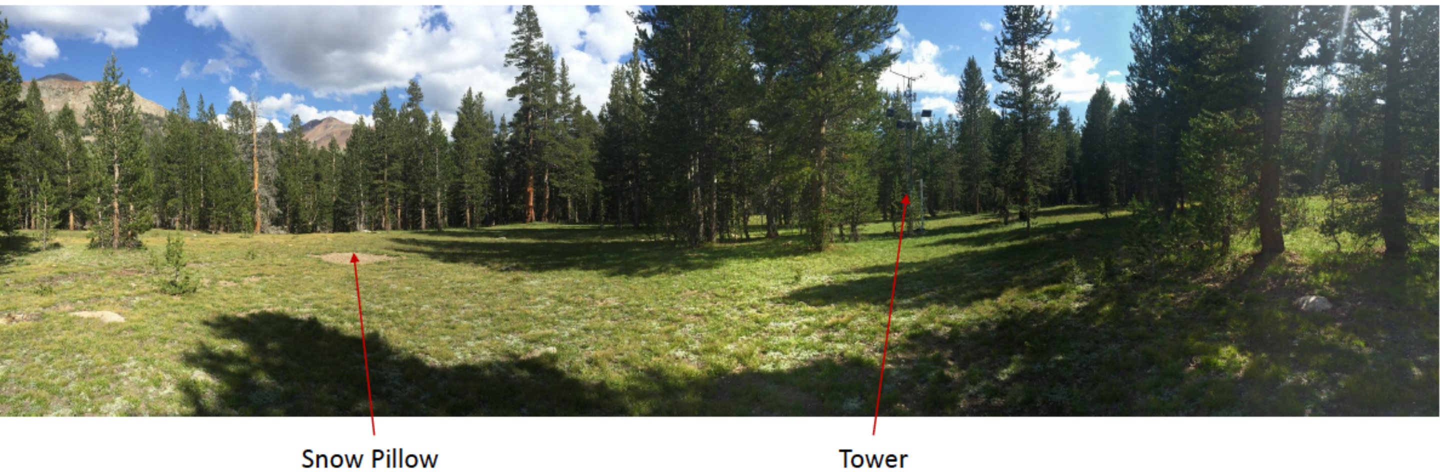


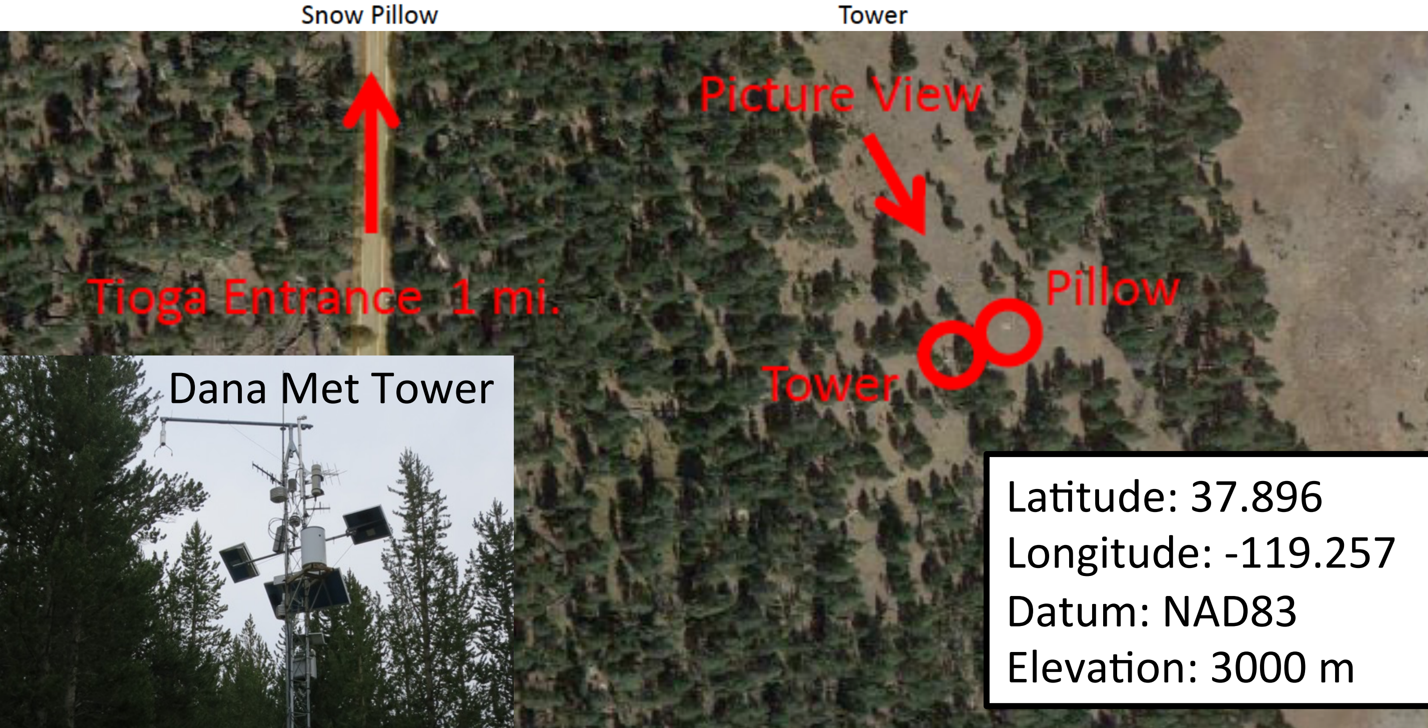
Latitude: 37.8730
Longitude: -119.350
Datum: NAD83
Elevation: 2600 m

Precipitation was measured in an accumulation gauge (photos above). Daily data were disaggregated to hourly data assuming uniform precipitation rates over the day.
Snow water equivalent (graph below) was measured with a weighing snow pillow (marked above) and a transect of manual depth and density measurements in the adjacent meadow.



DAN: Dana Meadows Met Station and Snow Pillow





Latitude: 37.896
Longitude: -119.257
Datum: NAD83
Elevation: 3000 m

Meteorological data were collected from the met tower (photos left and above) and quality controlled as detailed on the next page.

Dana Meadows (DAN) Meteorological Forcing Data

The provided data file is continuous and hourly. Exact time periods where data were estimated or interpolated to fill gaps are detailed in the README file. The 3-letter station abbreviations refer to the site names in the California Data Exchange (CDEC) system, which maintains the real-time data archive.

Variable	Units	Notes
air temperature	°C	measured hourly at DAN; gaps less than 3 hours filled with interpolation and longer than 3 hours filled with data from nearby Tioga Pass (TES) station or from self-recording temperature sensors as detailed in the README file
wind speed	$m\ s^{-1}$	measured hourly at DAN; gaps filled with data from nearby CDEC stations as detailed in the README file
relative humidity	%	measured hourly at DAN; gaps less than 3 hours filled with interpolation and longer than 3 hours filled with data from nearby Tioga Pass (TES) station or from self-recording temperature sensors as detailed in the README file
shortwave irradiance	$W\ m^{-2}$	measured hourly at DAN; corrected for snow obscuring the pyranometer, local shading effects due to topography and vegetation, and non-physical values using code posted on github*; gaps less than 2 days filled by interpolating for transmissivity*, longer gaps filled by empirical estimation following Bohn et al. 2013
longwave irradiance	$W\ m^{-2}$	estimated empirically following methods in Bohn et al. 2013
precipitation	m	measured daily at the Tuolumne station (TUM); multiplied by 1.26 to represent precipitation at DAN, and disaggregated to hourly assuming uniform precipitation over the day

** Radiation correction tools are available at github.com/Mountain-Hydrology-Research-Group/moq and described in Lapo et al. 2015.*

Distributed Air Temperature Data (2002-2005)

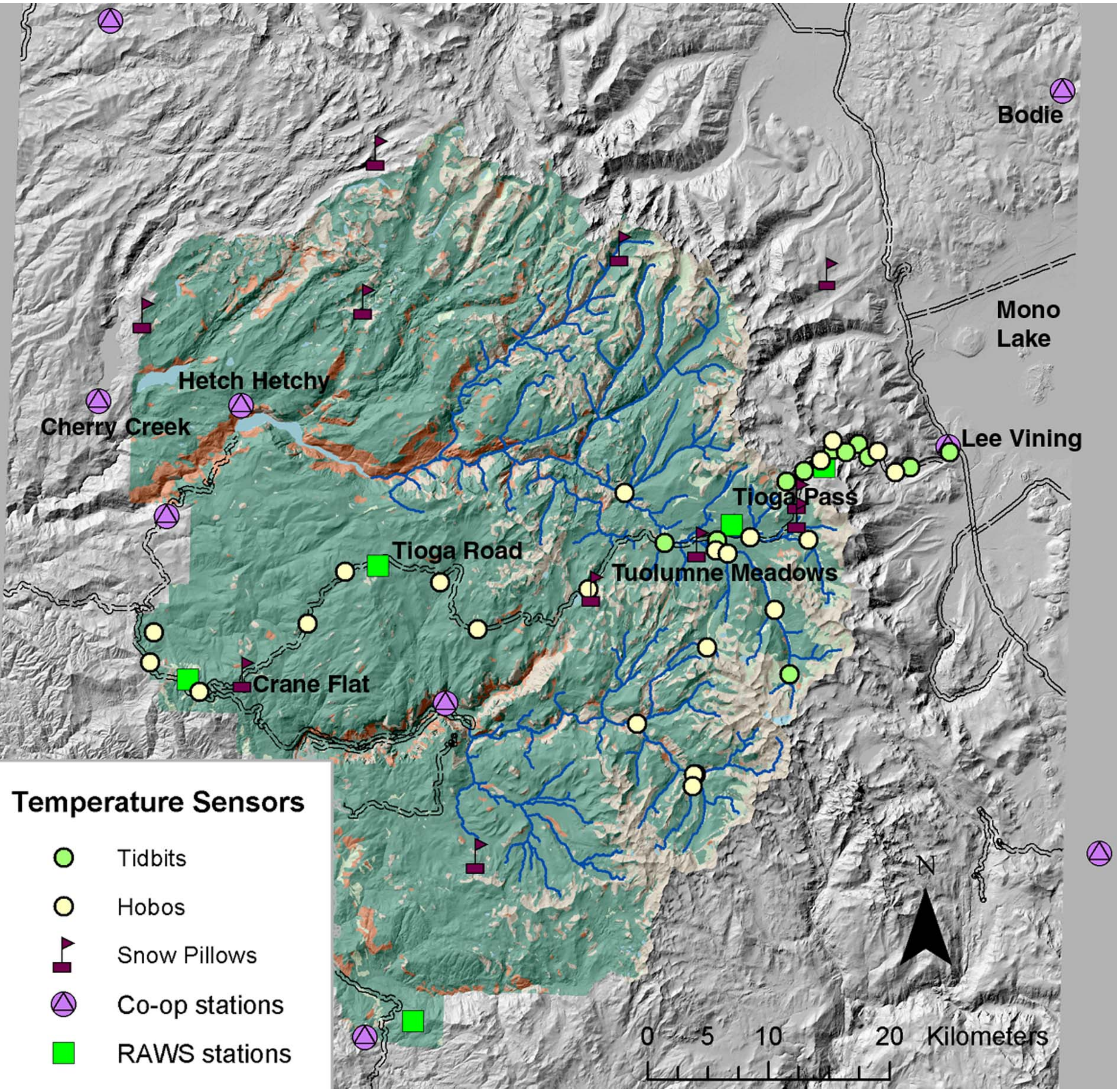


Table of Distributed Air Temperature Sensor types and characteristics

	Onset Hobos	Onset Stowaway Tidbits	California Snow Survey Stations	Remote Automated Weather Stations (RAWS)	Cooperative Observer (Co-op) Stations
Description	Fist-sized, self-recording temperature and relative humidity	Quarter-sized, self-recording temperature	Standard temperature sensors	Standard temperature sensors	Ventilated, sheltered thermometer
Site characteristics	in small radiation shields on north-facing side of tree on edge of forest	in small radiation shields on north-facing side of tree on edge of forest	in beehive radiation shields, on pole in the middle of a small clearing or meadow	in beehive radiation shields, on pole in the middle of a small clearing or meadow	Generally in a Stevenson Screen in a level, open clearing
Height above ground	4 to 8 meters	4 to 8 meters	10 meters	6 meters	2-3 meters
Sampling frequency*	30-minutes	30-minutes	60-minutes	15-minutes	twice daily
Agency in charge	Scripps Institution of Oceanography	Scripps Institution of Oceanography	California Department of Water Resources (CA DWR)	National Interagency Fire Center	National Weather Service (NWS)
Number of sensors in network (number used in analysis in Lundquist and Cayan 2007)	23 (15)	11 (5)	11 (7)	5 (3)	9 (7)

Onset HOBO

Onset Tidbit

* The data file reports daily values of Tmax, Tmean, and Tmin, which were derived from measurements at these sampling frequencies

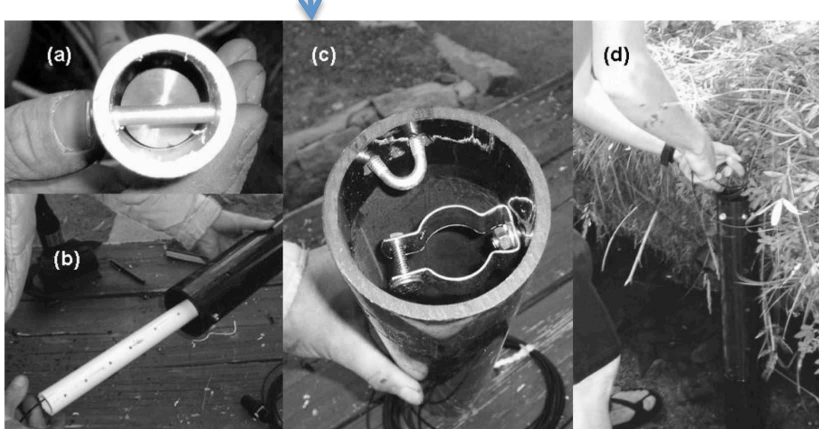
Stream Instruments and Installations

Brief History of “Wilderness Stream Gauging”

Aug 2005: Switch to wilderness stilling tube

Aug 2001: Solinst pressure sensors in anchors

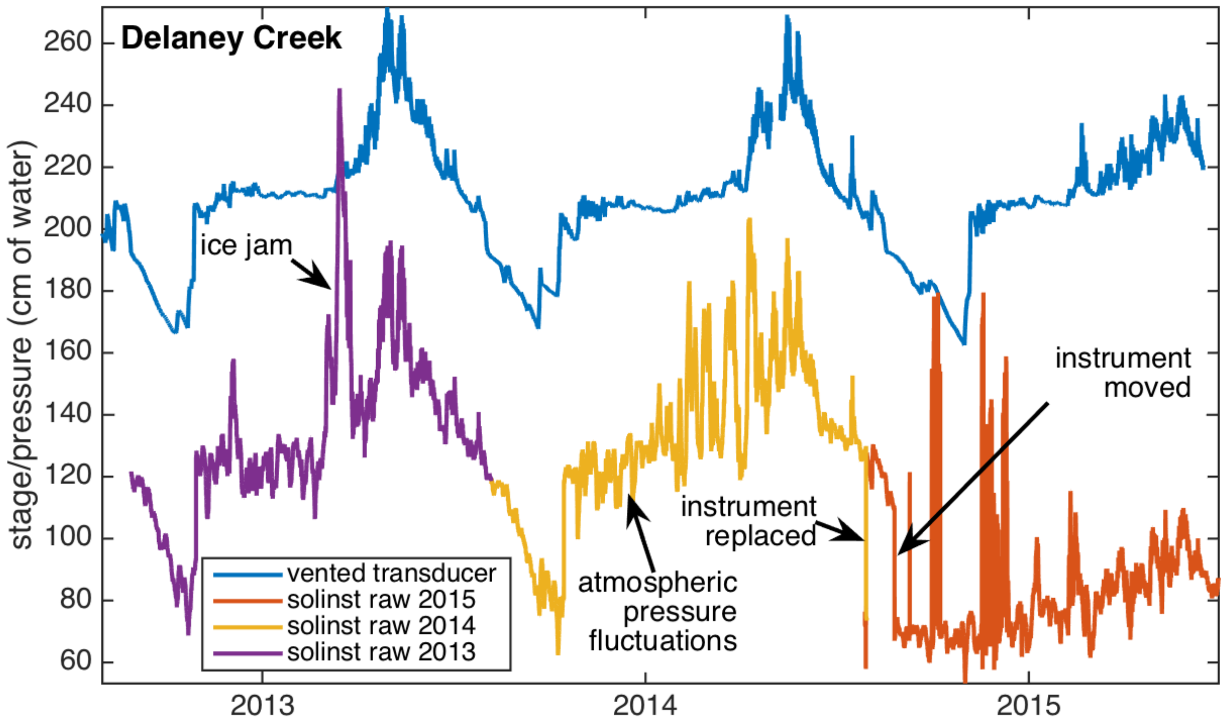
2015: Most sites upgraded to vented pressure transducer



Installation Type	Anchored Solinst	Solinst in Stilling Tube	Vented Pressure Transducer
Description	Instrument in a PVC pipe inside a concrete anchor, which is cabled to a tree, bridge, or culvert	Instrument in PVC pipe inserted in vertical pipe attached to the streambed and bank with rebar; with cord for downloading instrument	Same as stilling tube but with data cord connected to a data logger box (typically hidden in a tree) and another cord open to the atmosphere
Instrument Used	Solinst Levelogger	Solinst Levelogger	Druck[1] Or Campbell Scientific CS450 PT[2]
Instrument Specs/ Accuracy	Levelogger Model 3001: 0.1°C temp accuracy, ±0.5 cm pressure/depth accuracy; temperature compensated over the range of -10 to 40°C; drift of 0.1% of the full range (±0.5 cm for a 5 m model, used here)	Levelogger Edge and Gold: Temp accuracy ± 0.05°C Pressure ± 0.05% of FS (for 5 m model, this would be ±0.25 cm); Manufacturer states clock accurate to 1 minute per year, but 20 minutes of drift per year was typically observed	Druck: 0-5 PSI Range, 0.25% accuracy CS450: 0-7.25 PSI Range, 0.1% accuracy
Processing steps required	1) subtract off atmospheric pressure; 2) correct for offsets in instrument location; 3) check for instrument drift; 4) develop rating curve	1, 3, and 4	3 and 4
Total error estimates in stage (Note that these are worst case scenarios)	Up to ± 3 to 4 cm, with ± 2 cm due to summed instrument accuracy and drift for both stream and barometric instruments; and ± 1 to 2 cm more due to uncertainty in instrument location	Up to ± 2 cm due to summed instrument accuracy and potential drift for both stream and barometric instruments	Up to ± 0.5 cm due to summed instrument accuracy and potential drift
Error in estimated discharge*	± 0.92 $m^3 s^{-1}$ to ± 1.24 $m^3 s^{-1}$ (14-19%)	± 0.61 $m^3 s^{-1}$ (9%)	± 0.15 $m^3 s^{-1}$ (2%)

*Using Lyell Fork Twin Bridges summer flow, 0.7 m stage, as an example

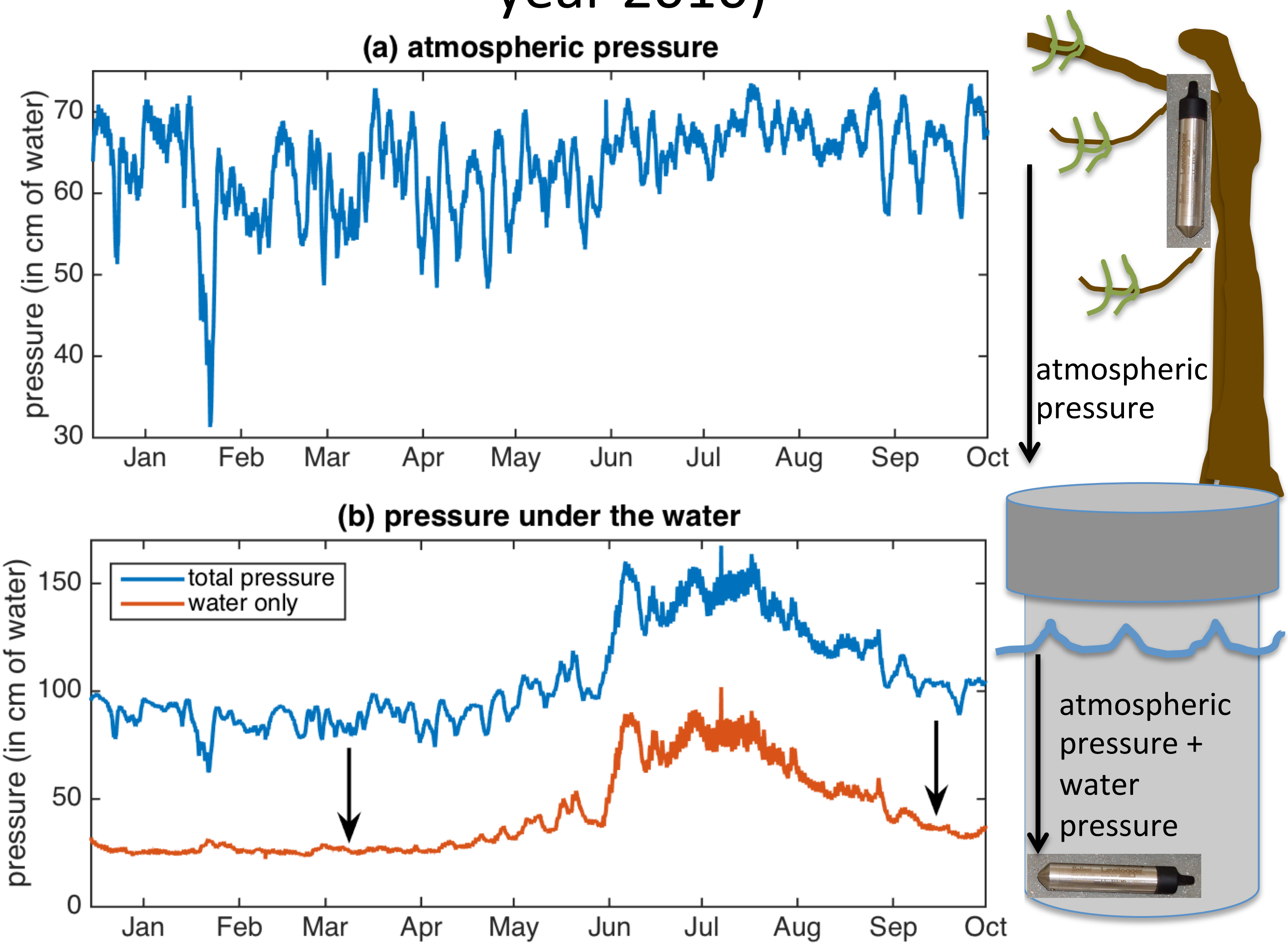
Stream Data Types:



1) Raw data: pressure recording, including both water in the stream and atmospheric pressure; pieced together from multiple instruments to create continuous record in the water
2) Baro-corrected data: Pressure due to water, after atmospheric pressure is subtracted off the raw data
3) Offset: Added to baro-corrected data to eliminate times when instrument moved and when different instruments had different local biases: corrected to match stage datum when and where available
4) Stage from instrument (in manual measurement files): This is baro-corrected data + offset. Used to create rating curve. Note: This timeseries can be plotted by adding the baro-corrected data and offset timeseries together.

Processing Steps for Stage

1. Subtract off atmospheric pressure (example from Lyell below Maclure water year 2010)



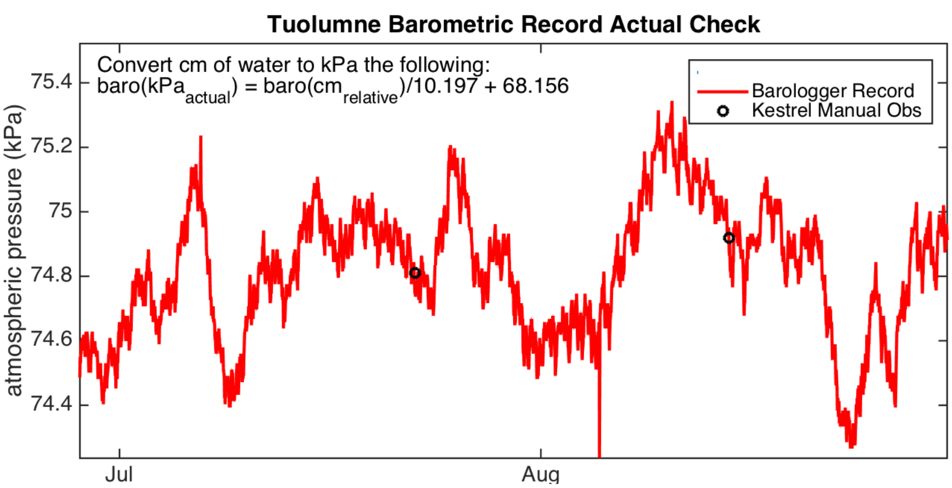
All of the instruments record pressure, the weight of both the overlying water and the overlying atmosphere. In vented transducers, the atmospheric pressure is subtracted off automatically. In all others, this step is done manually, using a nearby instrument exposed only to atmospheric pressure as a reference.

Processing Steps for Stage

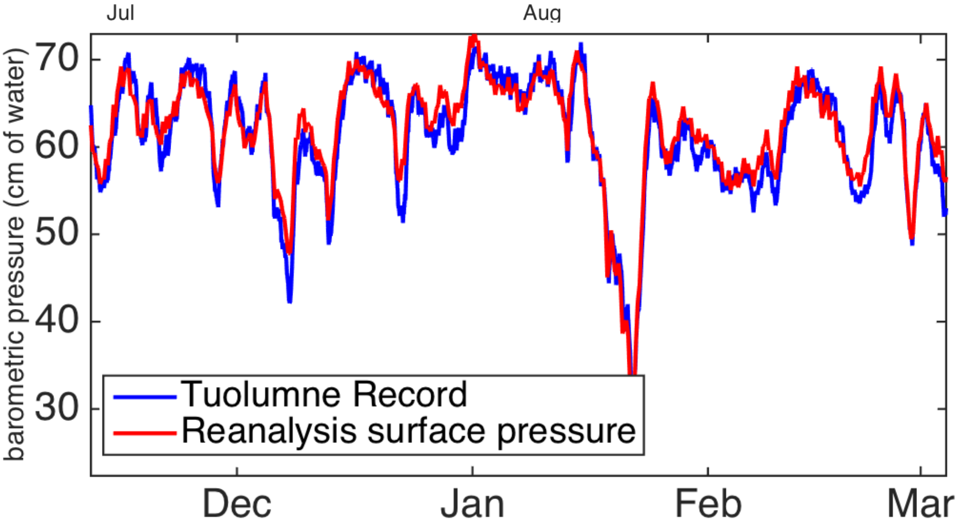
details on atmospheric pressure

Because atmospheric pressure was close to spatially uniform over the domain, one barometric pressure timeseries was used for correction of all of the instruments. This record was constructed by combining pressure recorded by Solinst Barologgers and by Hobo Water Level Loggers at a variety of locations (see below). We cross-compared instrument records at times when multiple records were available and manually selected the instrument subjected to the minimum diurnal air temperature fluctuations at any given time. When possible, this was an instrument in a dry groundwater well because temperature oscillations were muted by the overlying soil. The temperatures recorded by each instrument are provided in case users would like to develop their own further temperature compensation algorithms.

B01 - Tuolumne Snow Shed - 37.87638 N, 119.34818 W, 2600 m elevation
B02 - Tuolumne Bug Camp Lab - 37.8780889 N, 119.3402 W, 2600 m elevation
B03 - Glen Aulin - 37.90991 N, 119.41959 W, 2400 m elevation
B04 - Well 35 - 37.5223537 N, -119.2301655 W, 2600 m elevation
B05 - Official Baro Well - 37.5223537 N, -119.2301655 W, 2600 m
B06 - Well 01 - 37.52325193 N, -119.2323854 W, 2600 m elevation
BRe - Reanalysis Pressure - surface pressure field from the grid cell centered at 37.5 N, 120 W near Lee Vining, California, USA (Tuolumne County)



(left) Actual atmospheric pressure was checked against independent measurements from a hand-held Kestrel weather observer and then converted to the equivalent weight in cm of water.

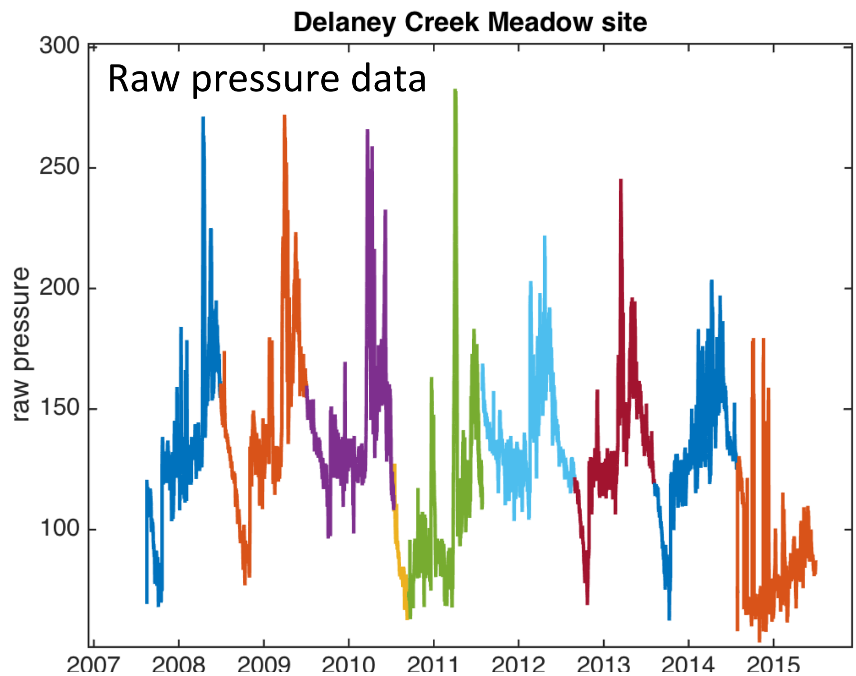


(left) Instruments were compared with each other via plotting and manual inspection. Here, pressure measured locally in Tuolumne Meadows is compared with pressure from NCEP-NCAR reanalysis, which was used for about a month in 2005 when all local instruments broke.

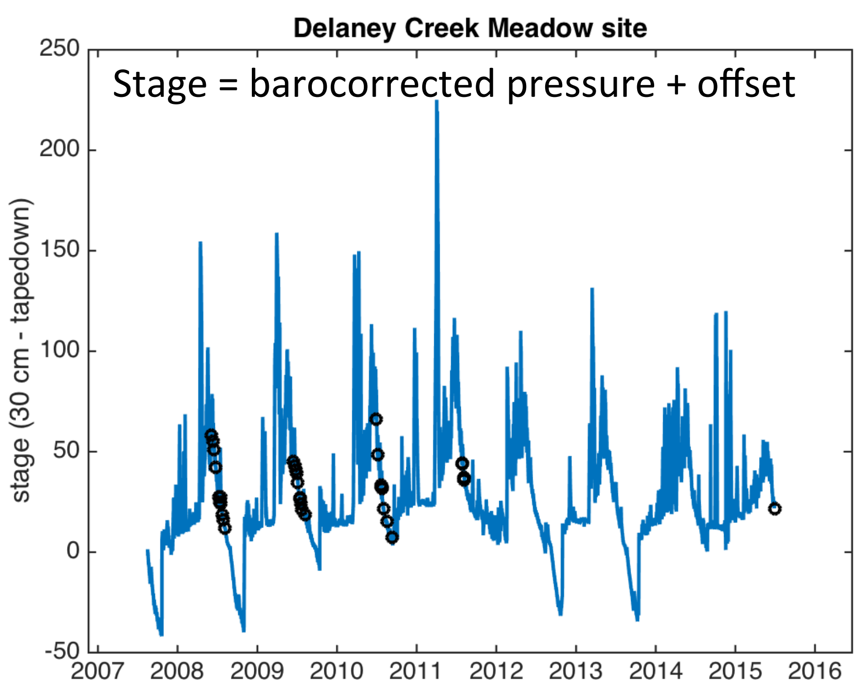
Processing Steps for Stage

2 & 3. Correct for offsets in instrument location and check for instrument drift (example from Delaney Creek)

Raw pressure from multiple years (each color represents a different instrument) illustrates how offsets are often required when instruments are replaced.



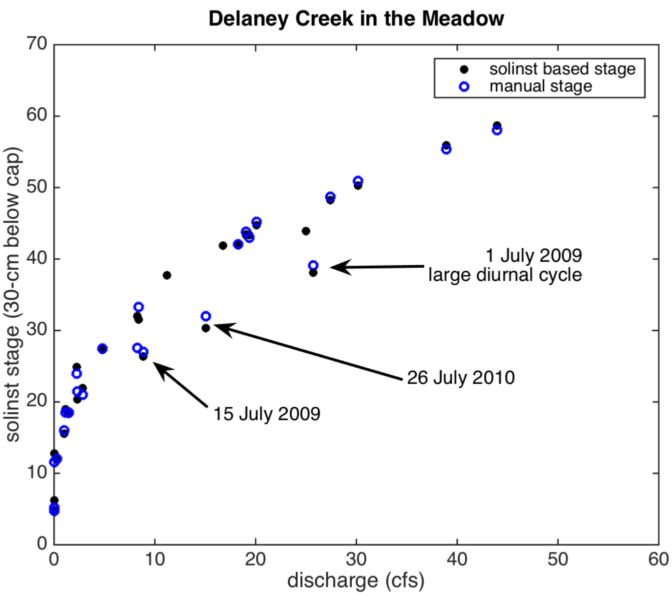
Manual stage measurements (black circles) provide guidance for offsets to adjust the barometrically-corrected water pressure values.

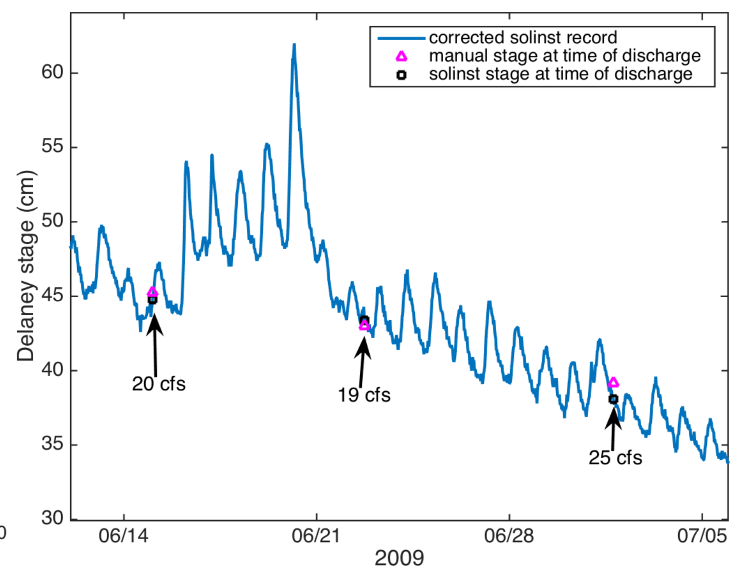


Processing Steps for Stage

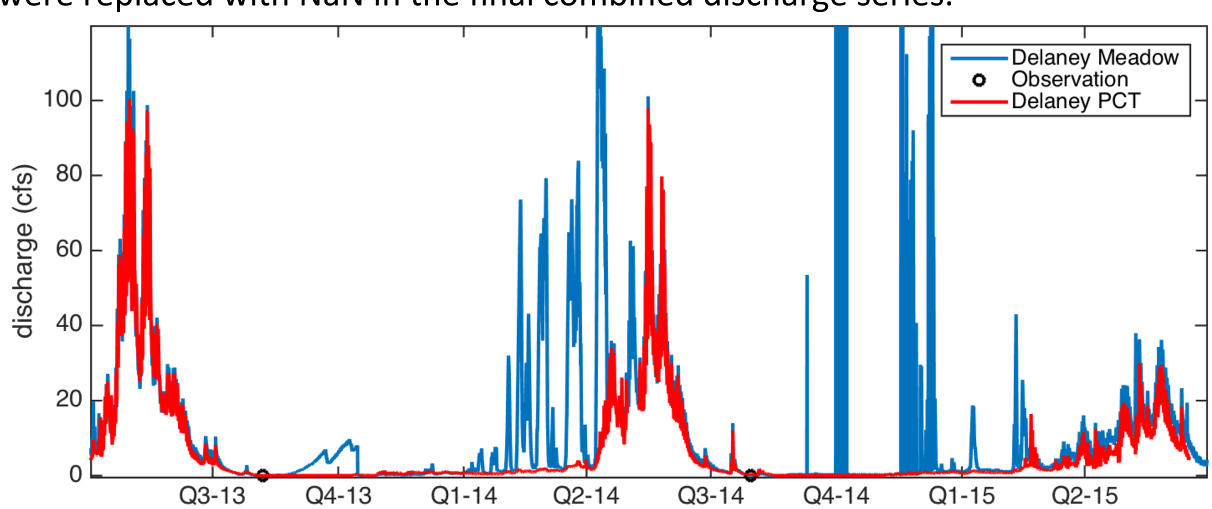
4. Develop rating curve (example from Delaney)

The manual measurements used to create the rating curves are included in .csv files associated with each site. Discharge was originally measured in cubic feet per second (cfs) and is reported in that unit in these files. All manual measurements were plotted and checked for consistency. Those appearing wrong (such as the 1 July 2009 observation shown below) were not used in further rating curve development. These unused observations are included in the .csv file but are labeled with NaN in the instrument_stage_used column.



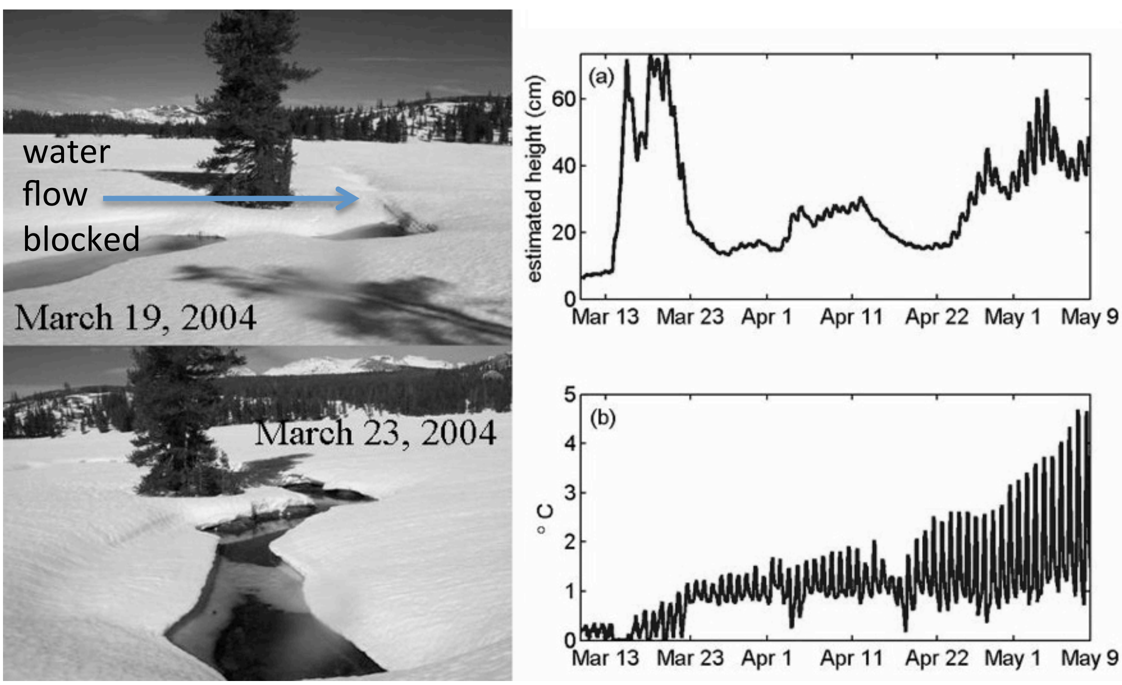


Discharge timeseries (below): Blue is the meadow record provided here; Red is an independently generated record from slightly upstream. The meadow site (blue) is prone to ice jams. Ice jams were identified by eye or by abnormally high values and were replaced with NaN in the final combined discharge series.



Ice Jams

Many of the sites in this data set are subject to freezing in the winter and exhibit large spikes in pressure due to either ice formation creating pressure on the sensor or ice jams locally backing up water (see prior page and graphics below). These effects are identified in many graphics in this document but were removed only in the combined discharge file. Because identifying ice jams is a subjective decision, in the site-specific files, data were replaced with NaN only when they exceeded a specified stage (see rating curve info for each site).



(a) Stream height (stage) at Budd Creek, in Tuolumne Meadows, Yosemite, California, reports higher levels at the start of melt each year than during peak melt. This occurs coincident with (b) water temperatures rising to above freezing levels and ice jamming, which is water pooling behind snow and ice (photos to left). Times of believed ice jams were removed from the combined discharge timeseries but not from the individual stream files. Photos by Bruce Carter and Tracy Wiese.

Rating Curve Development

- Pre-process manual data (as shown above)
  - Include 10% uncertainty in discharge
- Develop prior rating curve parameters from survey data, with substantial uncertainty values, using BaRatin (Le Coz et al. 2014), to fit the form $Q=a(h - b)^c$
  - Section Control: low flow acts like a rectangular weir
    - Inputs for determining prior “a” = $C_r B_r \sqrt{2g}$
      - Discharge Coefficient (C_r): default = 0.4 ± 0.05
      - Width of “weir”, perpendicular to flow direction (B_r)
    - Inputs for determining prior “b”
      - Average elevation of “weir” crest
    - Inputs for determining prior “c”
      - Default: 1.5 ± 0.05
  - Channel Control: mid flow acts like a rectangular channel, use the Manning–Strickler equation
    - Inputs for determining prior “a” = $K_s B \sqrt{S_e}$
      - Slope of channel bed (S_e)
      - Channel width (B)
      - Roughness coefficient (K_s): 20 ± 5 for all channels to be conservative
    - Inputs for determining prior “b”
      - Average elevation of Channel bottom
    - Inputs for determining prior “c”
      - Default: 1.67 ± 0.05
  - Channel + Floodplain Control: high flow acts like the sum of the channel and floodplain (sum of 2 channel controls)

Rating Curve Development
(continued)

- Use the BaRatin MCMC routine (see LeCoz et al. 2014 and references therein) to use manual stage and discharge observations, along with their estimated uncertainty (10%), to determine the posterior rating curve parameters and control segment breaks to fit the following piecewise power function:

$$Q = \sum_{r=1}^{N_{range}} \left(1_{[\kappa_{r-1};\kappa_r]}(h) \times \sum_{j=1}^{N_{control}} M(r,j) \times a_j (h - b_j)^{c_j} \right)$$

  - Where N_{range} is the number of stage ranges
  - $N_{control}$ is the number of hydraulic controls
  - K_r is the upper water level at stage range *r*
  - *M* is the hydraulic control matric (*M(r,j)* = 1 if hydraulic control *j* is active in stage range *r*
  - *h* is stage
  - *a*, *b*, and *c* are the fitted parameters for stage range *j*

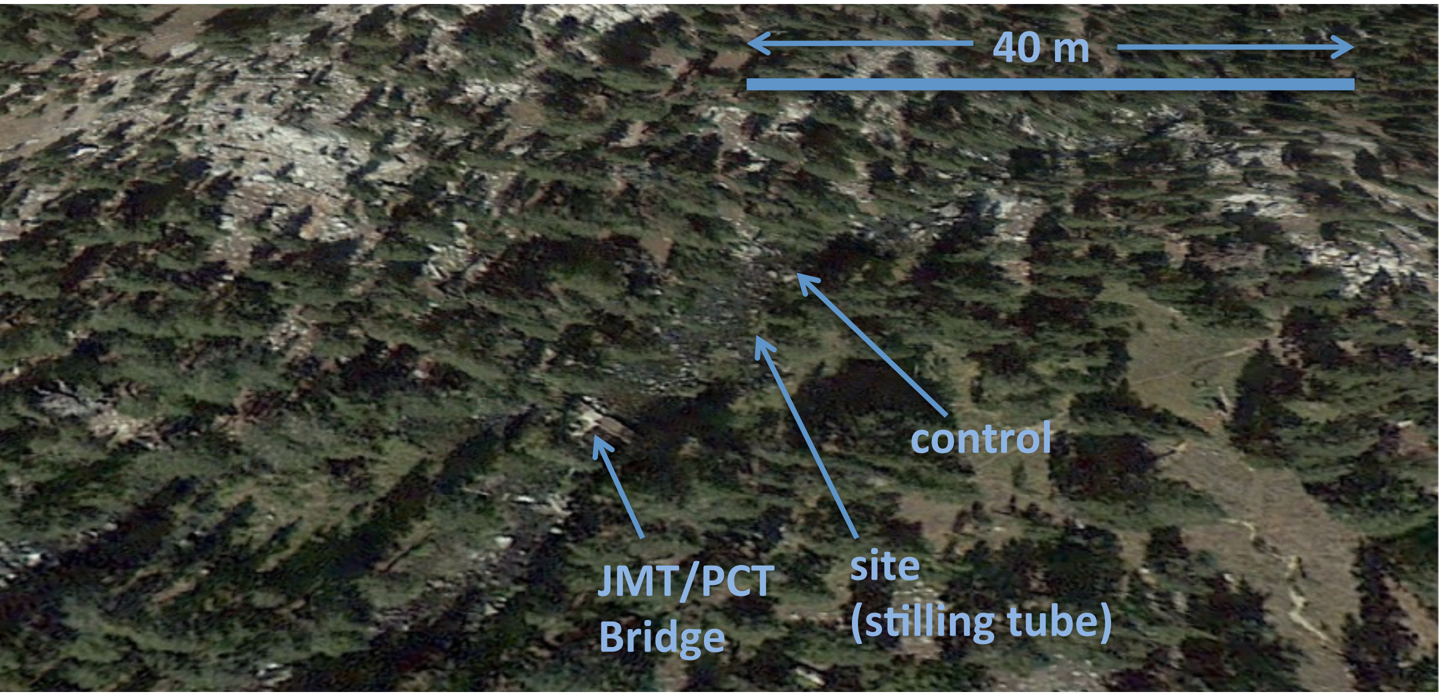
- Outputs include the rating curve equation for each stage range, as well as a look up table of values for the upper and lower limits of the 95% confidence intervals (which vary by stage and are determined as part of the MCMC process)
- These are illustrated for each site in the pages that follow.
- For comparison, a single equation of the form $Q=a(h-b)^c$ was also calculated for each site using transformed least squares (Rantz et al. 1982), and this equation and its 95% confidence intervals are also shown

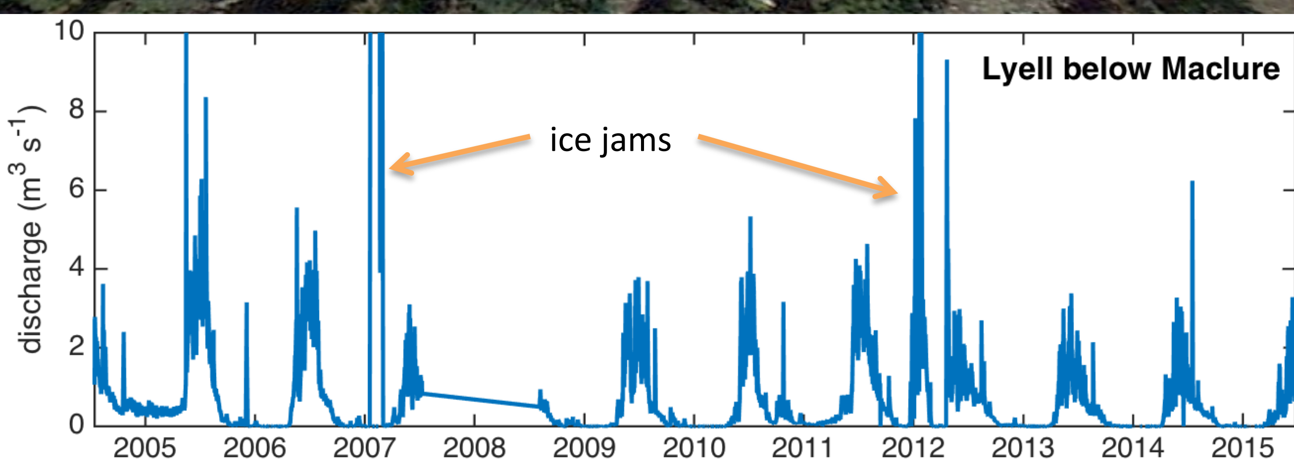
Name Cross-referencing:

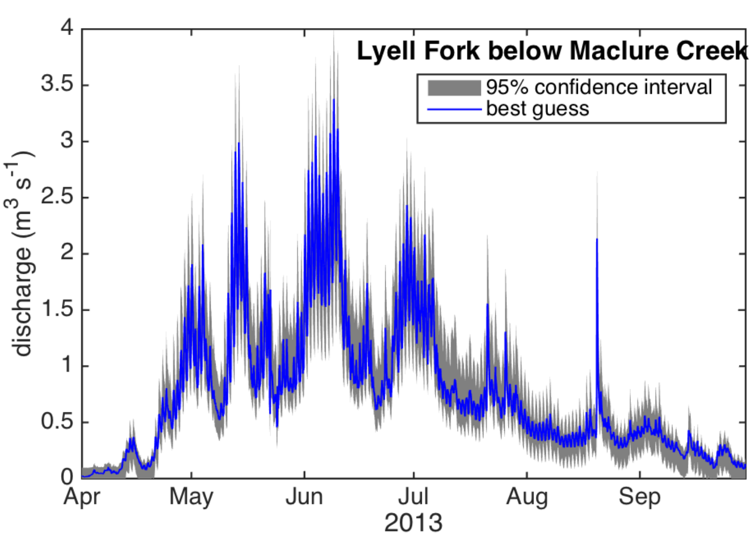
For clarity in this data collection, we have numbered the stream locations from upstream to downstream (Q01 to Q07). Due to the historical evolution of this network, different names have been attributed to the sites by different agencies through time. Here, after the site ID used in this document, we reference codes used in the original Hydroclimate Network, codes used by the National Park Service, and codes used by the USGS for water quality monitoring. This information is provided in case anyone needs to cross-reference these data with information obtained from an alternate source (e.g., from the USGS water quality archives).

Site Name	Site ID	Historical Site Code	NPS Site Code	USGS Site ID
Lyell below Maclure	Q01		HB270	374640119154100
Lyell Fork, upstream	Q02a	H03a	NP269	375210119195000
Lyell Fork, downstream	Q02b	H03b		
Dana Fork, lodge	Q03a	H02a		375233119200401
Dana Fork, Bug Camp	Q03b	H02b	NP188	
Tuolumne 120	Q04	H05	NP238	375234119211400
Delaney Creek, meadow	Q05			
Budd Creek upstream	Q06a	H01a		
Budd Creek downstream	Q06b	H01b		
Hetch Hetchy Reservoir	Q07	H99		

Q01: Lyell Fork below Maclure





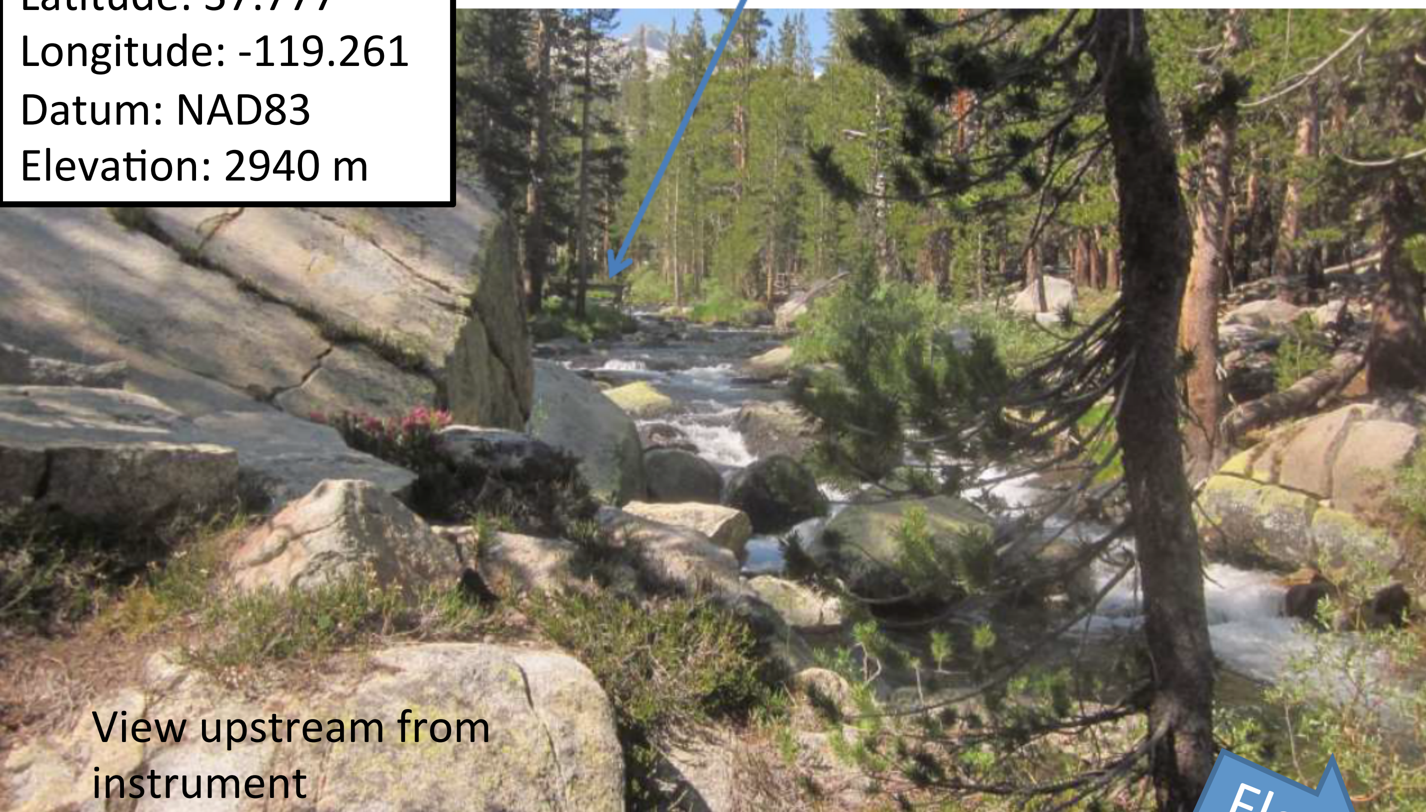


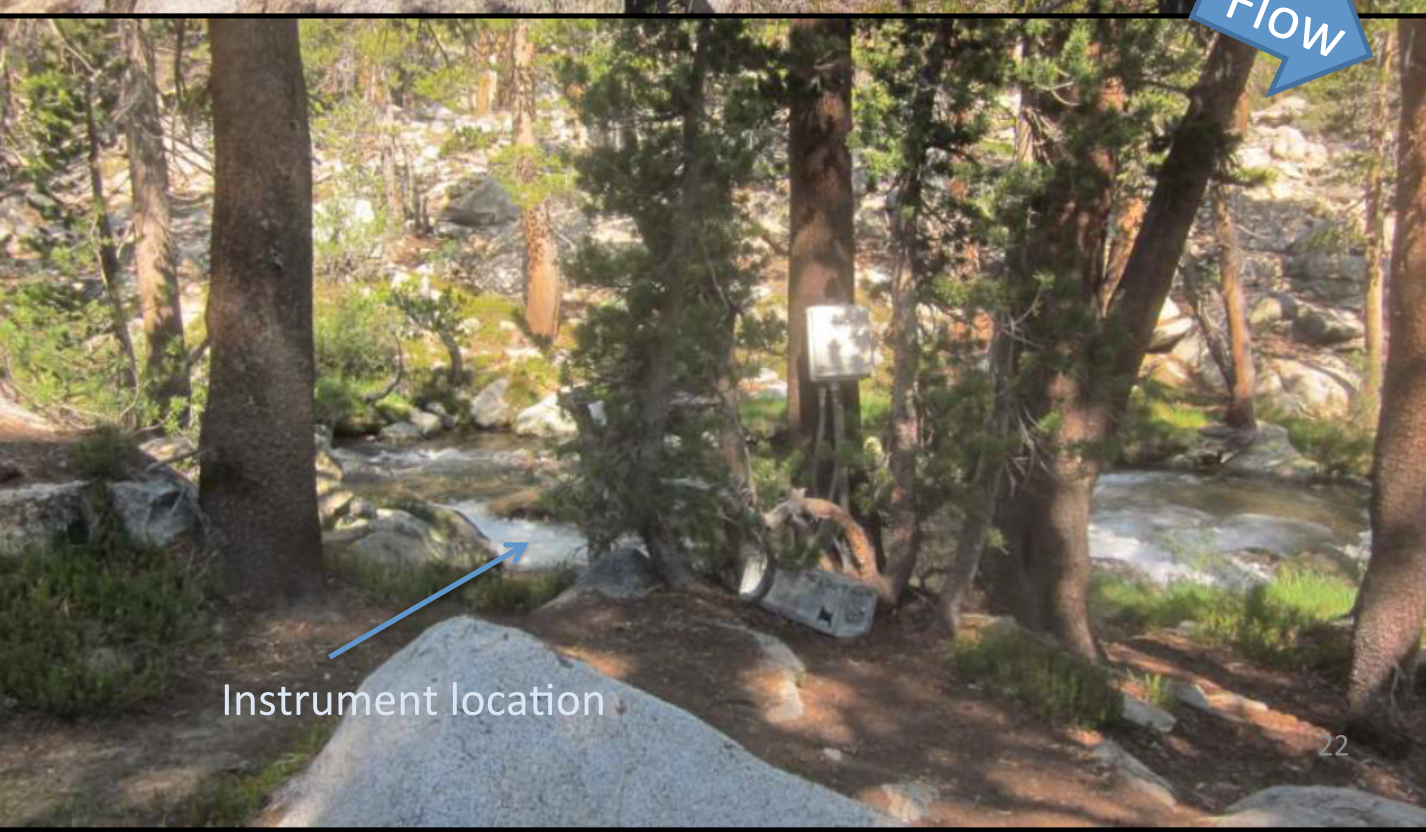
Overall, the rating curve is good, but there is greater uncertainty in the datum before 2008, and there are occasional ice jams.

Q01: Lyell Fork below Maclure

Latitude: 37.777
Longitude: -119.261
Datum: NAD83
Elevation: 2940 m

PCT/JMT footbridge



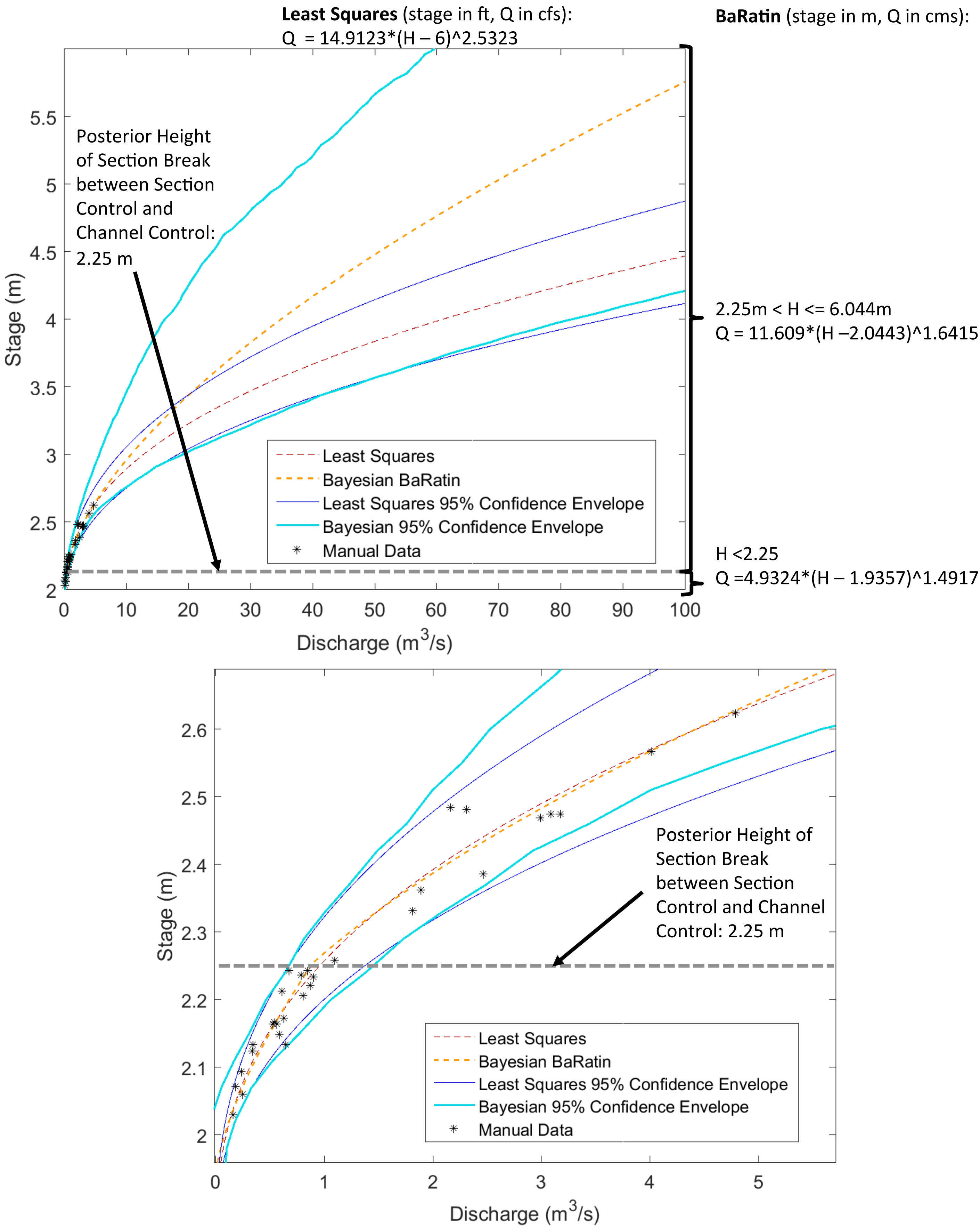


Lyell Fork below Maclure Creek

Based on photographs, we estimated two cross-sections:

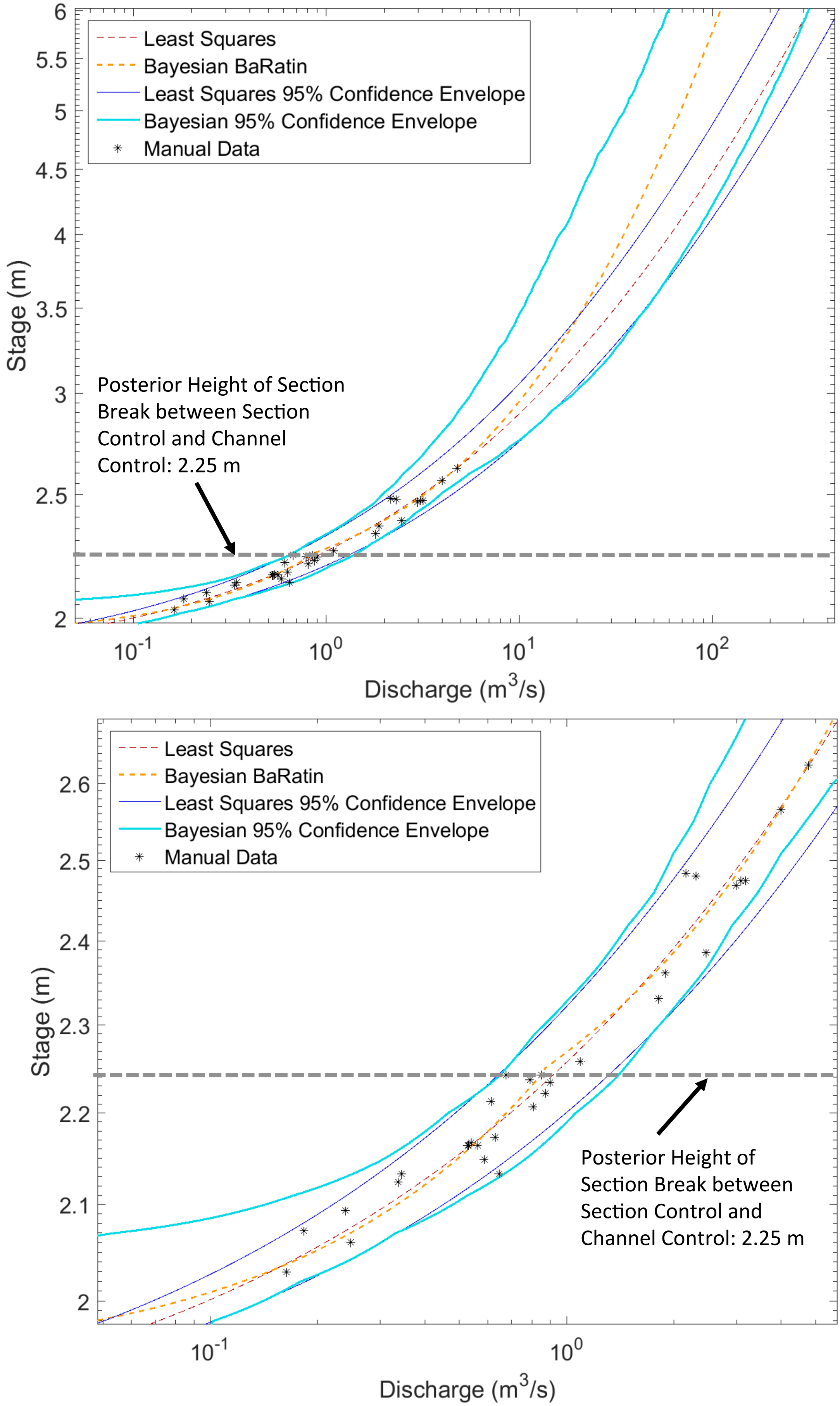
- Channel Control
  - Width: 6 m ± 2 m
  - Slope: 0.04 ± 0.02
- Section Control
  - Width: 3 m ± 3 m (unknown cross-section)
  - Height of control break: 3 m ± 3 m (unknown cross-section, maximum depth measured is 6 m)

Lyell Fork below Maclure Creek



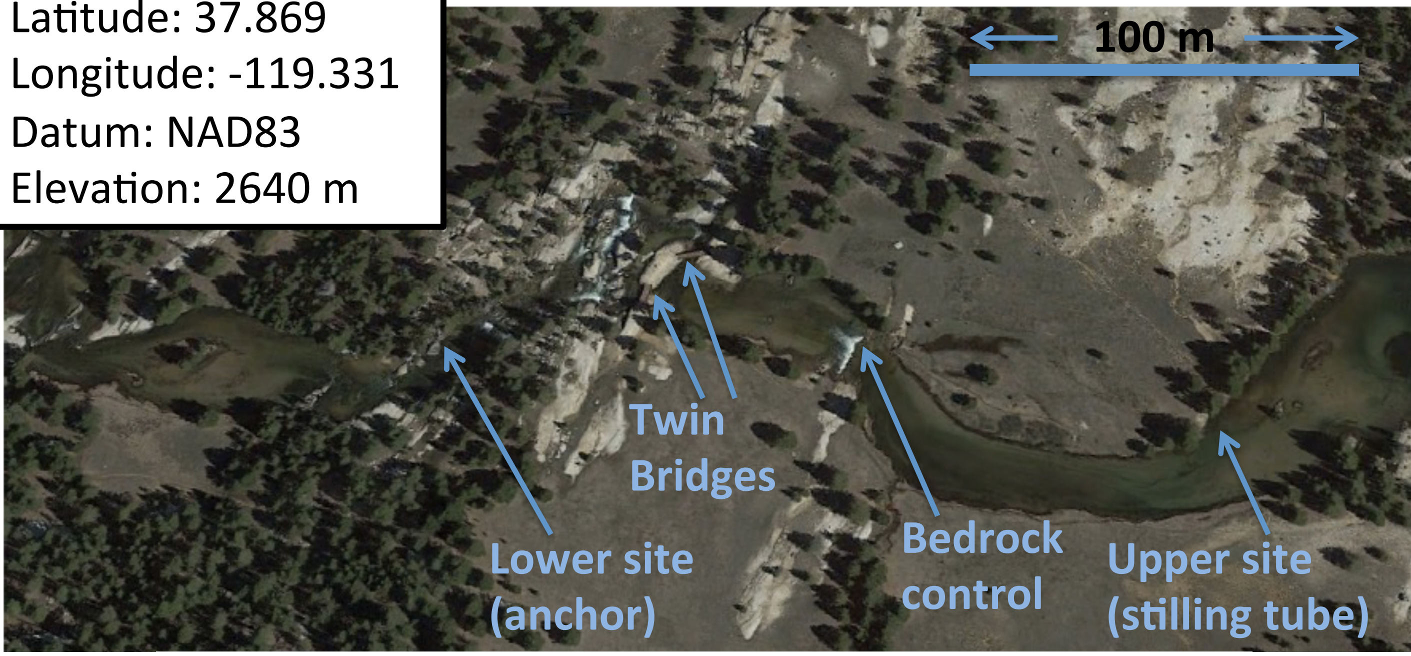
Log-Log View

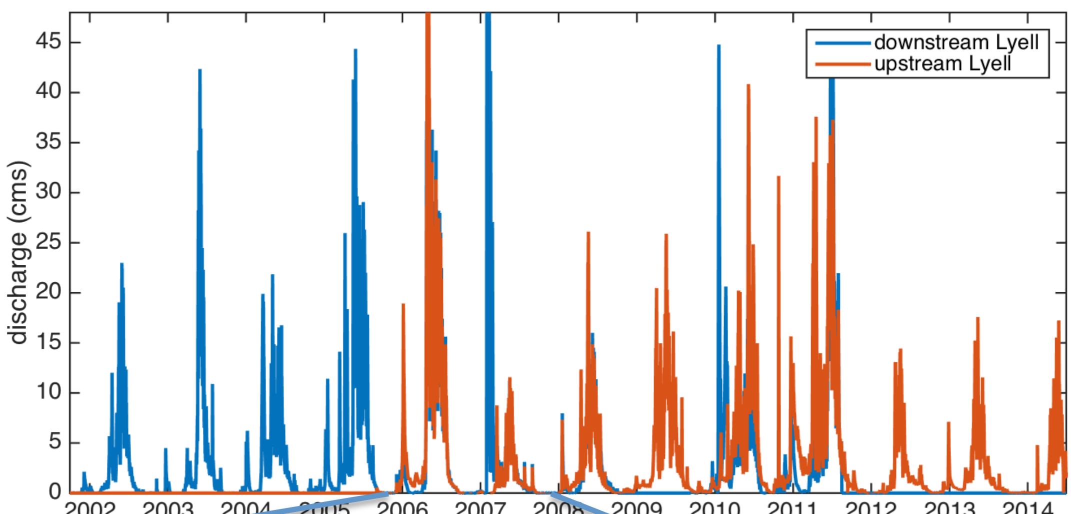
Lyell Fork below Maclure Creek

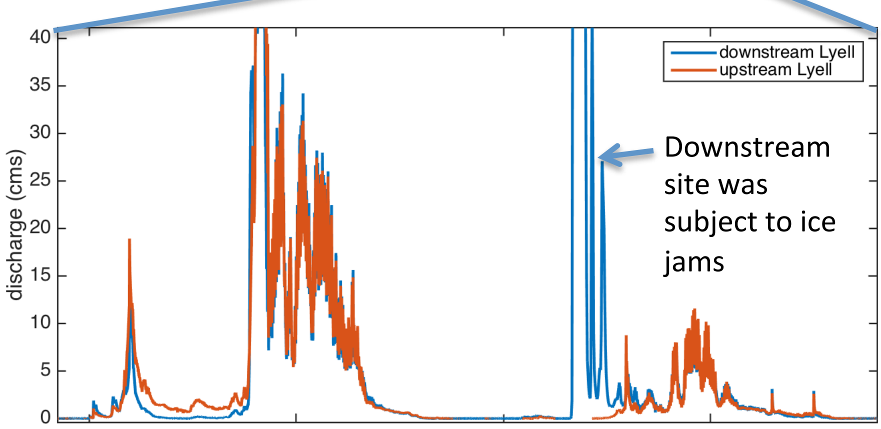


Q02: Lyell Fork at Twin Bridges

Latitude: 37.869
Longitude: -119.331
Datum: NAD83
Elevation: 2640 m







The downstream site was installed first (WY 2002), with the upstream site designed to replace it starting in WY 2006. Calculated discharge agrees very well during the 2006-08 period of overlap, with the exception of winter and early spring ice jams. For 2009 on, the downstream site was less frequently maintained, and the upstream site record should be used.

Q02a: Lyell Fork abv Twin Bridges

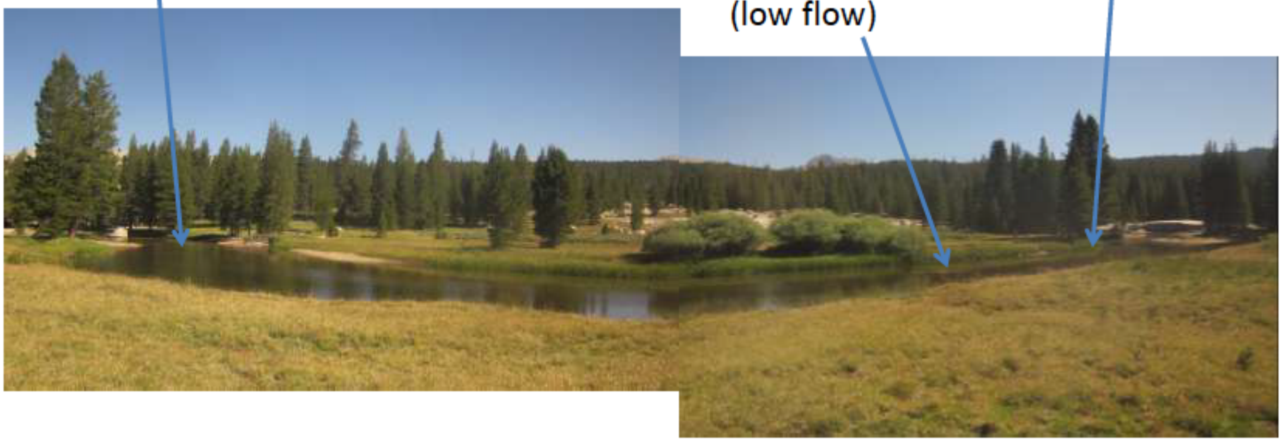
Latitude: 37.869
Longitude: -119.331
Datum: NAD83
Elevation: 2640 m

Lyell Fork above Twin Bridges

bed-rock control
(moderate-high flow)

stilling tube gage

gravel-bar control
(low flow)



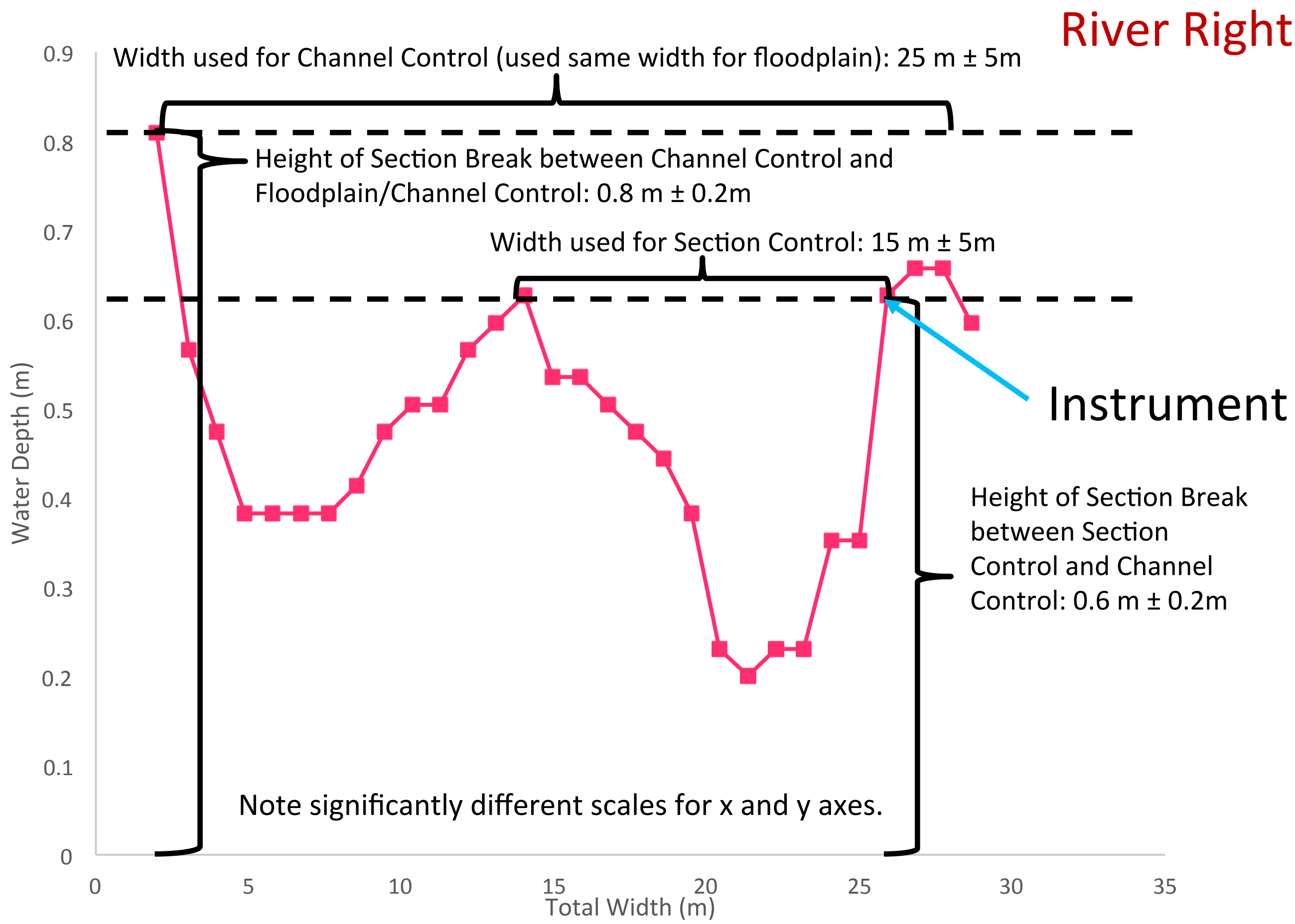
bed-rock control

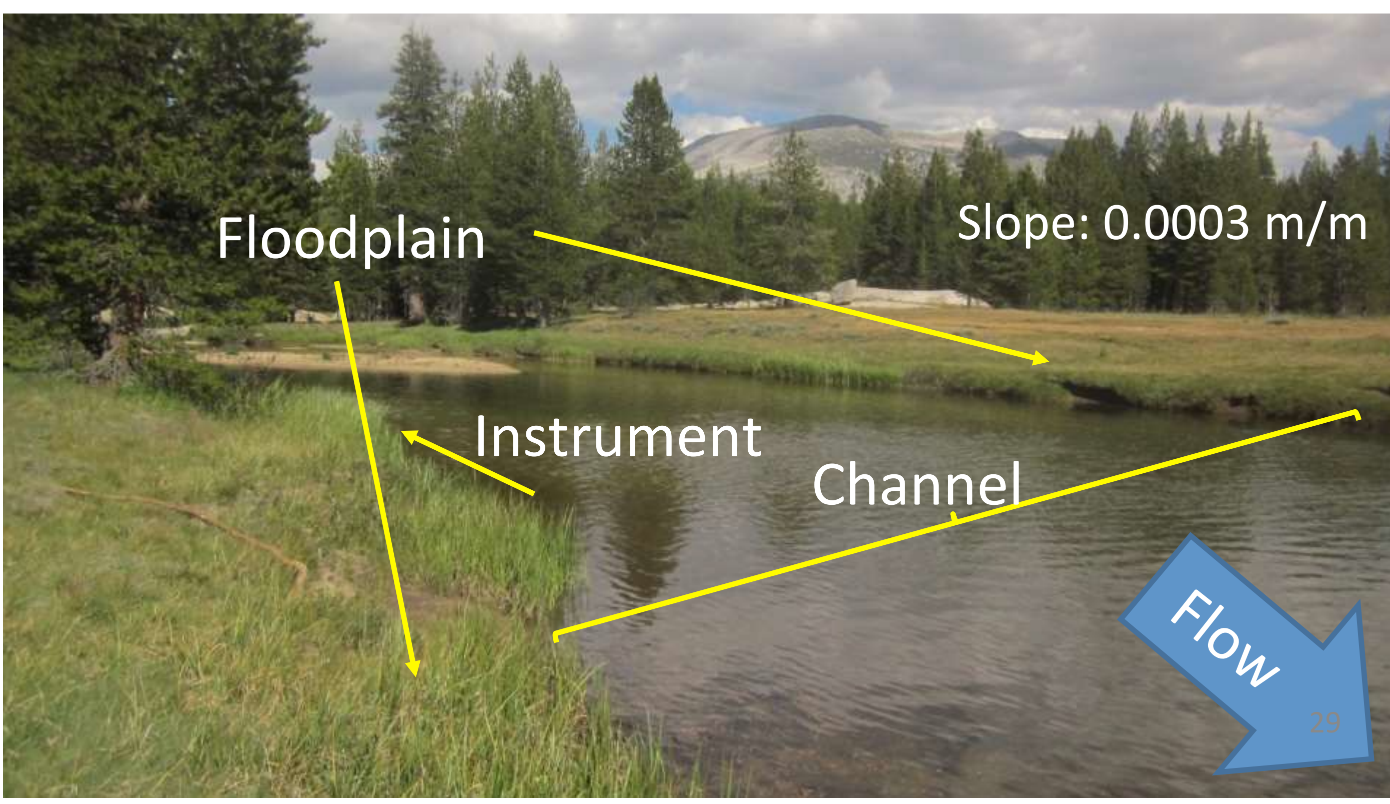
gravel-bar control

Note: On 17 July 2015 at 9:15 am local time, the depth of water over the bed-rock control was 0.68 ft and over the gravel-bar control was 1.50 ft. Gauge height measured as 10 ft – distance from top of stilling tube to water (0.78 ft) at that time was 9.22 ft; making gauge height 8.54 ft when the bedrock control matters and 7.72 ft when the gravel-bar control matters. These measurements are included here for reference but were not used in rating curve calculations.

Lyell Fork above Twin Bridges

Cross-Section at Instrument Site with Stage Measurement Datum





Lyell Fork above Twin Bridges

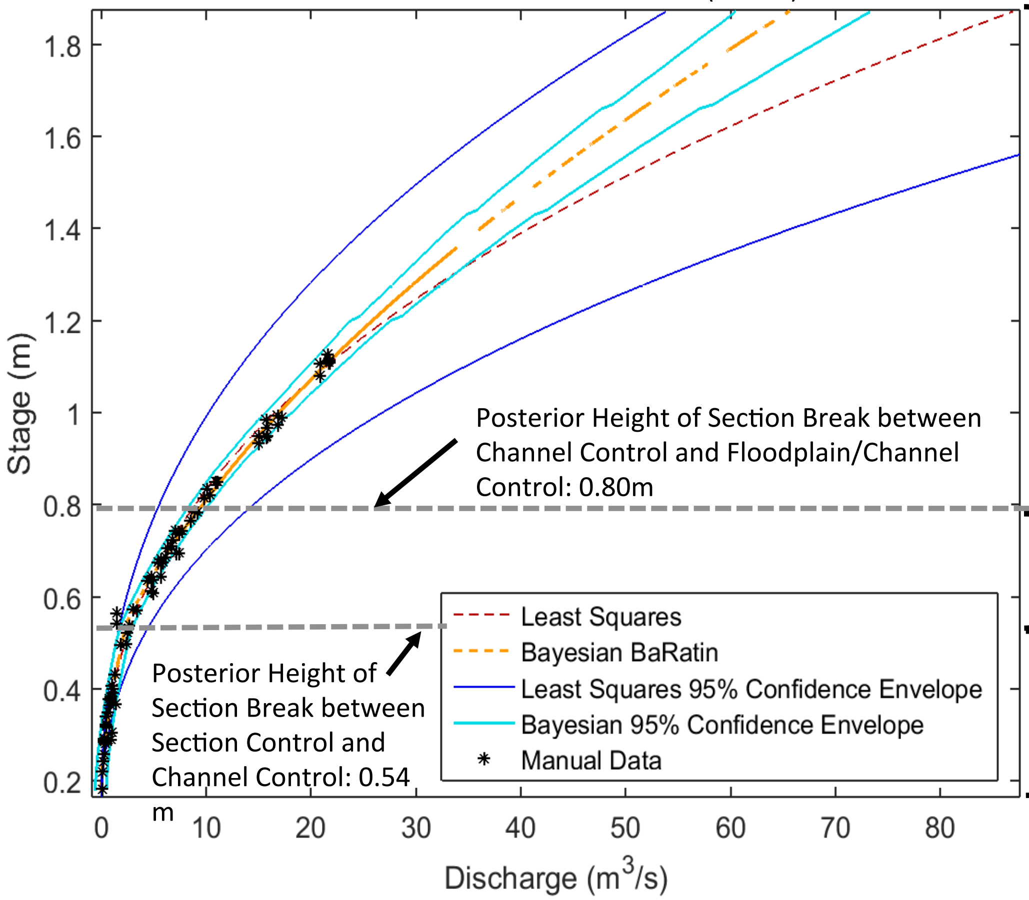
Least Squares (stage in cm, Q in cfs):
Q = 0.00965*(H – 10)^2.4474

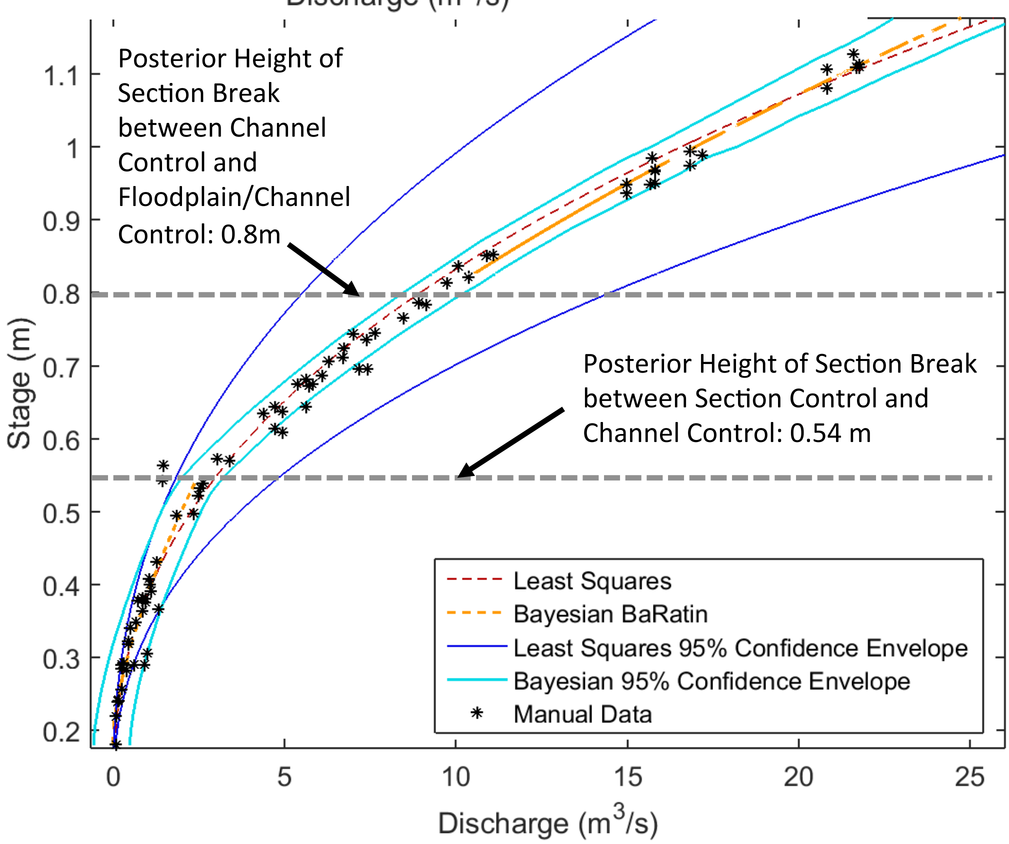
BaRatin (stage in m, Q in cms):

0.79875m < H
Q =30.94*(H –0.3023)^1.6658

0.540748m < H < 0.79875m
Q =35.6095*(H – 0.343)^1.662

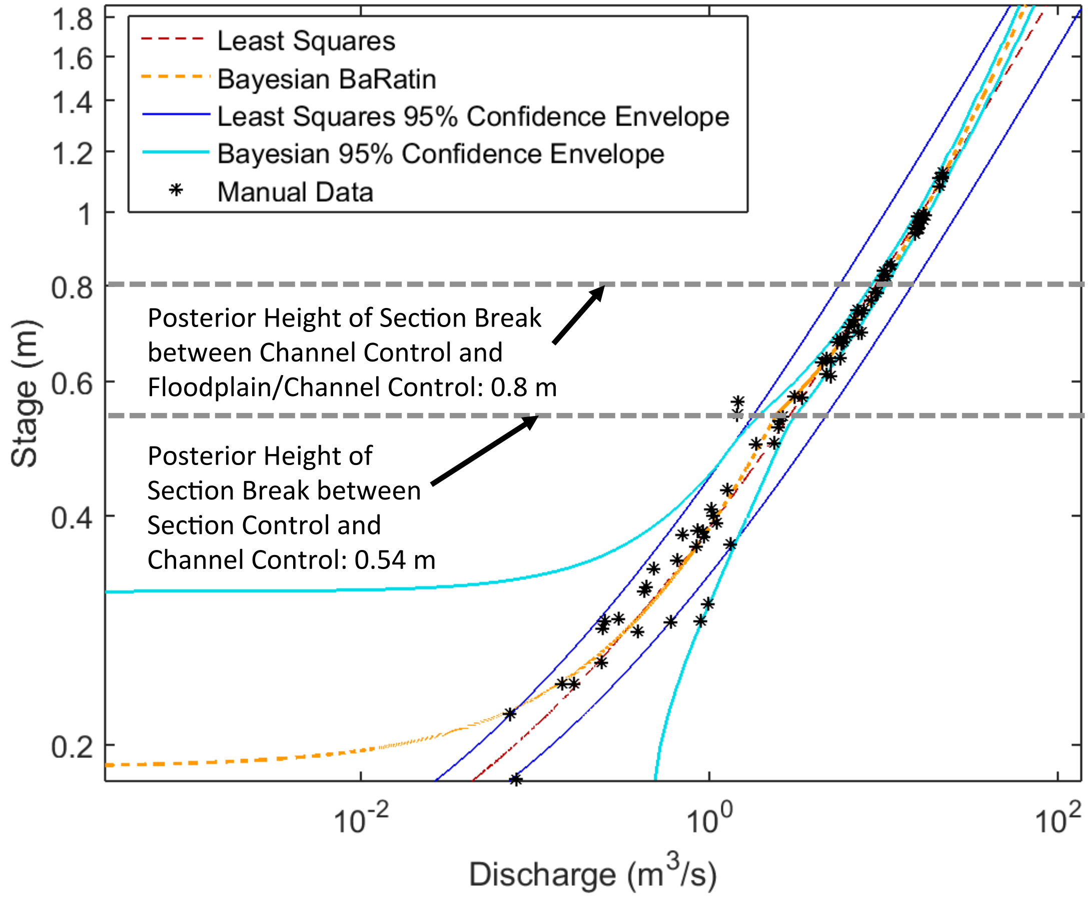
H < 0.540748m
Q =11.5733*(H –0.1873)^1.512

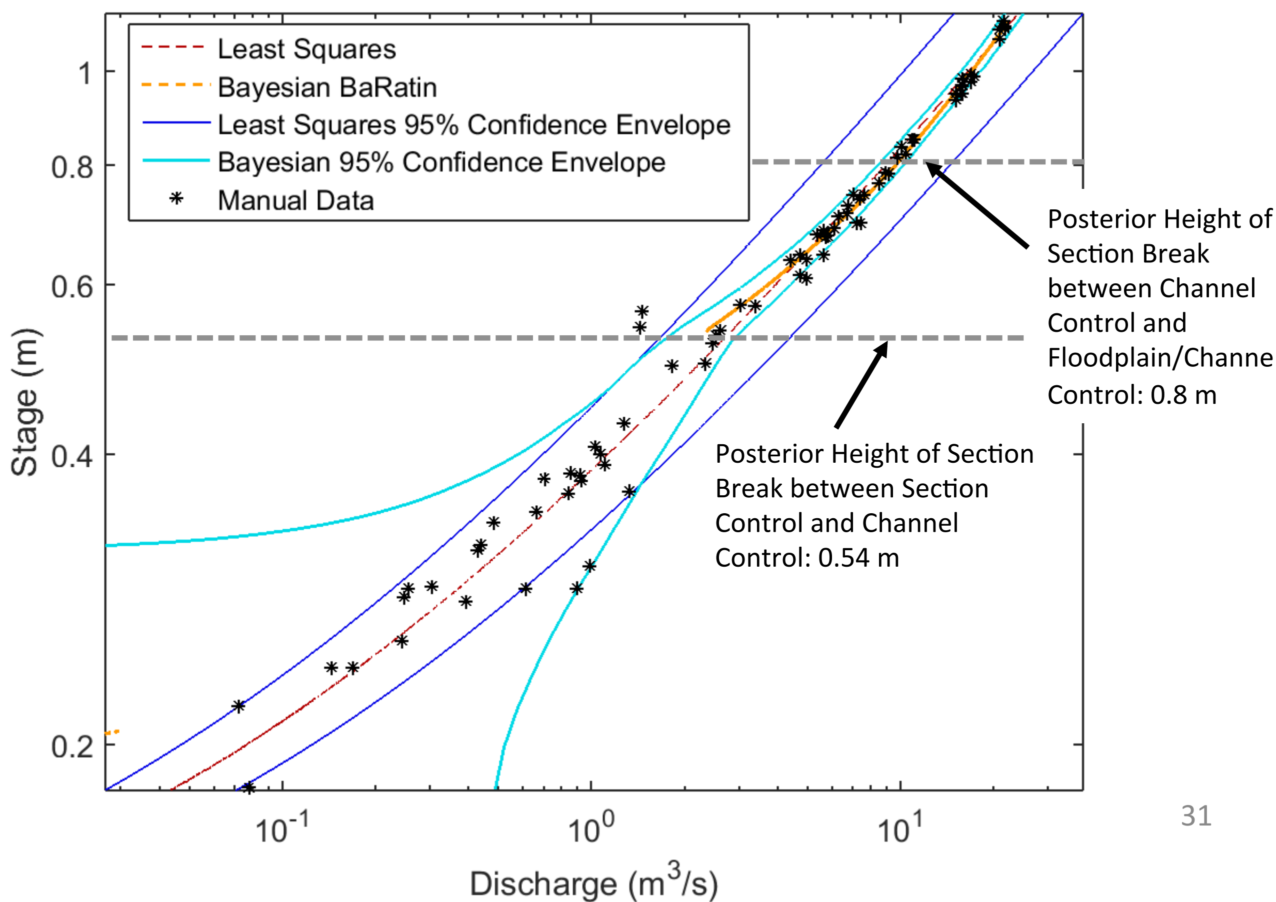




Log-Log View

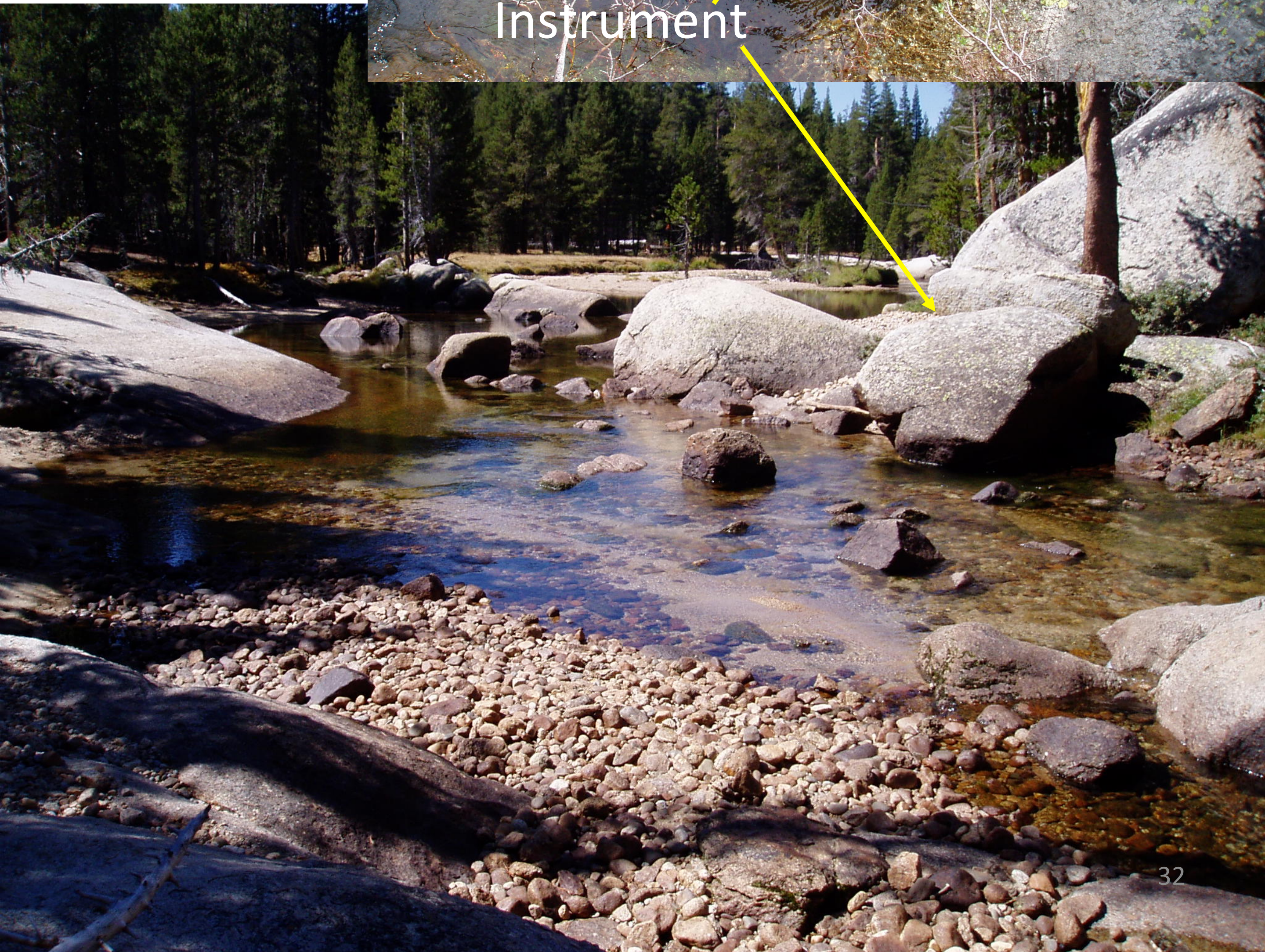
Lyell Fork above Twin Bridges





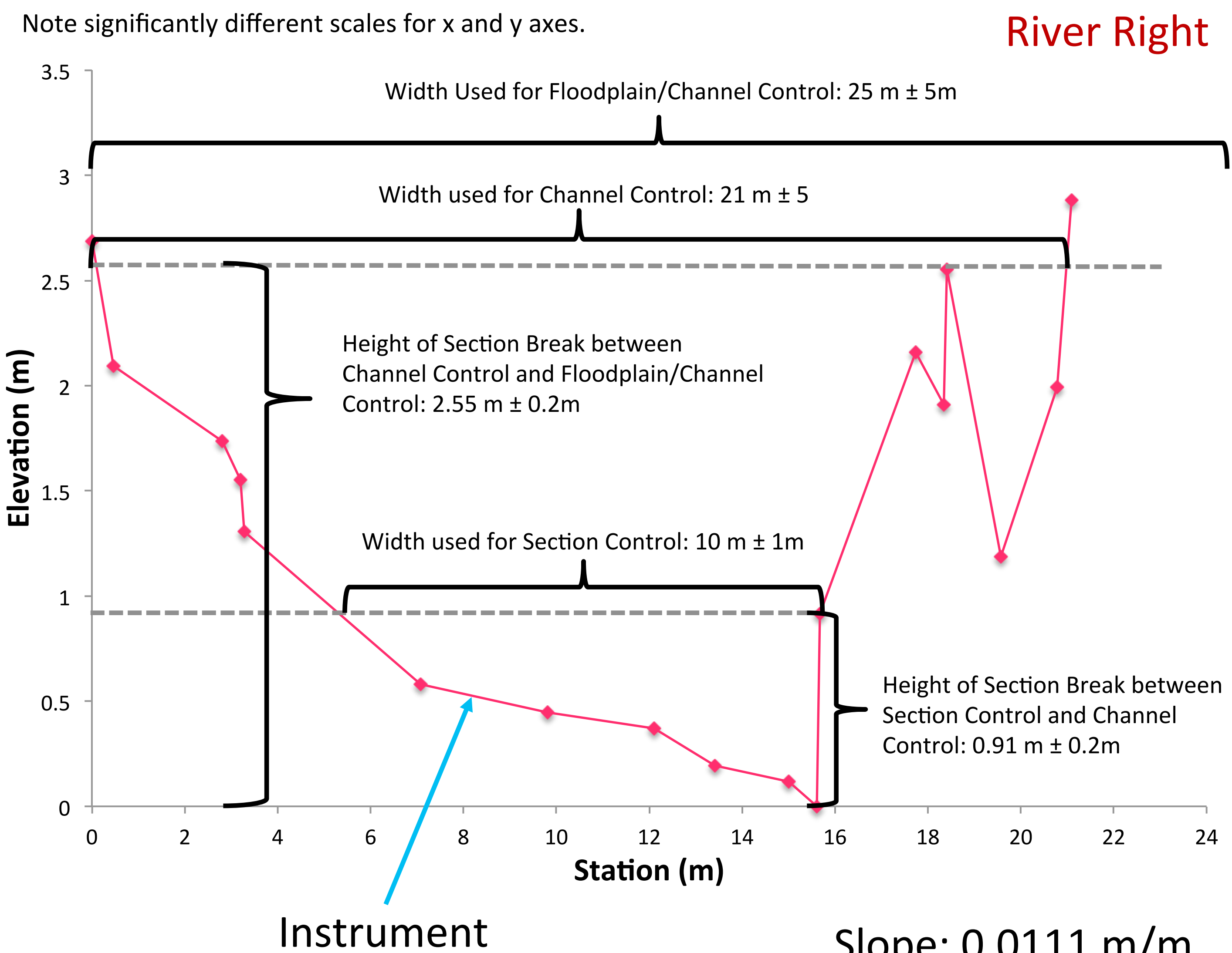
Q02b: Lyell Fork blw Twin Bridges

Latitude: 37.869
Longitude: -119.331
Datum: NAD83
Elevation: 2640 m



Lyell Fork below Twin Bridges

Note significantly different scales for x and y axes.



Slope: 0.0111 m/m

Lyell Fork below Twin Bridges

Height above which we expect an ice jam is likely: 2.5m

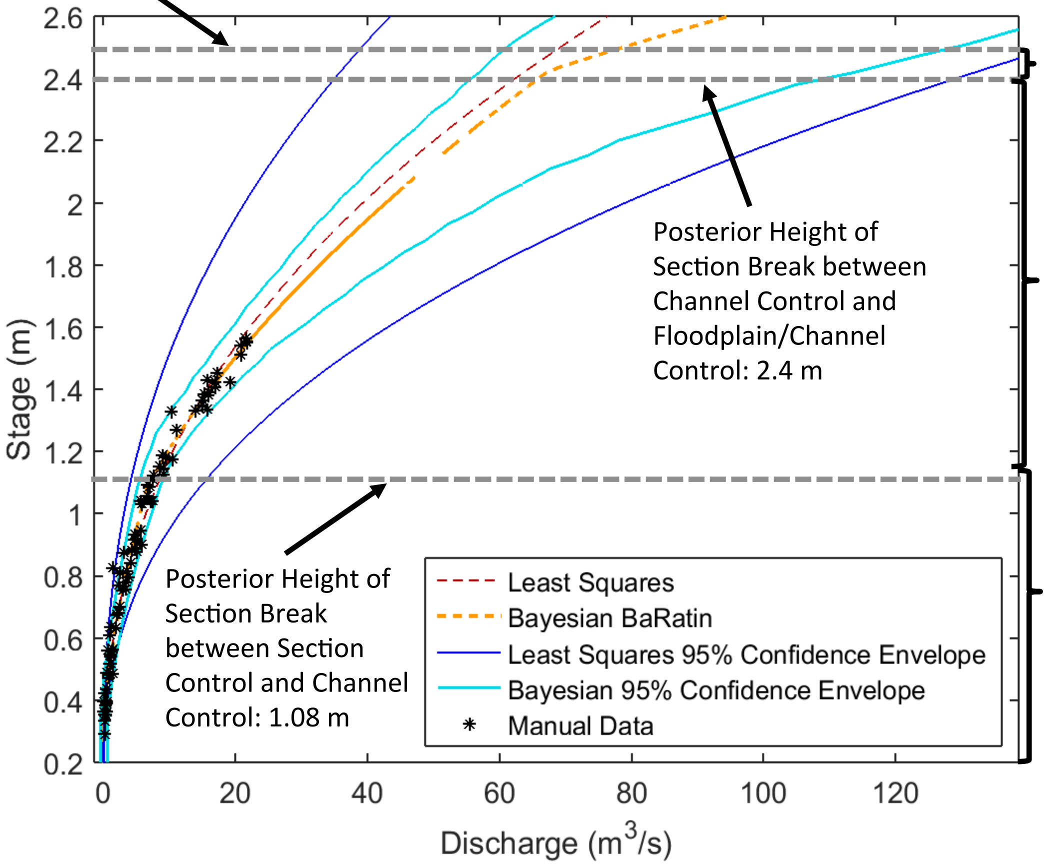
Least Squares (stage in cm, Q in cfs):
Q = 0.0043*(H – 10)^2.4177

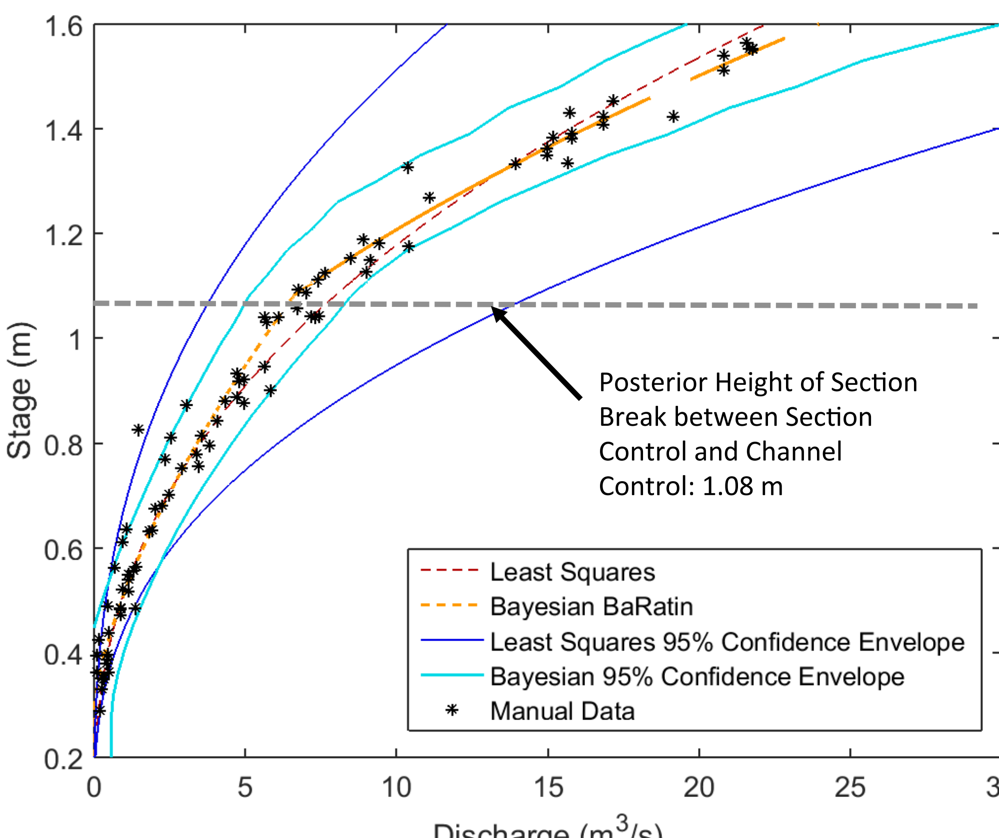
BaRatin (stage in m, Q in cms):

2.425m < H <= 2.5m
Q = 103.003*(H –1.6484)^1.671

1.08171m < H < 2.425m
Q = 25.193*(H –0.6297)^1.6848

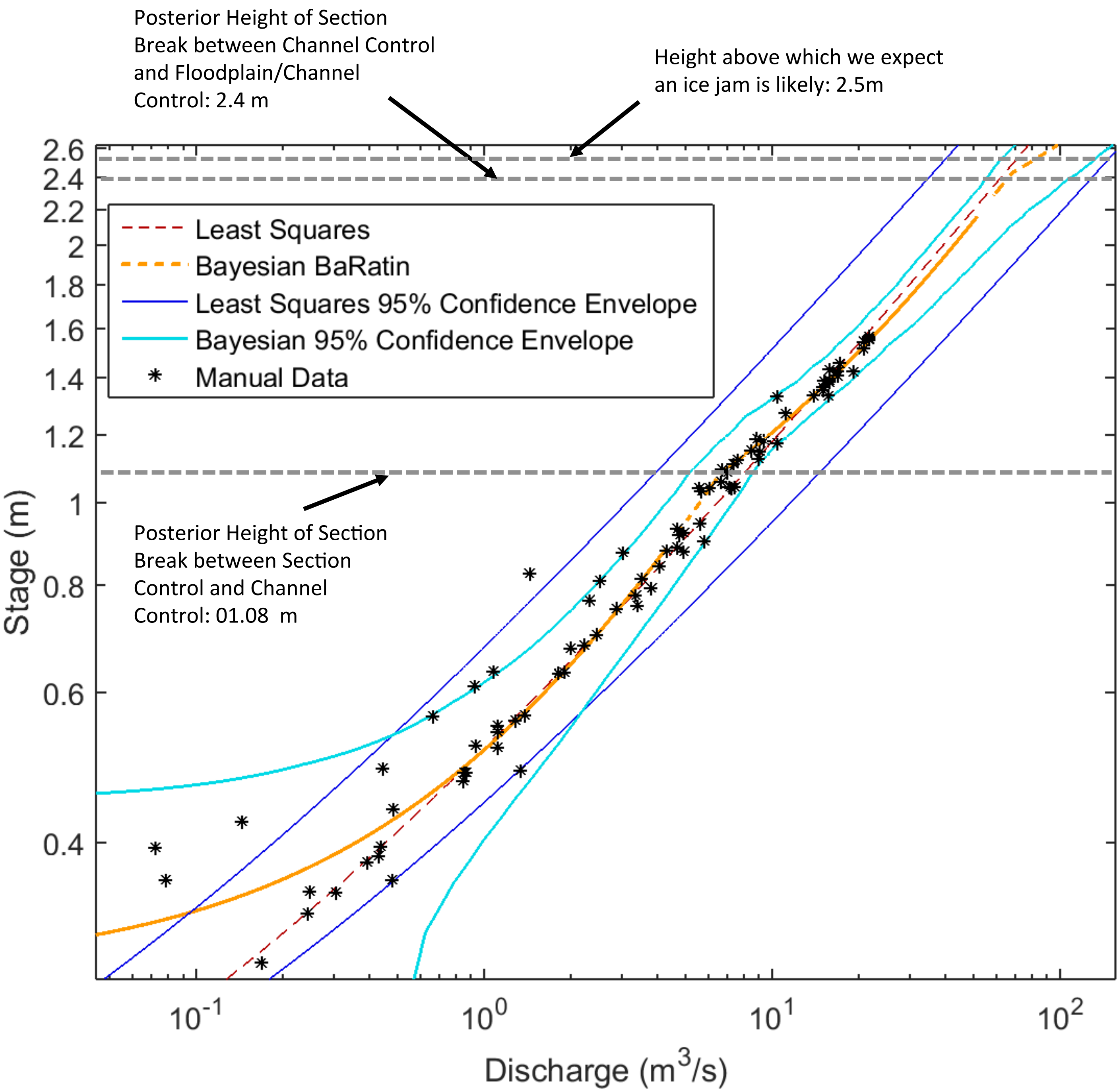
H < 1.08171m
Q =9.3003*(H – 0.28214)^1.526



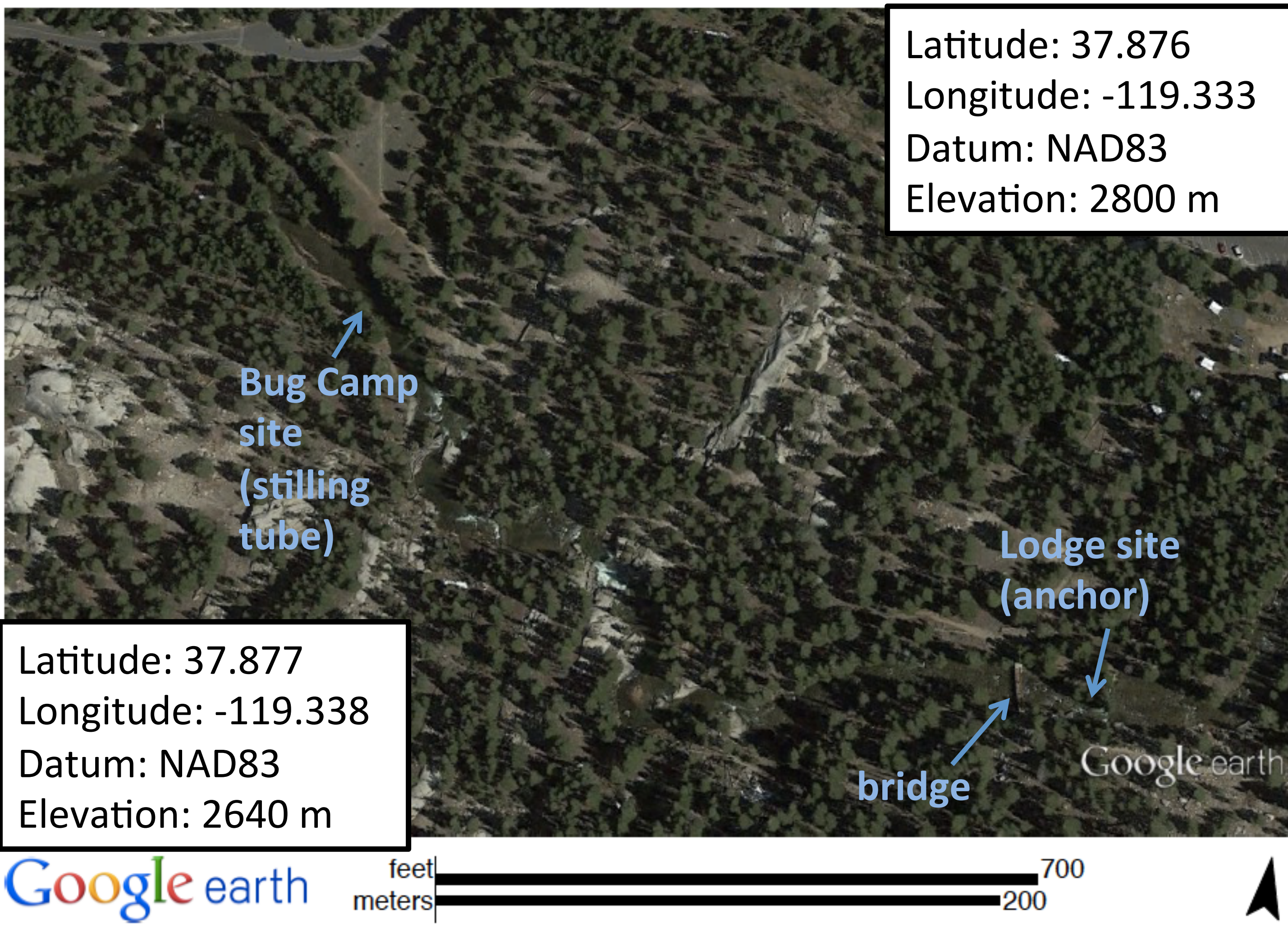


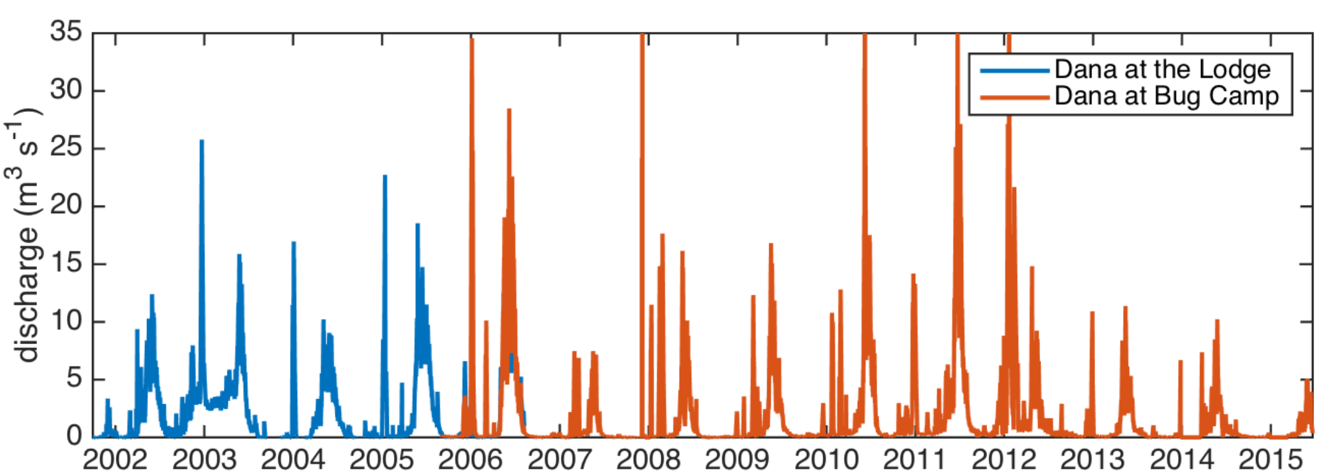
Log-Log View

Lyell Fork below Twin Bridges



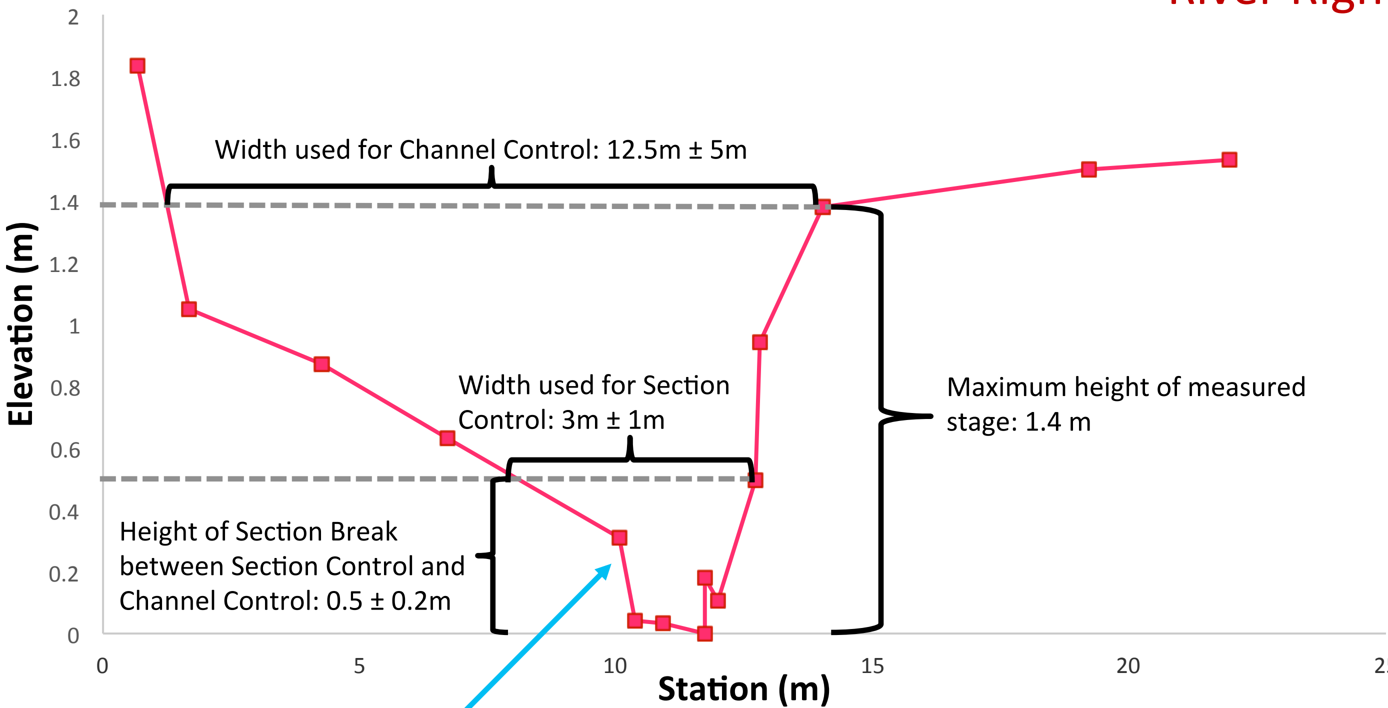
Q03: Dana Fork, Tuolumne Lodge and Bug Camp





H02a (NP188): Dana Fork near Tuolumne Lodge

River Right



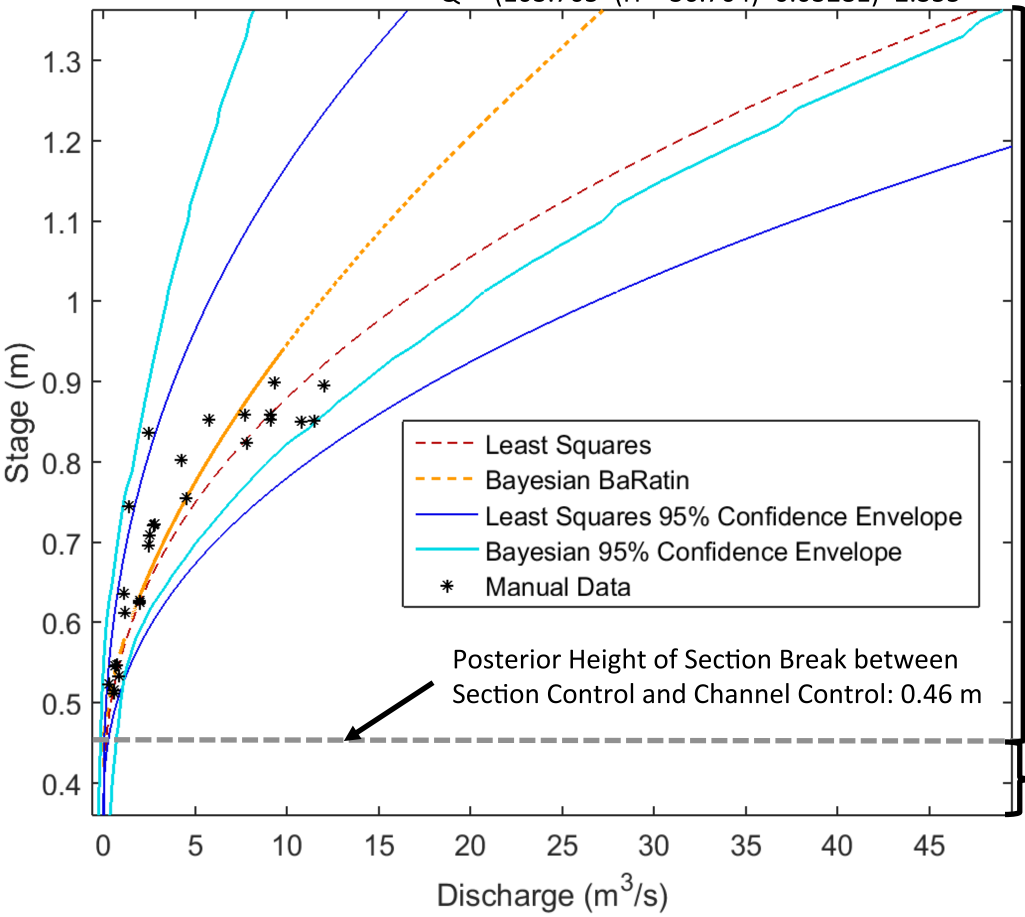
Instrument

Note significantly different scales for x and y axes.

Dana Fork near Tuolumne Lodge

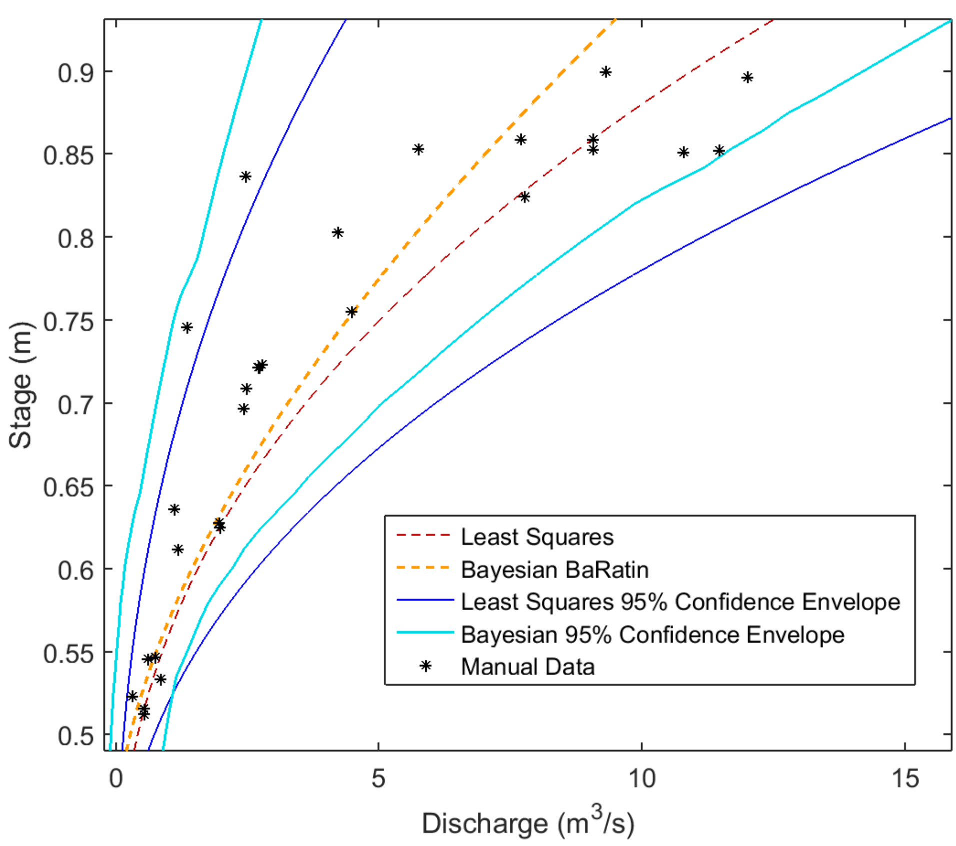
Least Squares (stage in ft, Q in cfs):
Q = (103.705*(H – 36.704)*0.03281)^2.355

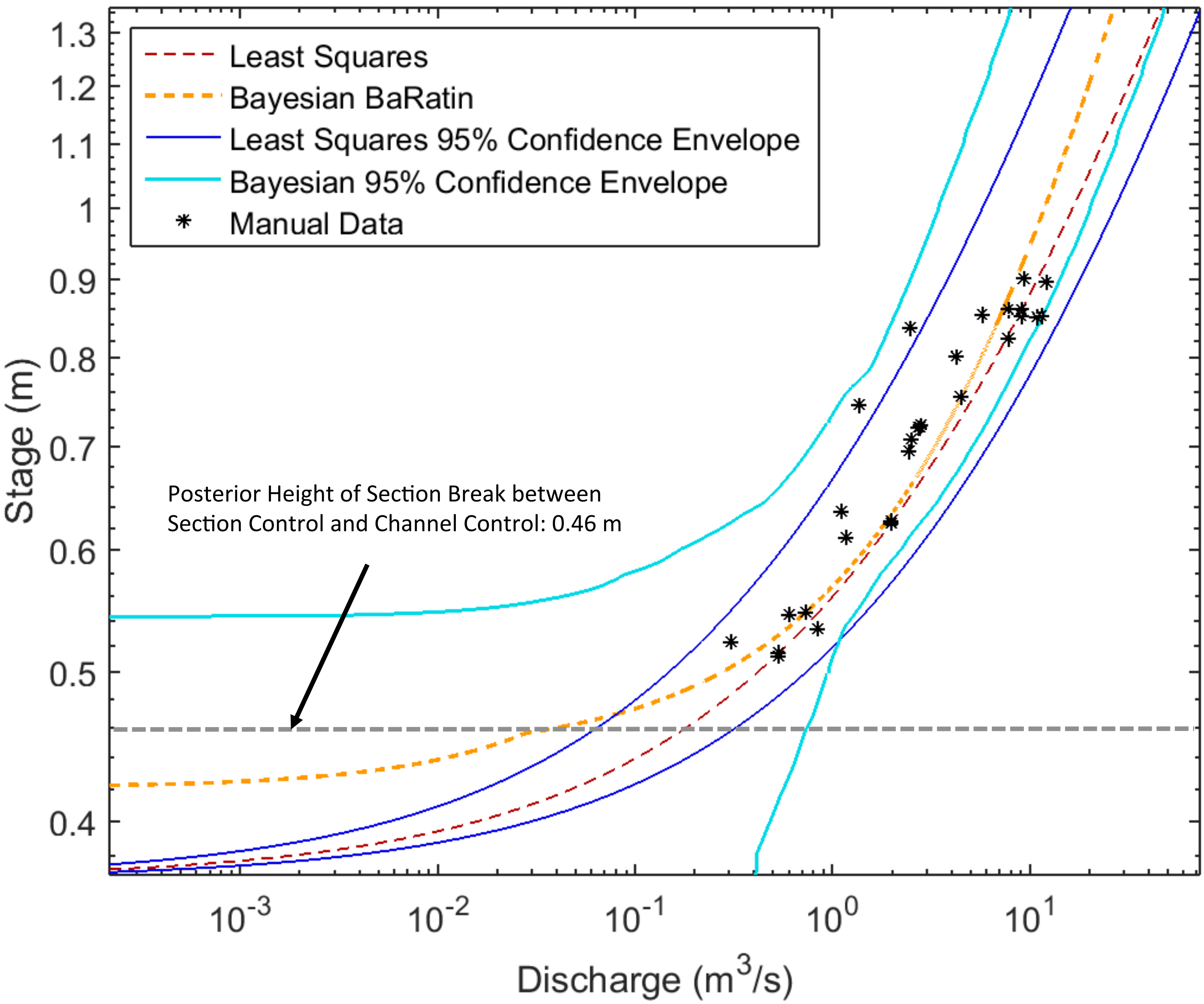
BaRatin (stage in m, Q in cms):



0.456733m =< H
Q = 31.249*(H –0.4419)^1.6651

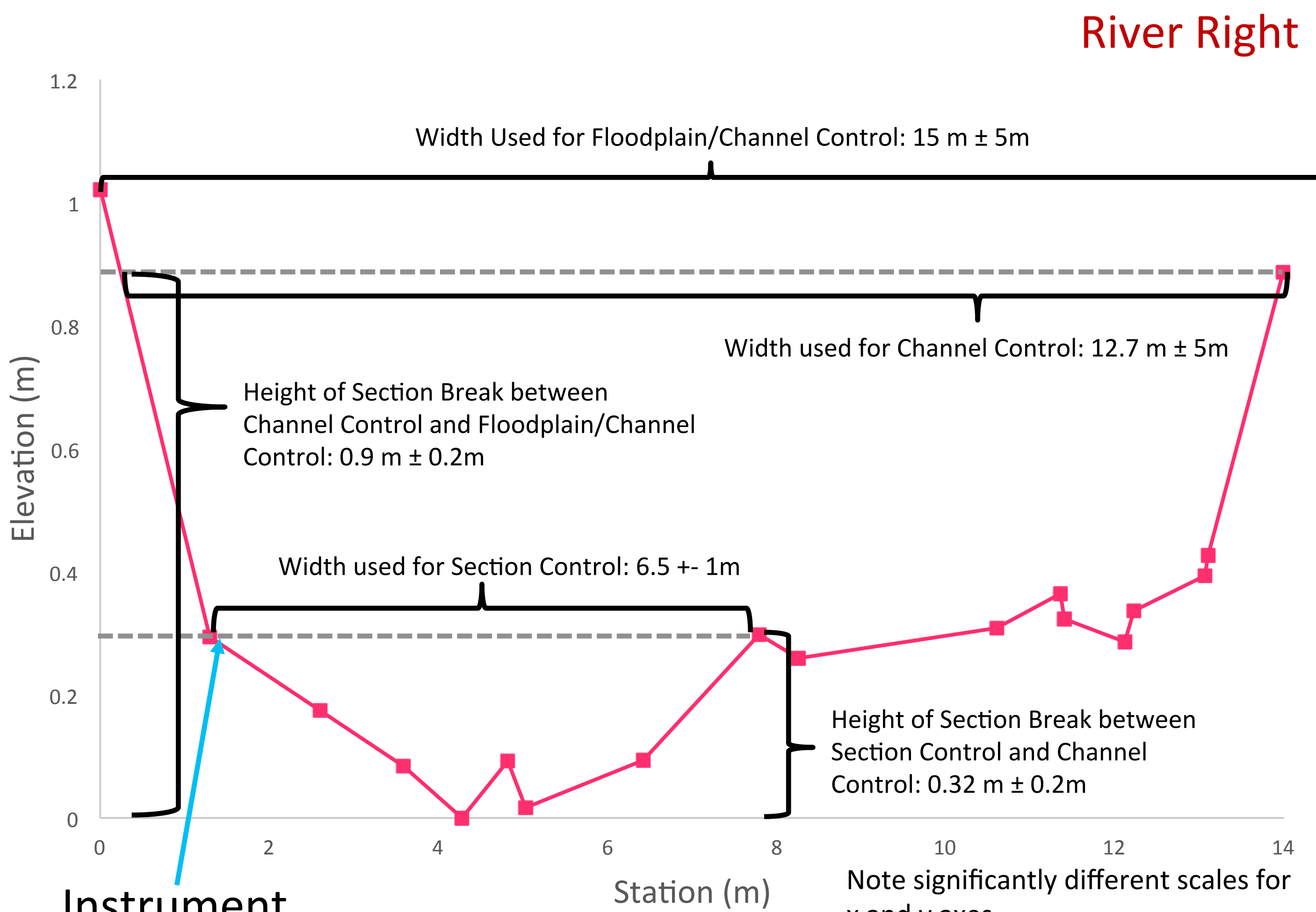
H < 0.456733m
Q =4.0361*(H –0.421)^1.4915



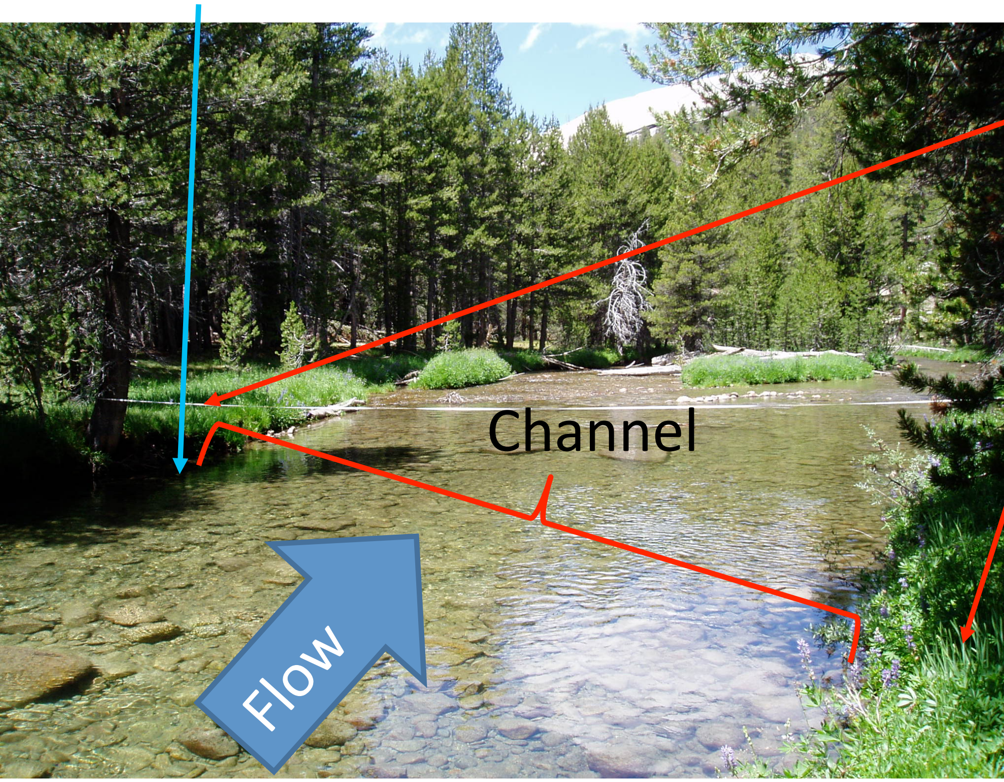

Least Squares
Bayesian BaRatin
Least Squares 95% Confidence Envelope
Bayesian 95% Confidence Envelope
Manual Data
Stage (m)
Discharge (m3/s)
Posterior Height of Section Break between
Section Control and Channel Control: 0.46 m

H02b: Dana Fork at Bug Camp

Dana Fork at Bug Camp



Note significantly different scales for x and y axes.

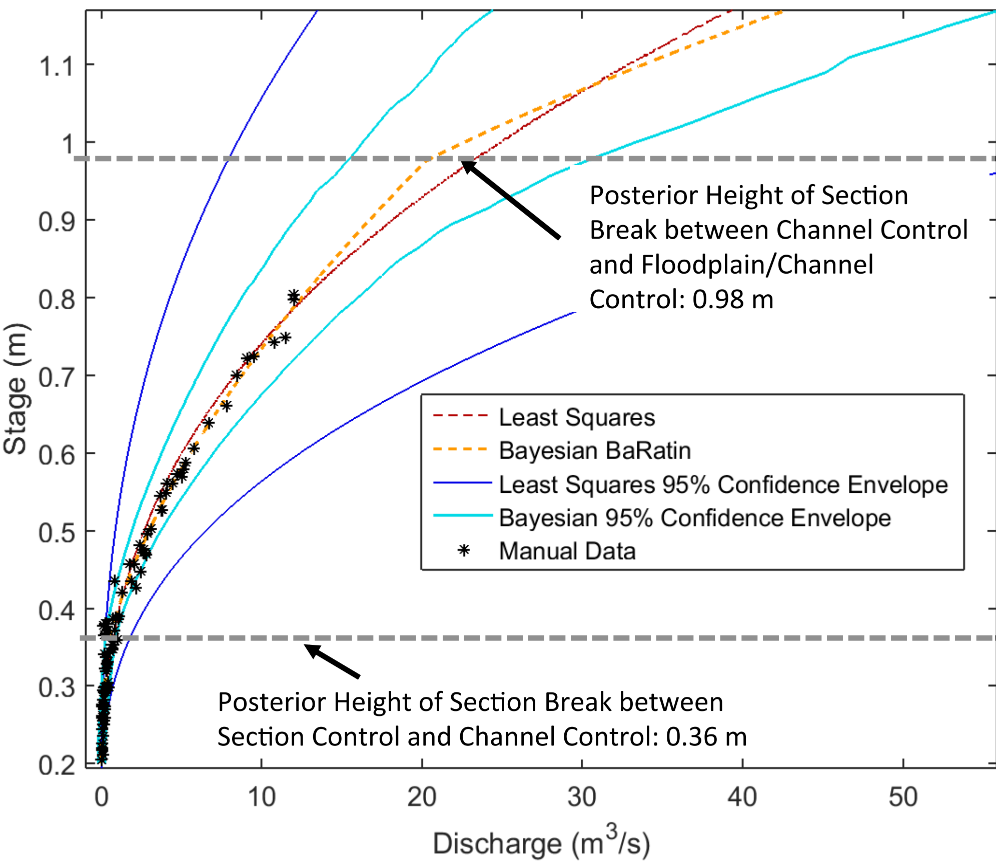


Slope: 0.033 m/m

Dana Fork at Bug Camp

Least Squares (stage in ft, Q in cfs):
Q = 68.09*(H –0. 5)^2.5

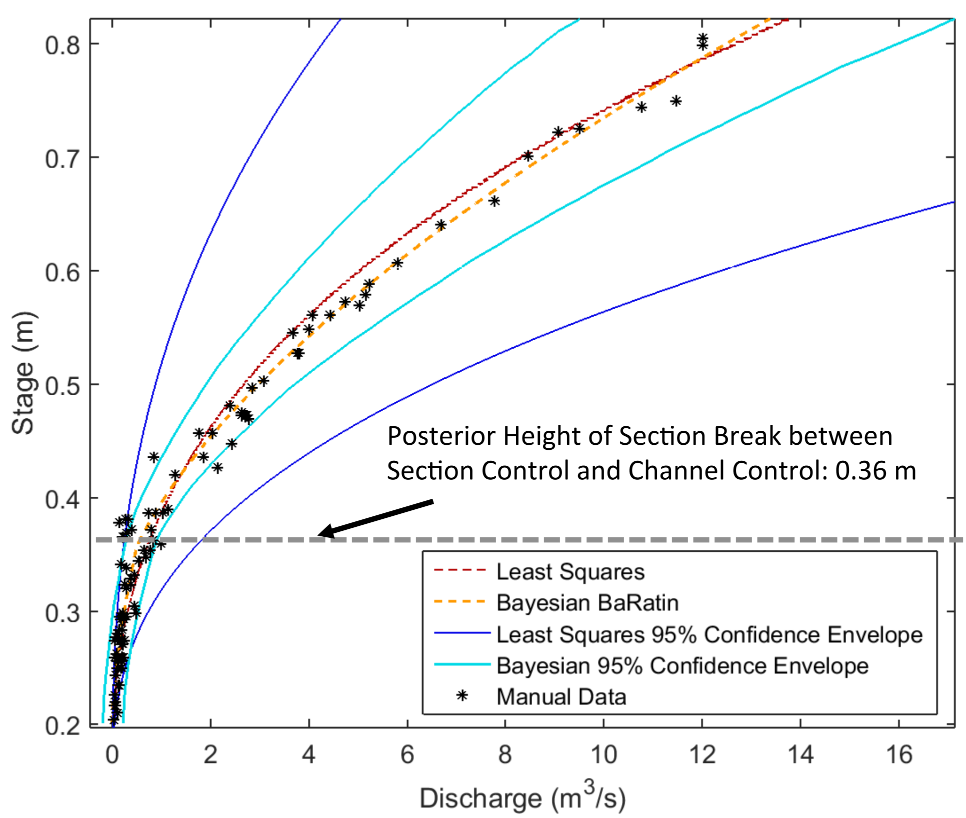
BaRatin (stage in m, Q in cms):



0.976552m < H
Q = 119.294*(H – 0.623132)^1.70361

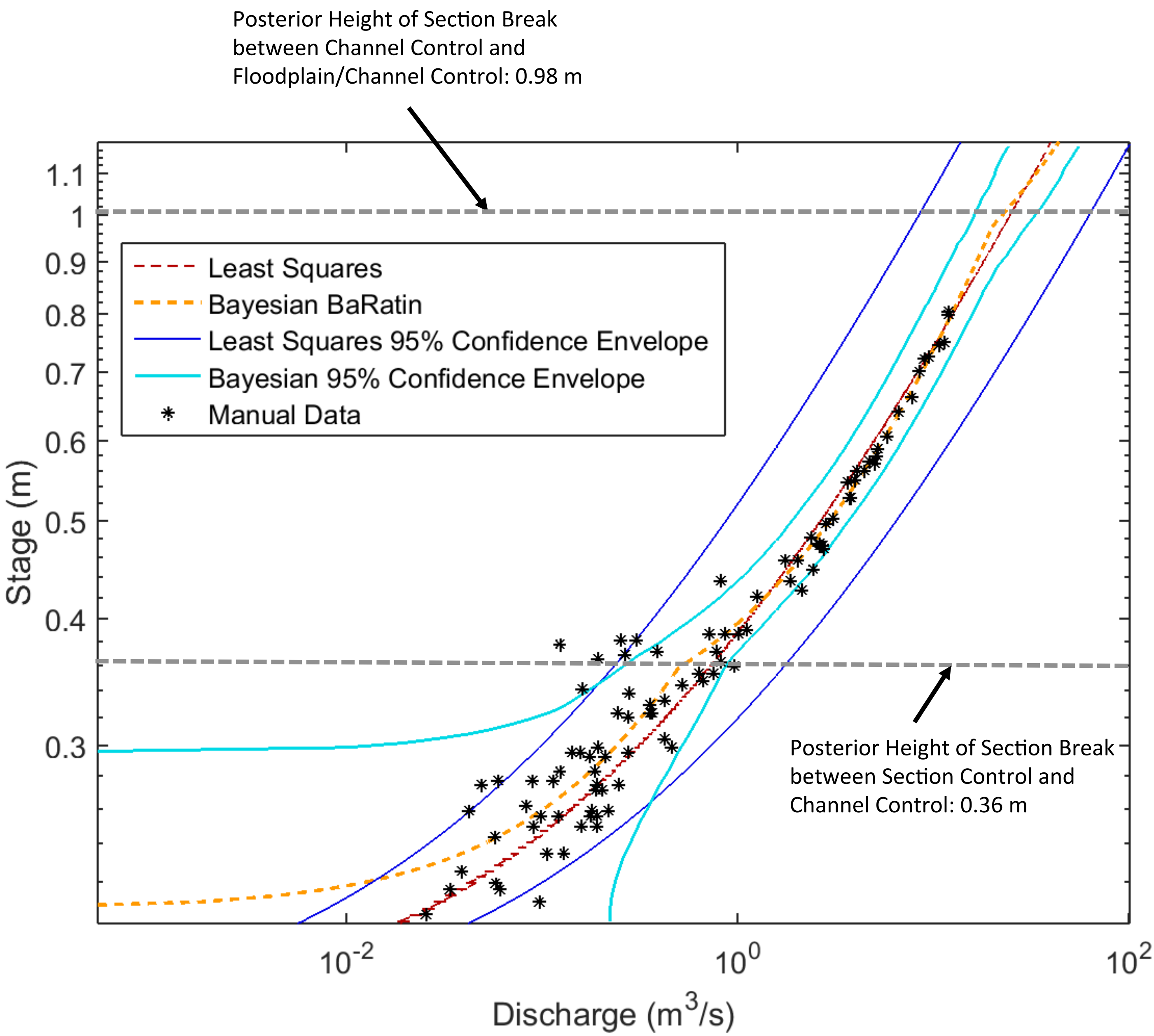
0.357608m < H < 0.976552m
Q = 37.16*(H – 0.2854)^1.6395

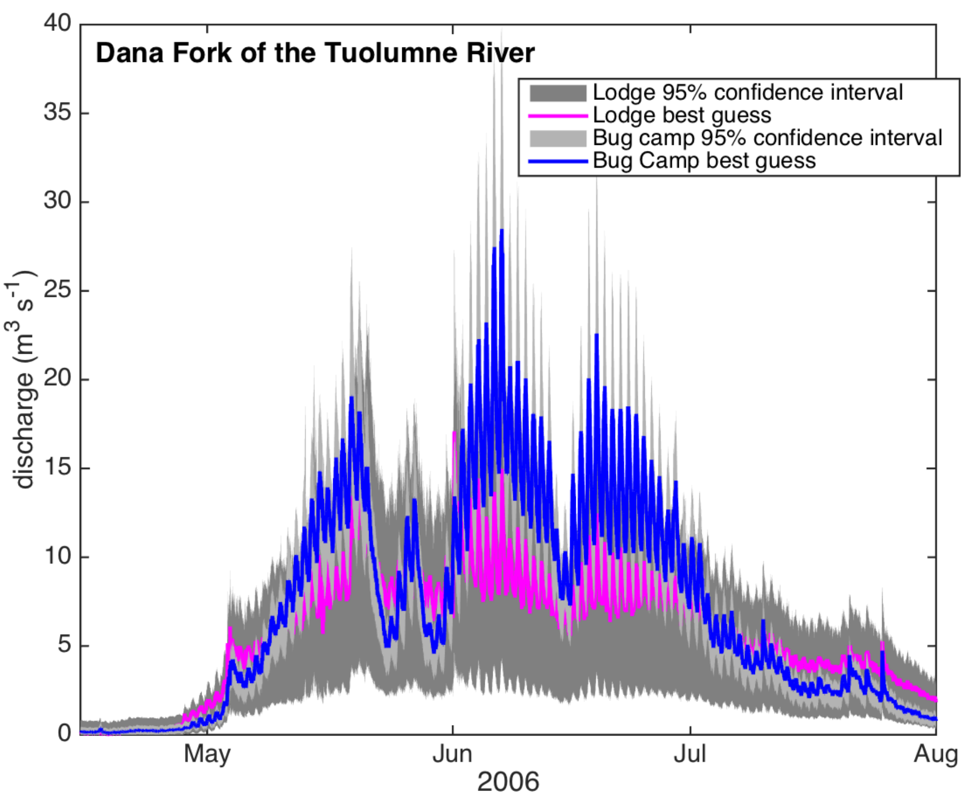
H < 0.357608m
Q =8.822*(H – 0.2066)^1.5183



Log-Log View

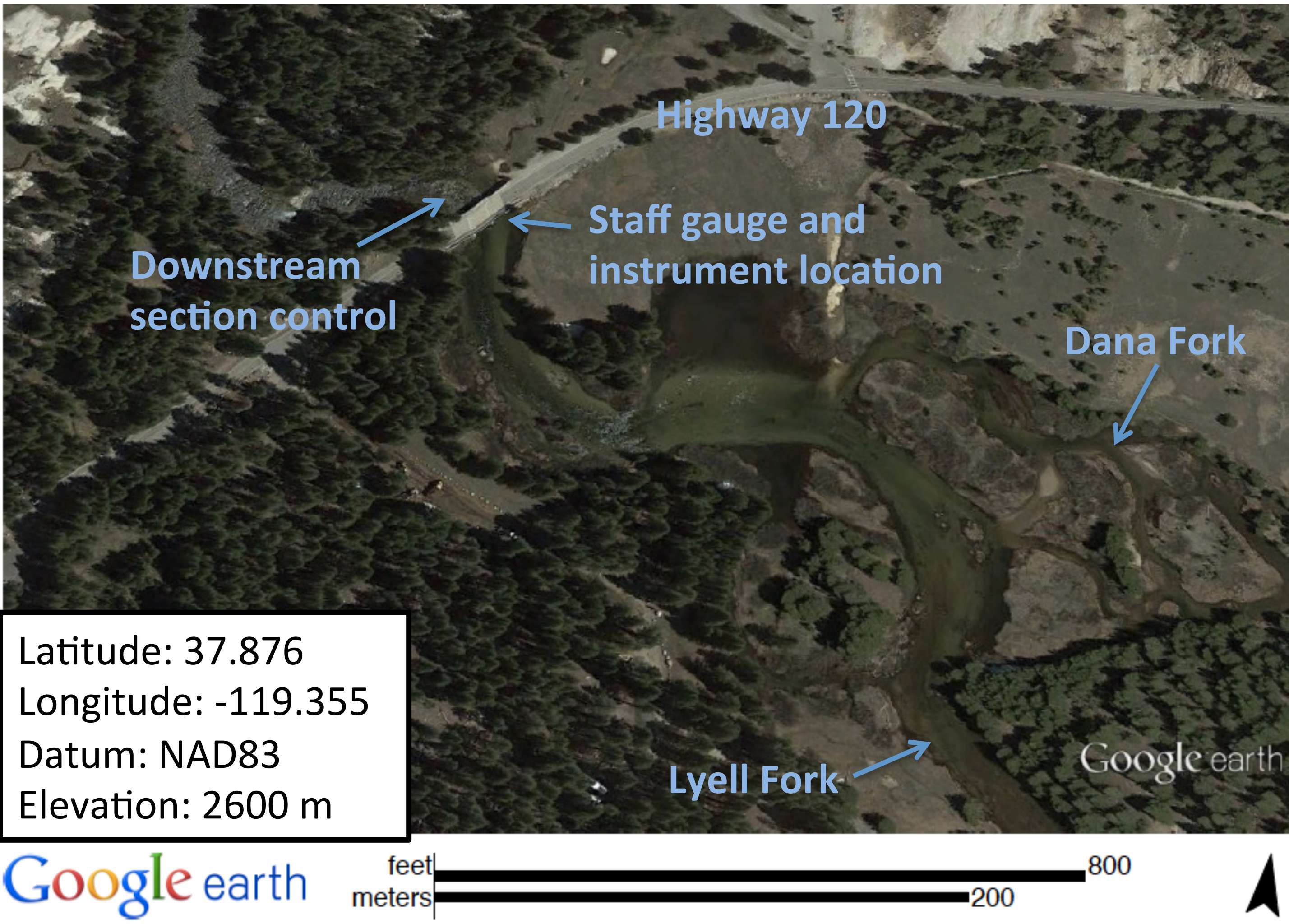
Dana Fork at Bug Camp

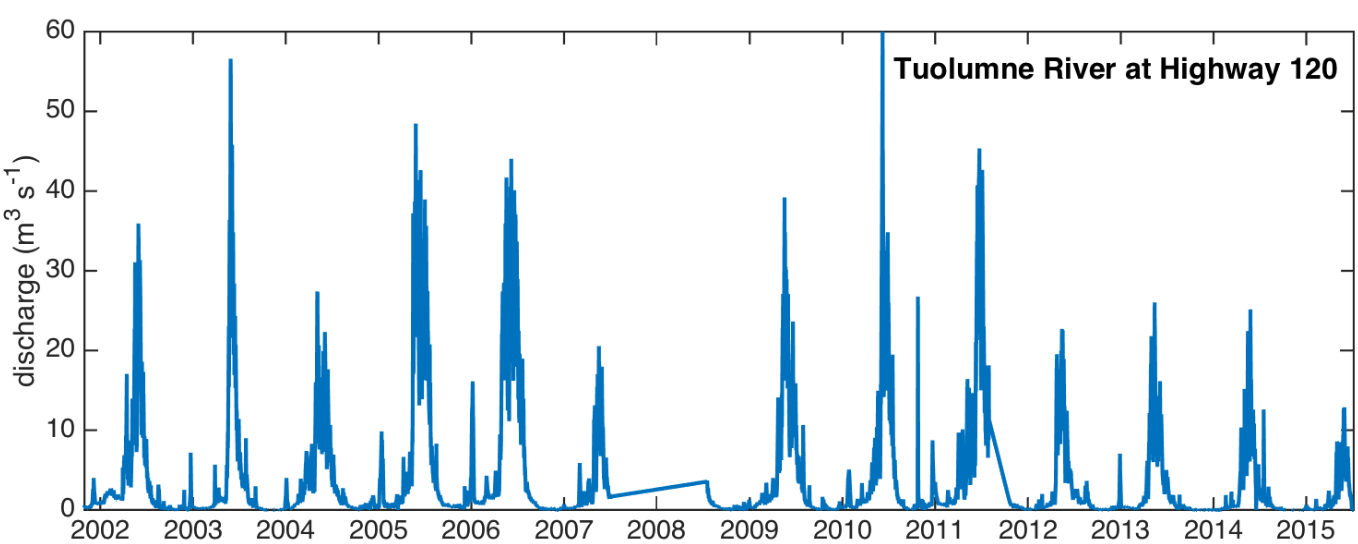




Substantial uncertainty exists in the rating curve at the lodge location (see confidence intervals). Recommended to use the Bug Camp location data when possible.

Q04: Tuolumne at Highway 120





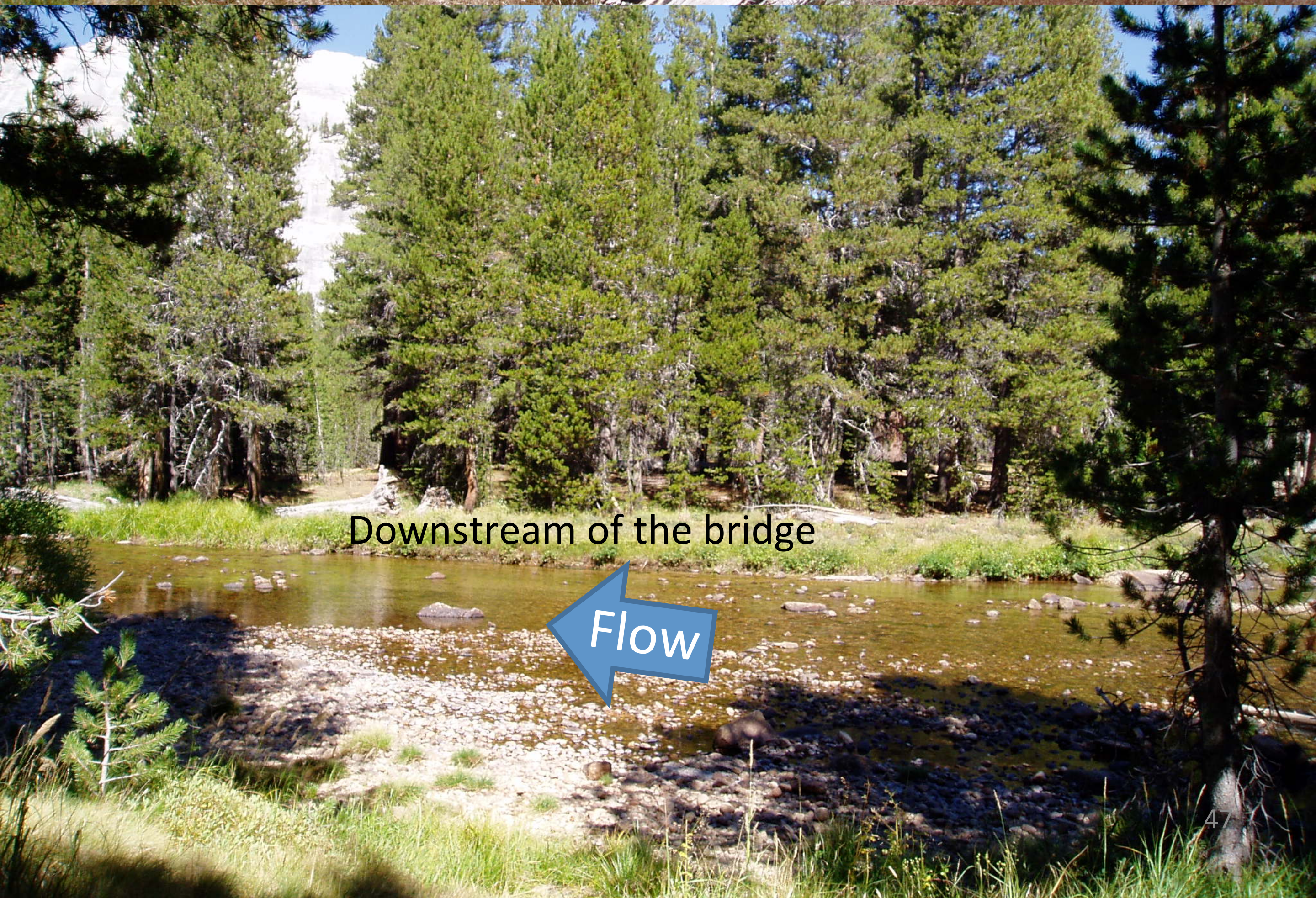
Tuolumne River at Highway 120

Staff gauge, installed in 2006

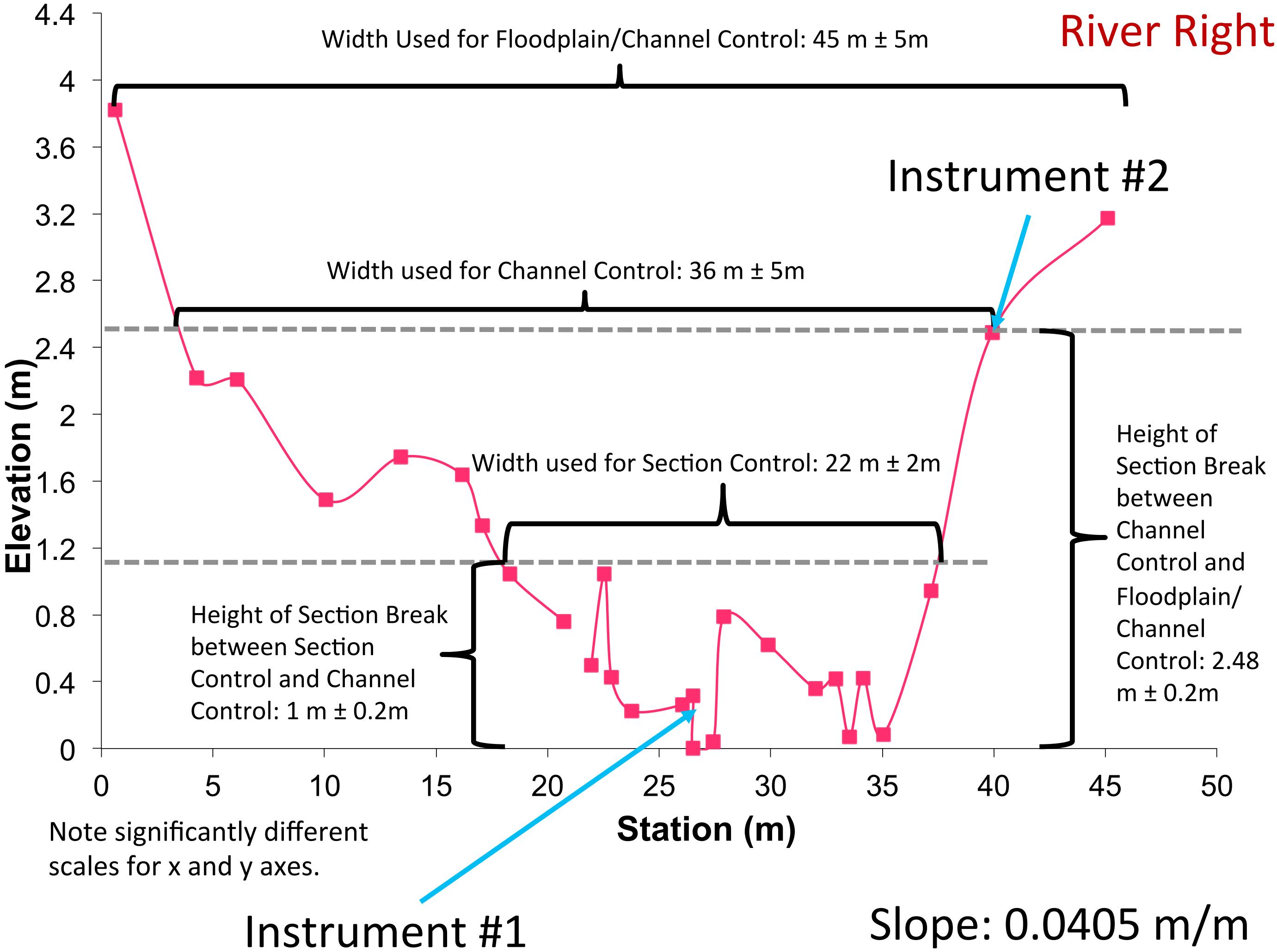
Corded pressure transducer, installed in 2006

Original install in 2001, anchored solinst at the base of this abutment.


Tuolumne River at Highway 120
Upstream of the bridge, photo taken 23 September 2003
Flow

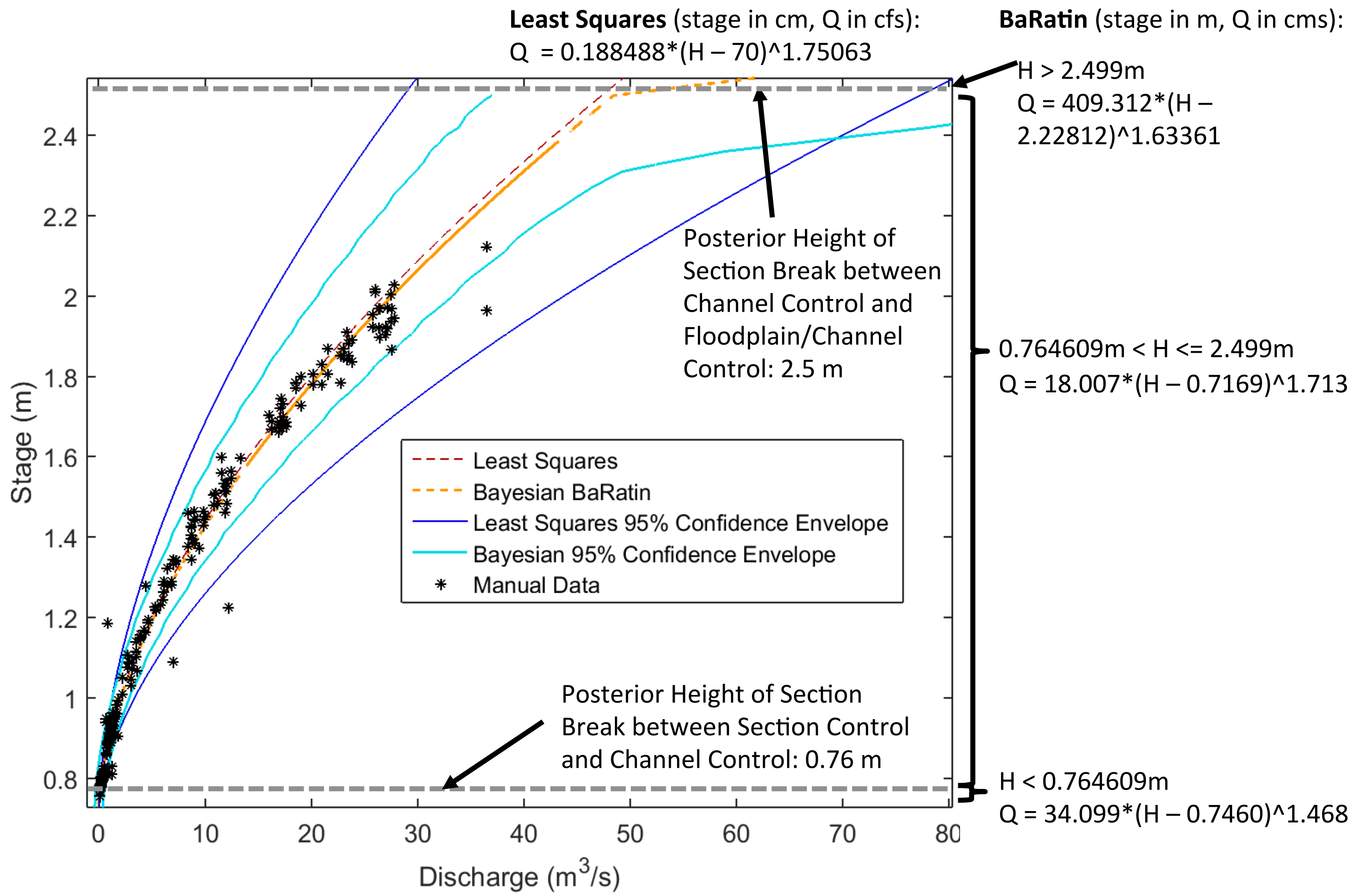

Downstream of the bridge
Flow

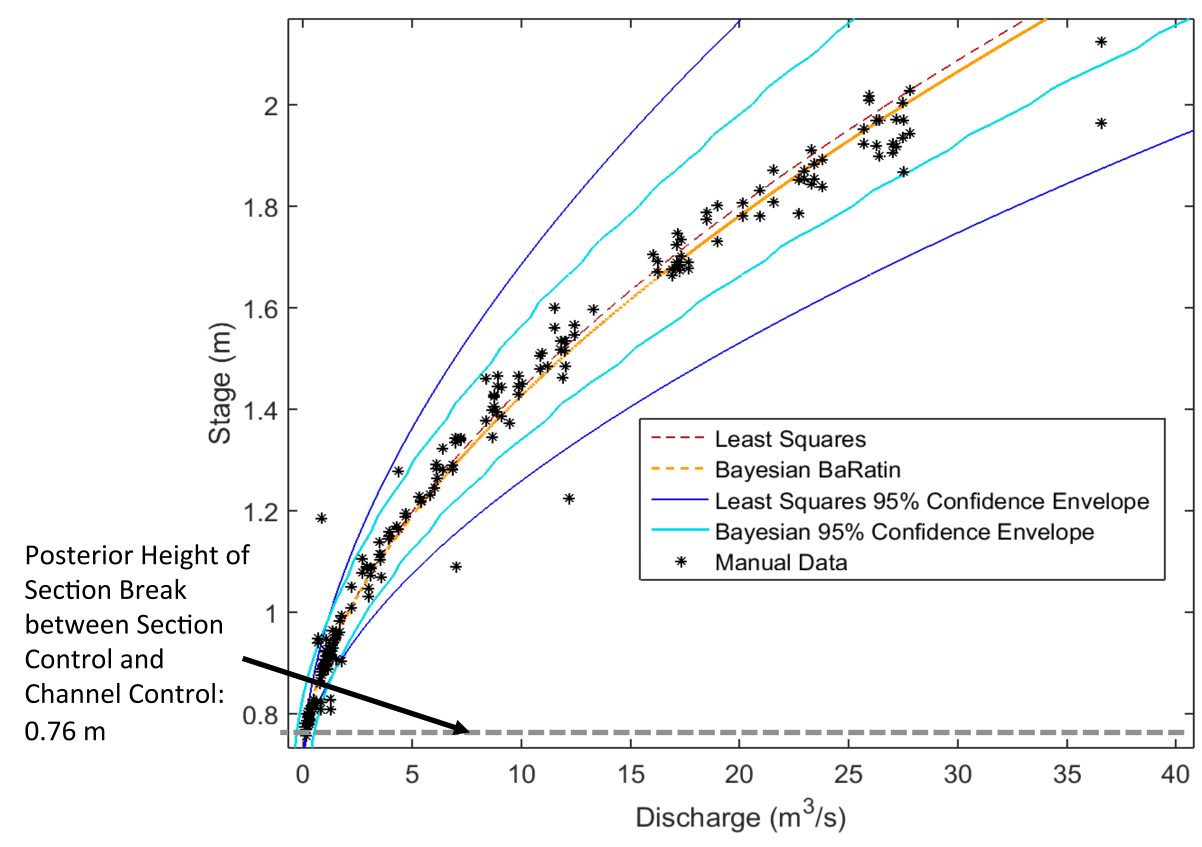
Tuolumne River at Highway 120



Slope: 0.0405 m/m

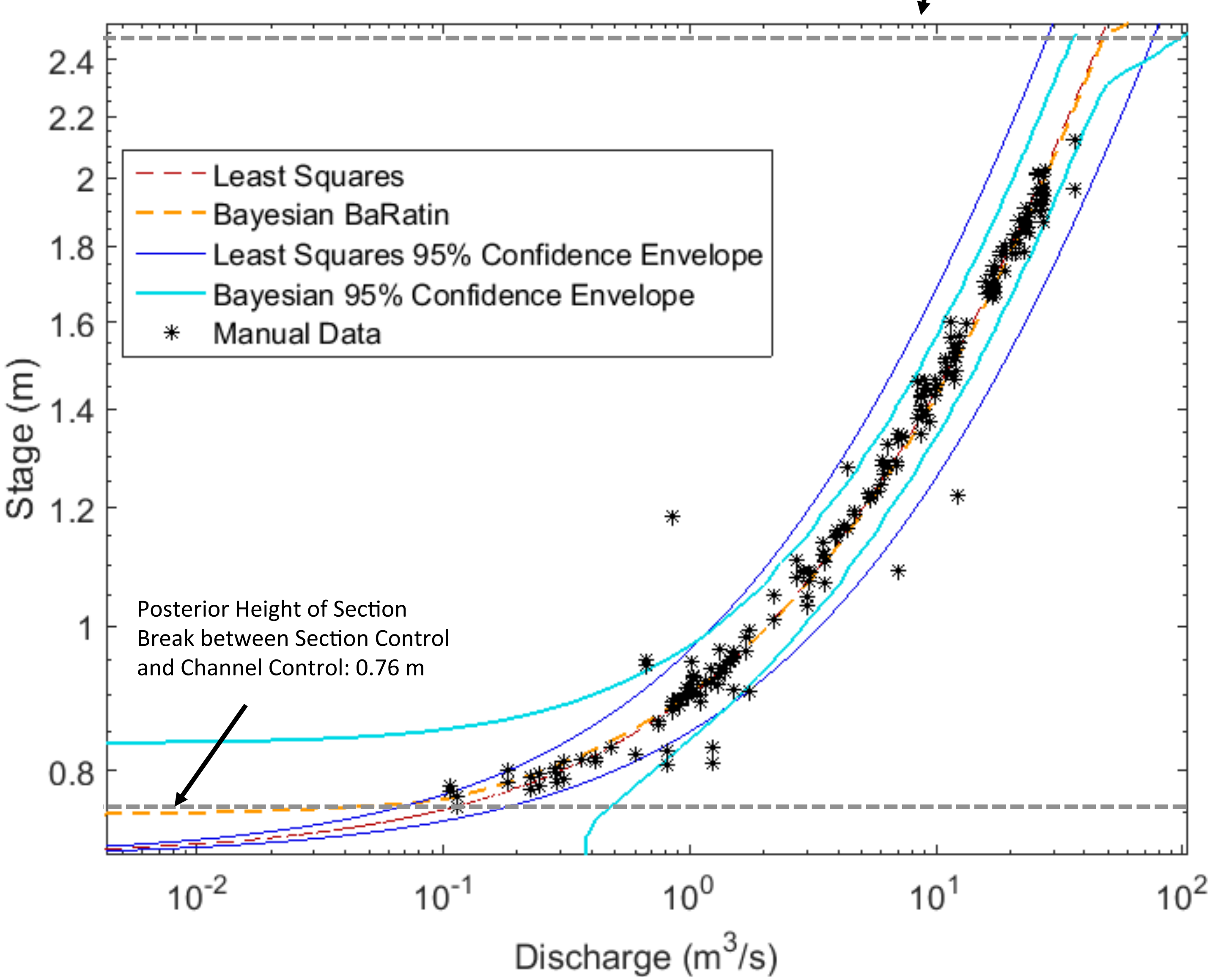
Tuolumne River at Highway 120





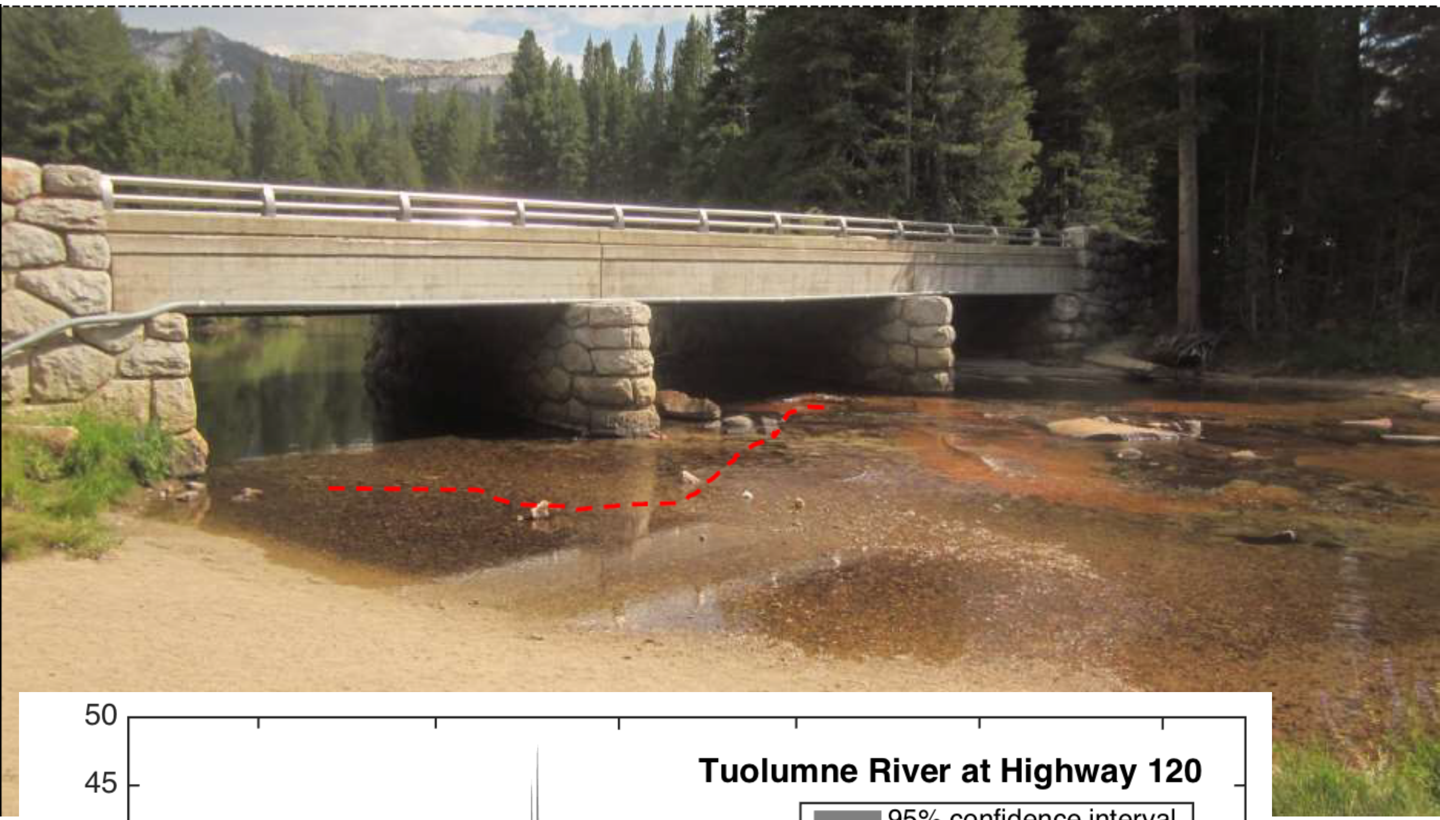
Tuolumne River at Highway 120

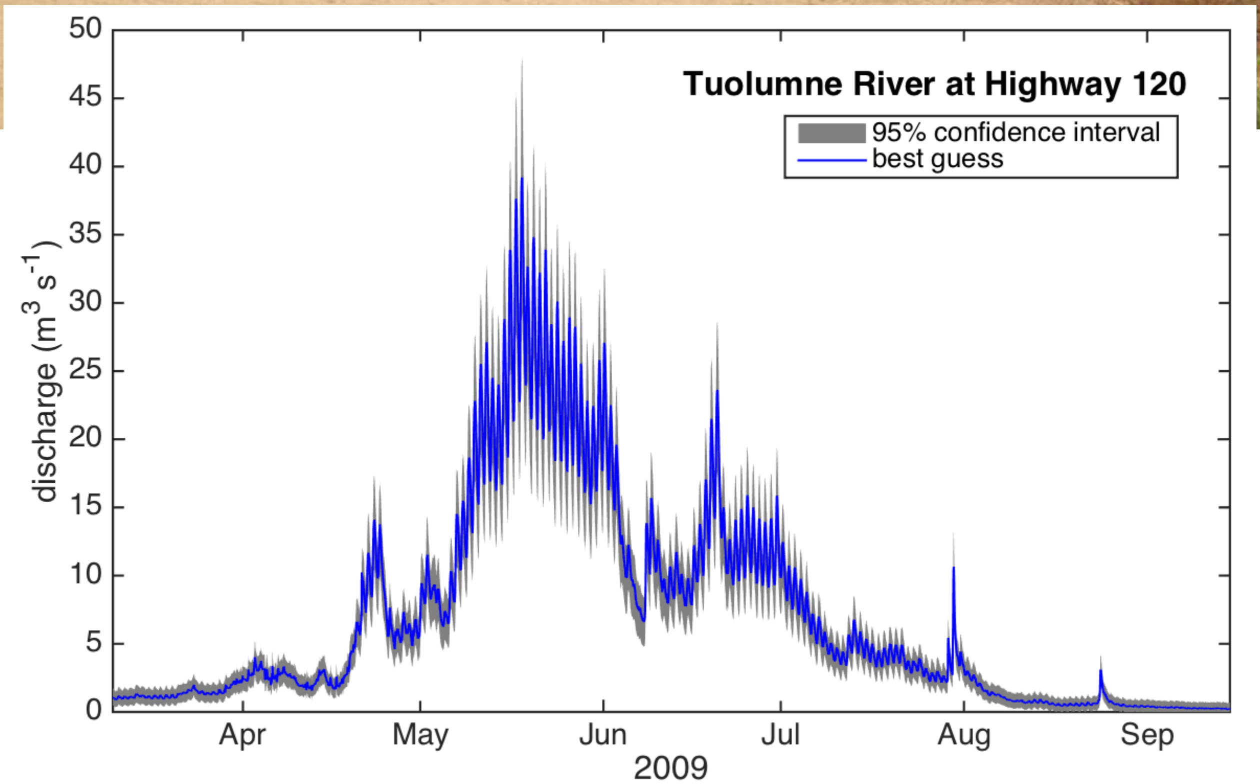
Posterior Height of Section Break between Channel Control and Floodplain/Channel Control: 2.5 m



Posterior Height of Section Break between Section Control and Channel Control: 0.76 m

Photo on 29 July 2015; red shows gravel bar section control.
16:00 on 29 July 2015: Gage height of zero flow 2.79 ft – 0.86 ft = 1.93 ft

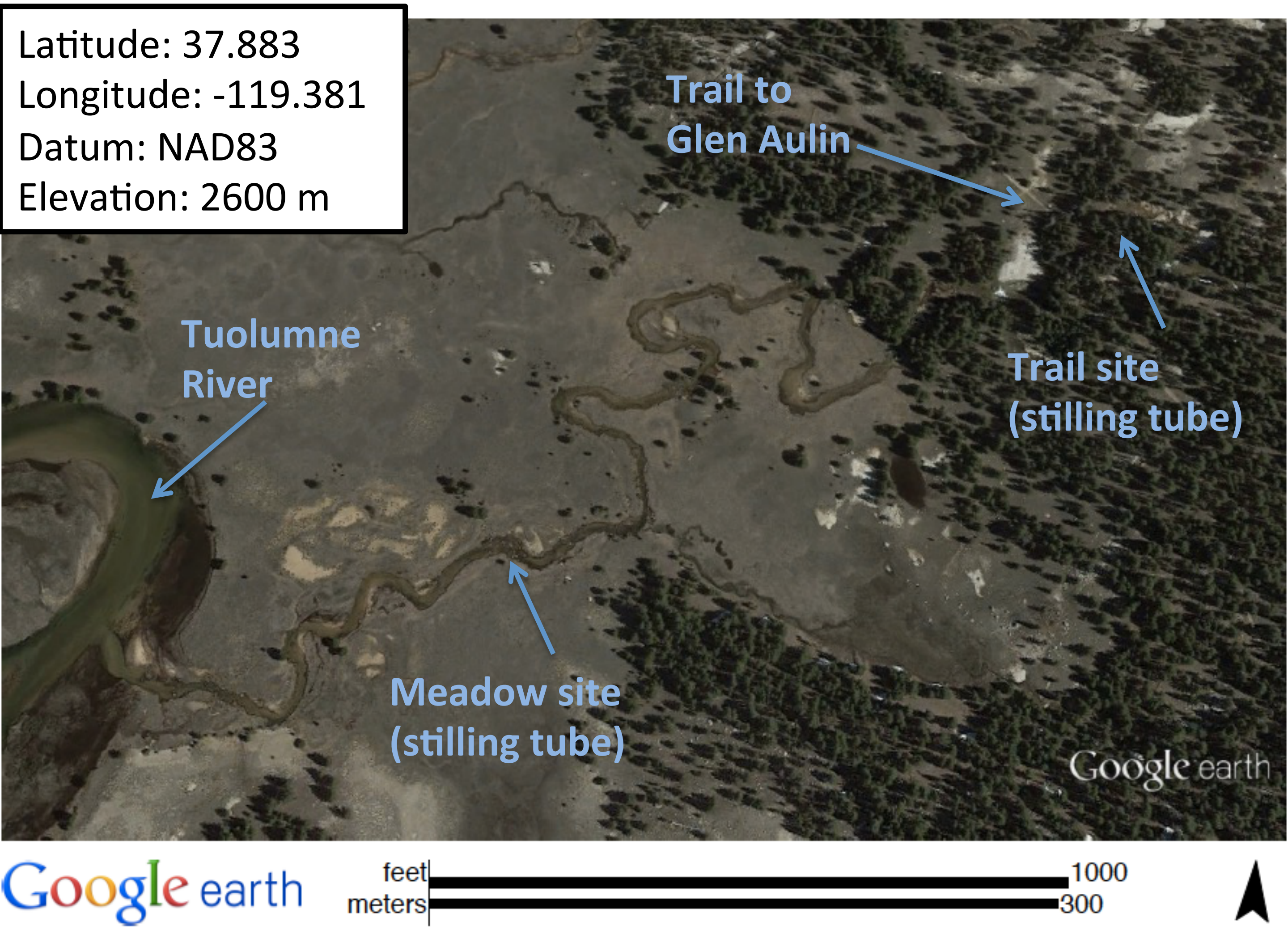


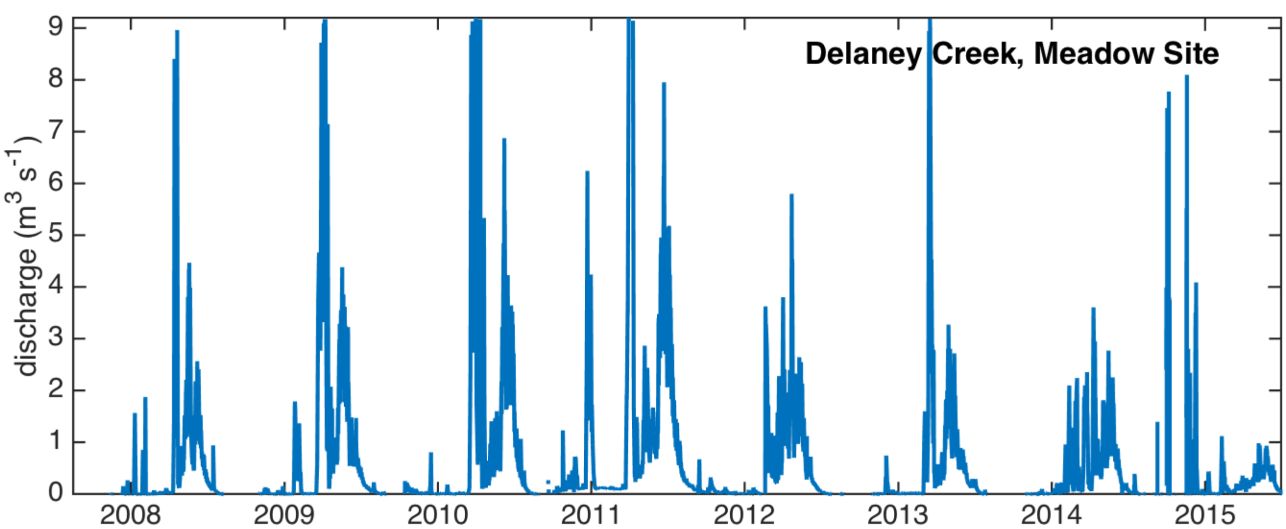


The rating curve at this location has greater confidence than at many of the other sites.

Q05: Delaney Creek

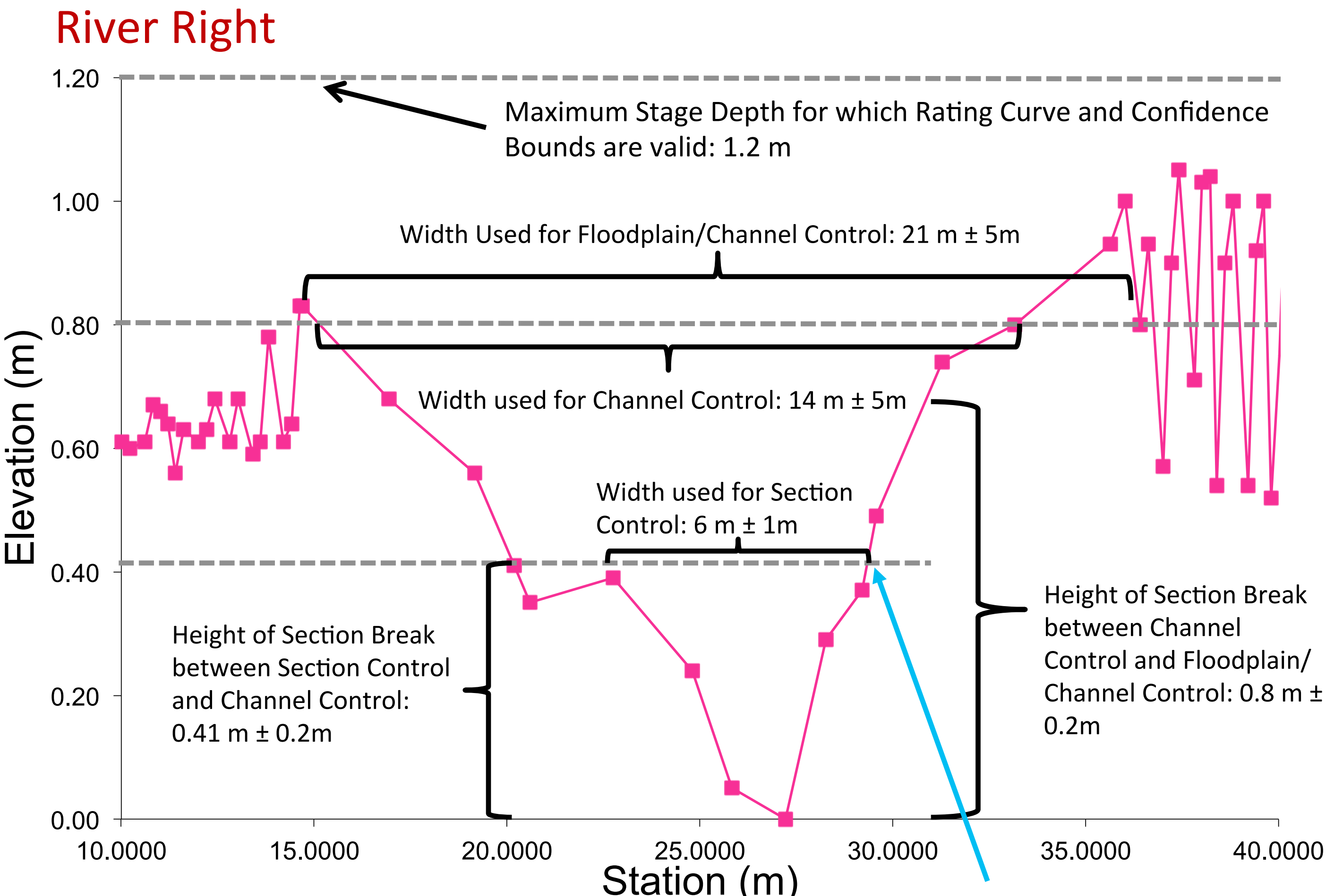
Latitude: 37.883
Longitude: -119.381
Datum: NAD83
Elevation: 2600 m



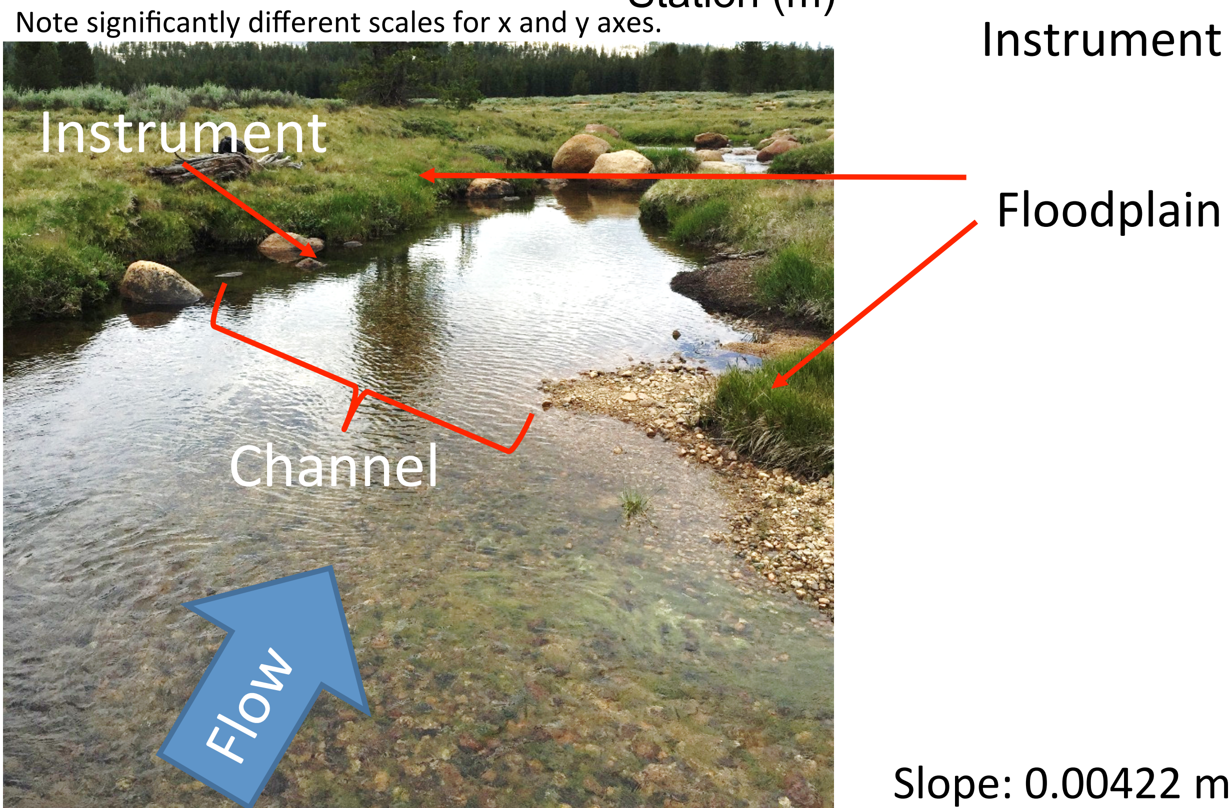


Meadow site only is available at this time. Notice frequency of ice jams.

Delaney Creek

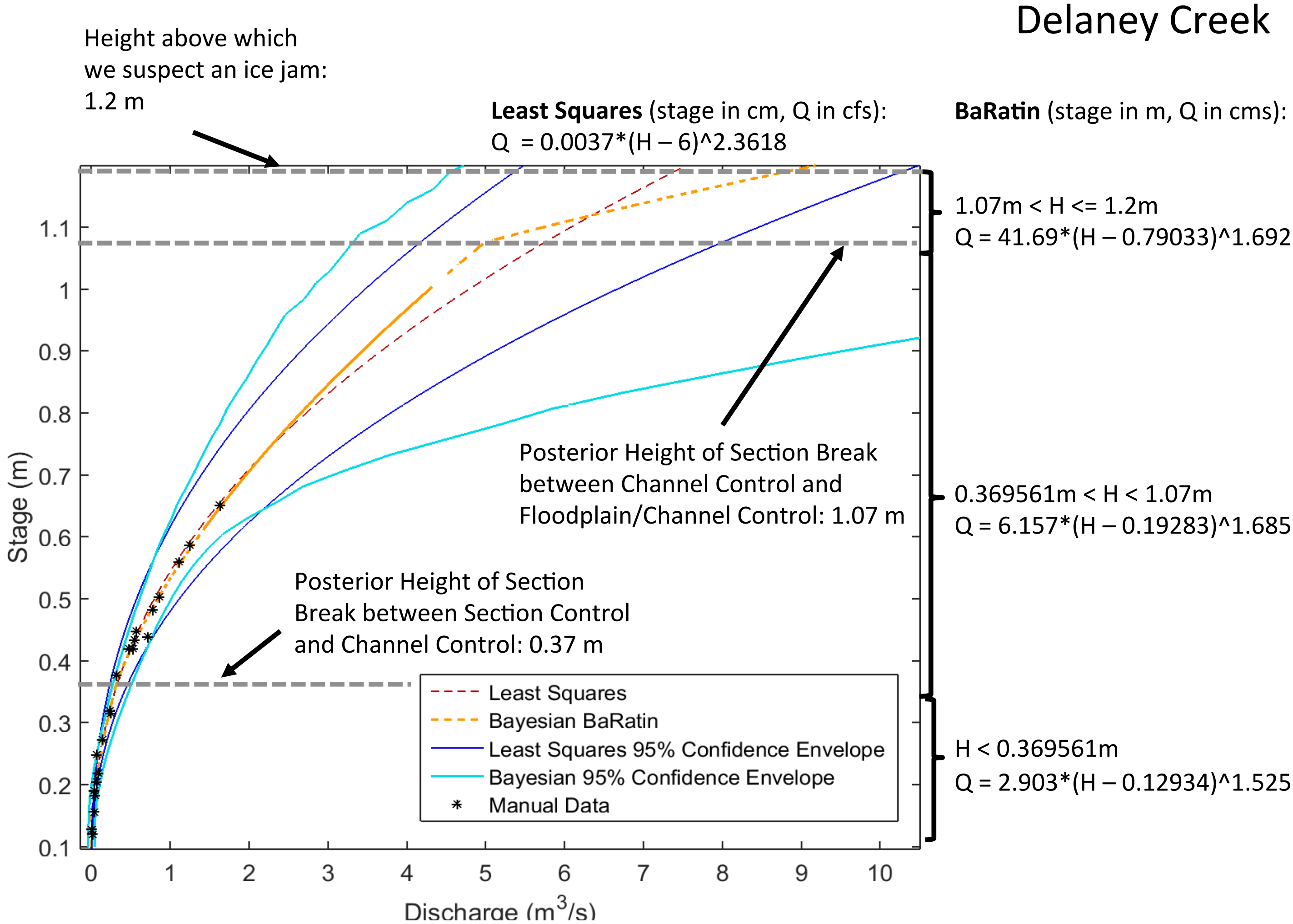


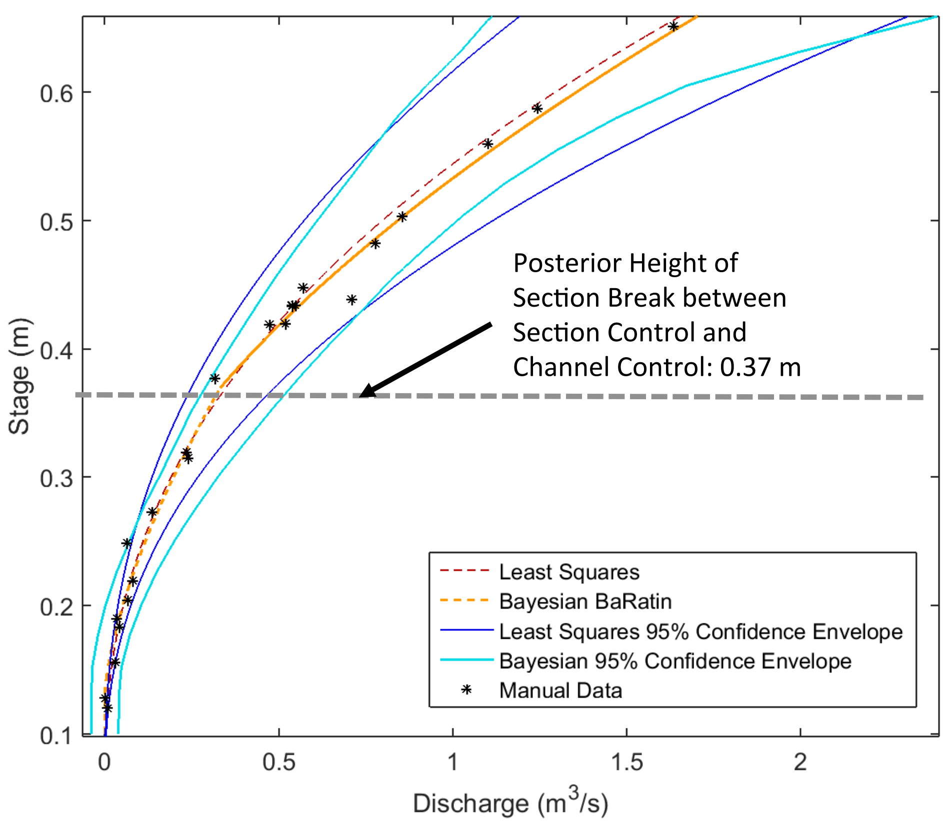
Note significantly different scales for x and y axes.

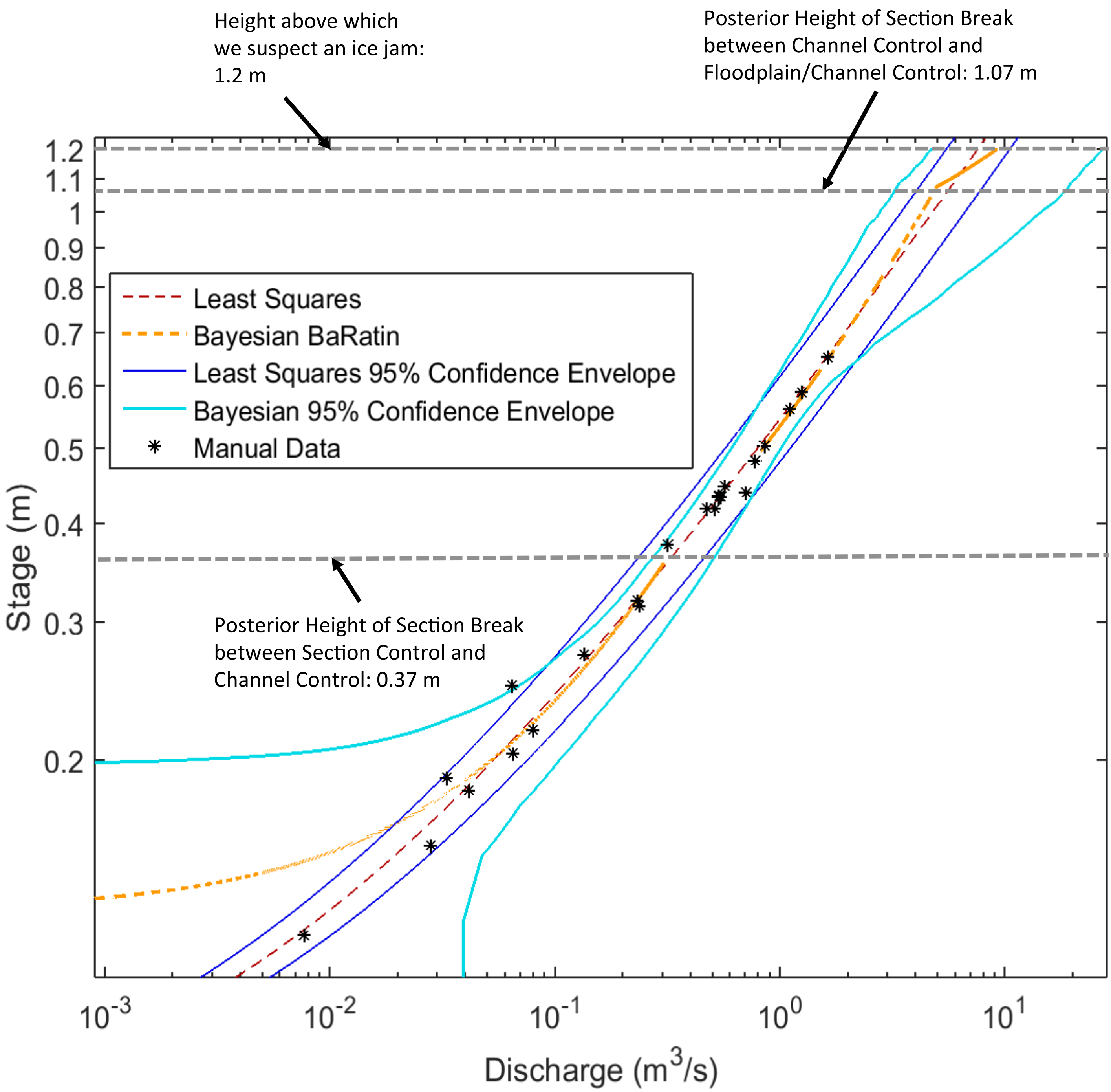


Slope: 0.00422 m/m

Delaney Creek

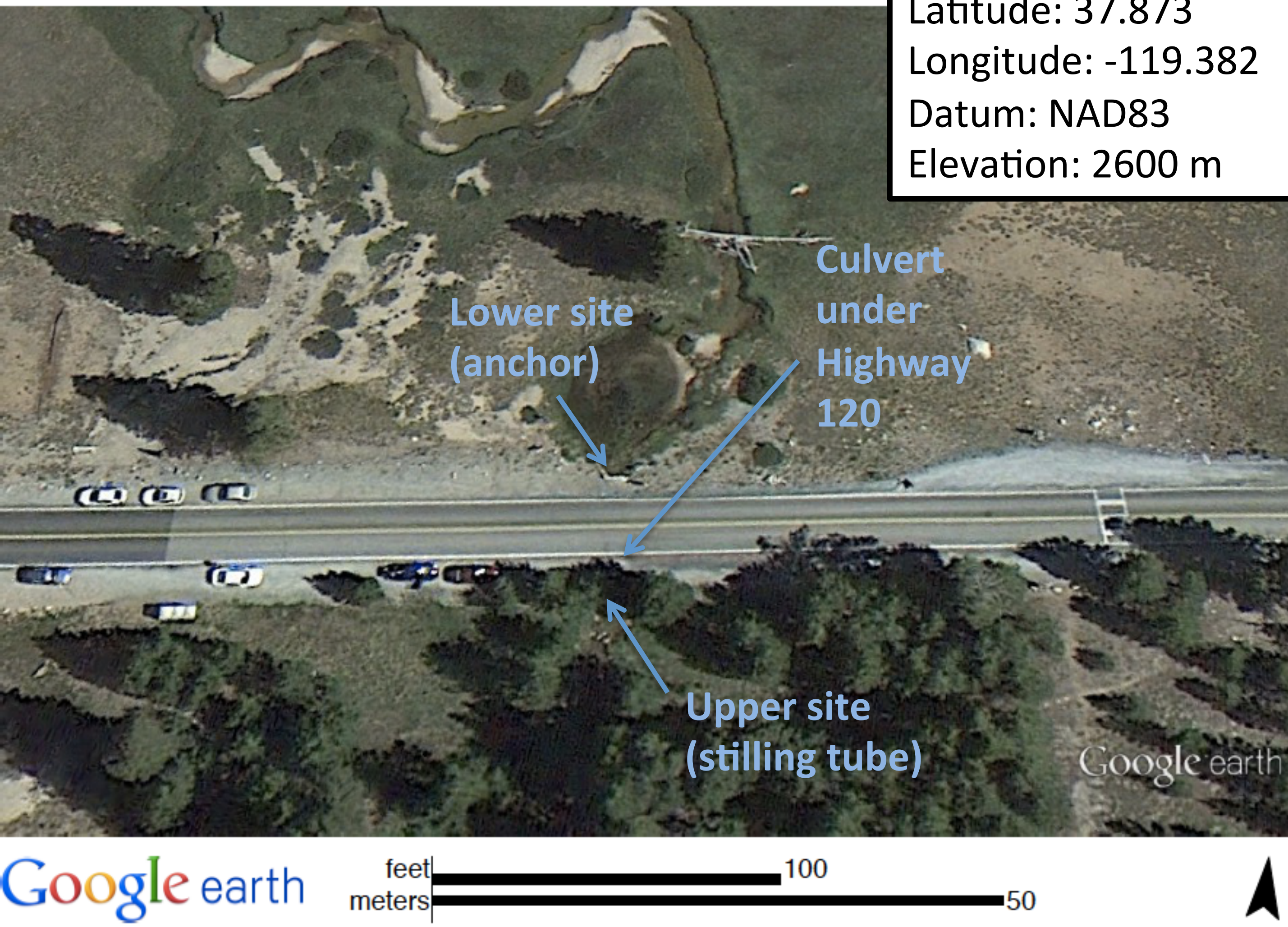


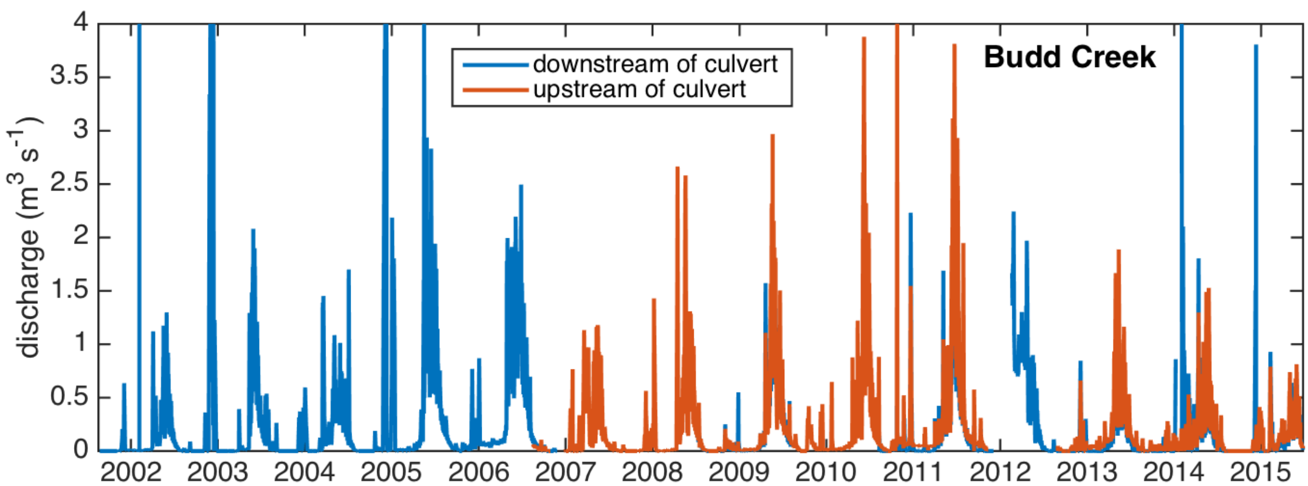


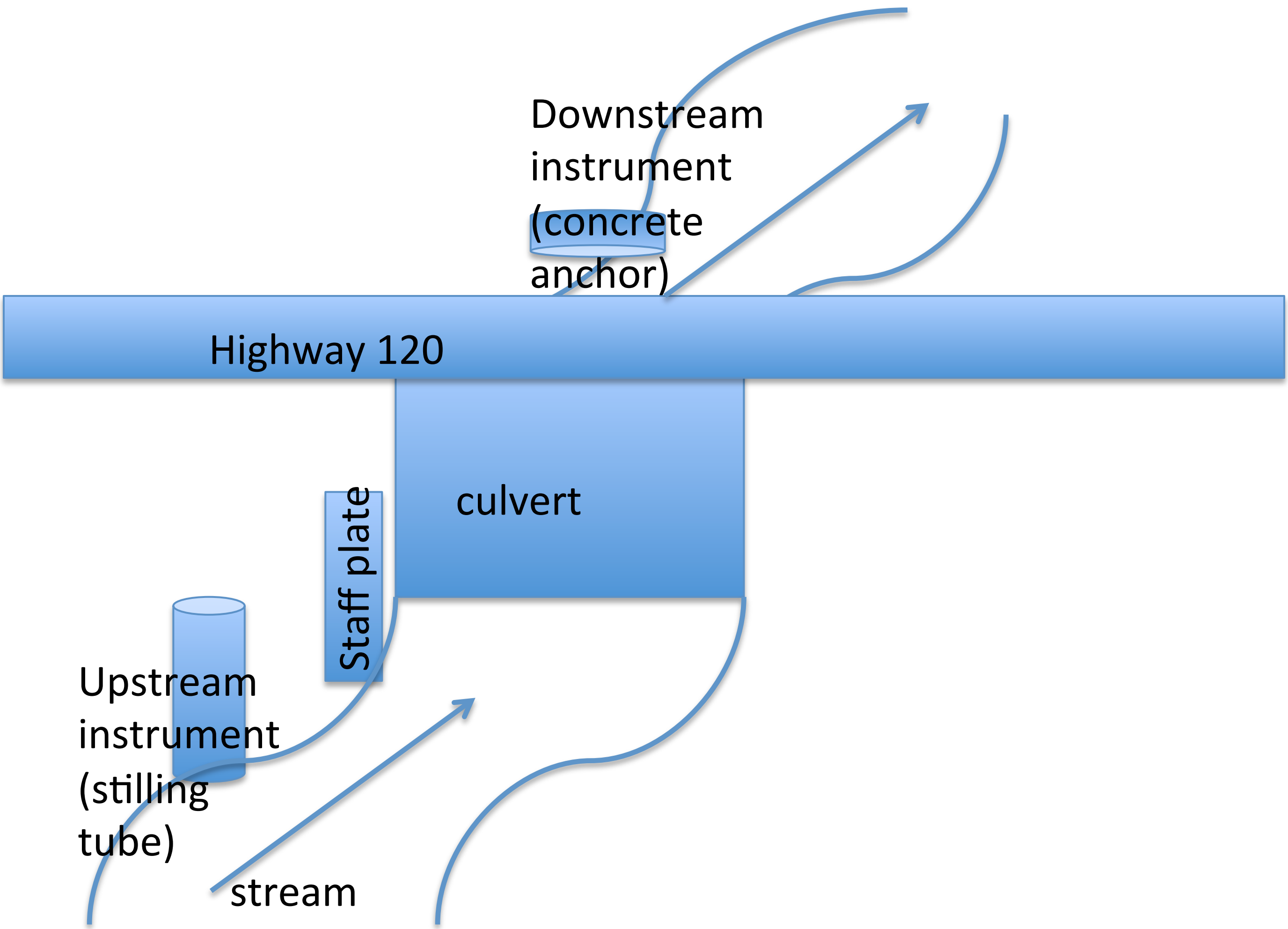

Height above which
we suspect an ice jam:
1.2 m
Posterior Height of Section Break
between Channel Control and
Floodplain/Channel Control: 1.07 m
Posterior Height of Section Break
between Section Control and
Channel Control: 0.37 m
Least Squares
Bayesian BaRatin
Least Squares 95% Confidence Envelope
Bayesian 95% Confidence Envelope
Manual Data
Stage (m)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
10^-3
10^-2
10^-1
10^0
10^1
Discharge (m^3/s)

Q06: Budd Creek

Latitude: 37.873
Longitude: -119.382
Datum: NAD83
Elevation: 2600 m







Budd Creek has a long record and two instruments, but due to a shifting channel bed, backwater effects from the culvert, and shifts in instrument location, the rating curve has high uncertainty. We used least squares (as in Rantz et al. 1982) and do not provide 95% confidence values for this site.

Upstream of culvert

Stilling tube

Staff plate, used as stage datum

The upstream site serves as the principal record, except in the case of known ice jams or backwater effects. In the event of backwater or ice jam events the downstream record was used.

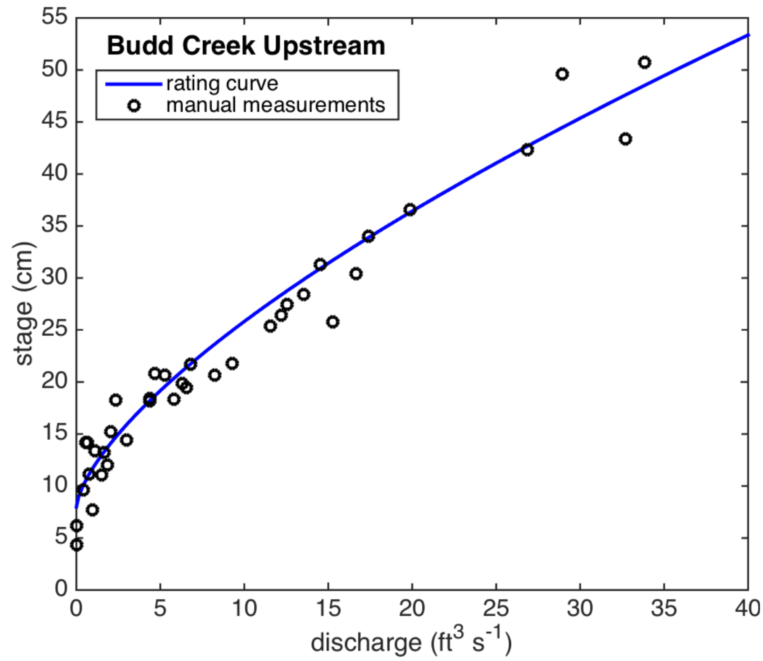
The upstream site has a corded Solinst pressure transducer located inside of a stilling tube. Just downstream of the stilling tube is a white staff plate designed to standardize periodic manual stage measurements. These manual stage measurements were used to correct instrument drift in the Solinst pressure transducer.

Backwater from the culvert and changing downstream sediment make this site not work well with the BaRatin method.

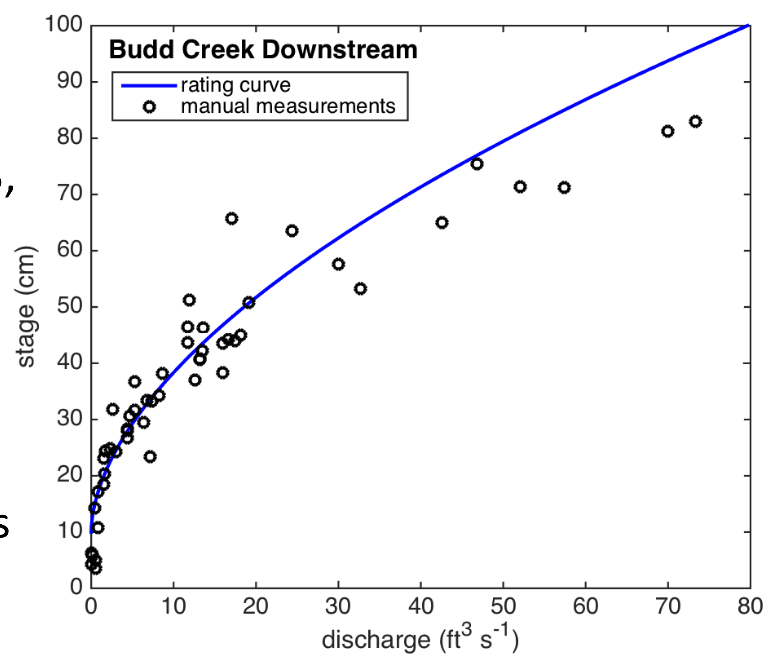
Downstream of culvert

The downstream Solinst pressure transducer is located in a concrete anchor. The anchor occasionally is moved during high flows, thus requiring an estimated offset in order to provide a consistent record. The upstream of culvert site therefore provides a preferred record for Budd Creek.

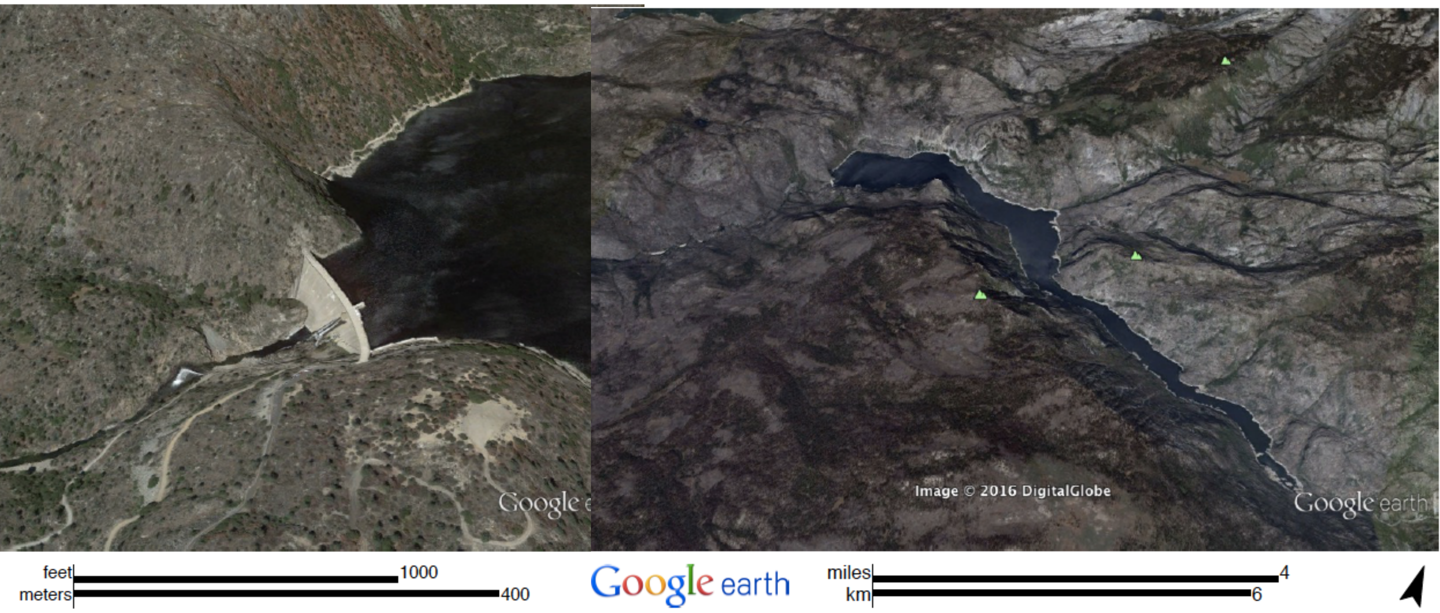
Rating curve for Budd Creek upstream of culvert: Q=0.1392*(stage-8)^1.4840, where the stage, barocorrected_pressure +offset, is in cm, and the discharge is in cubic feet per second. Note the lack of measurements at high flows.

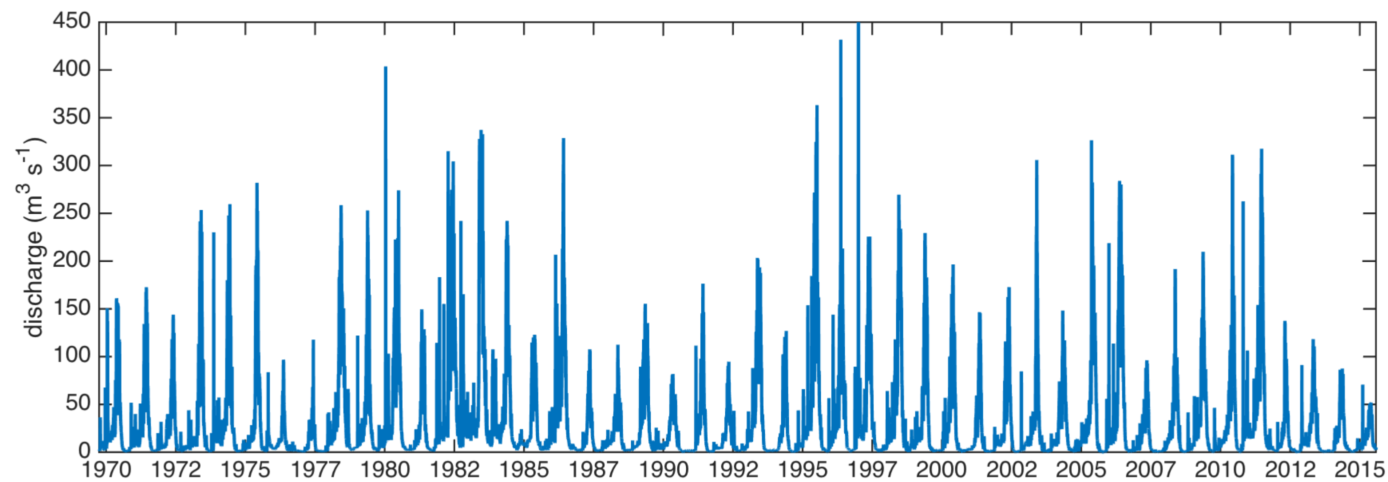


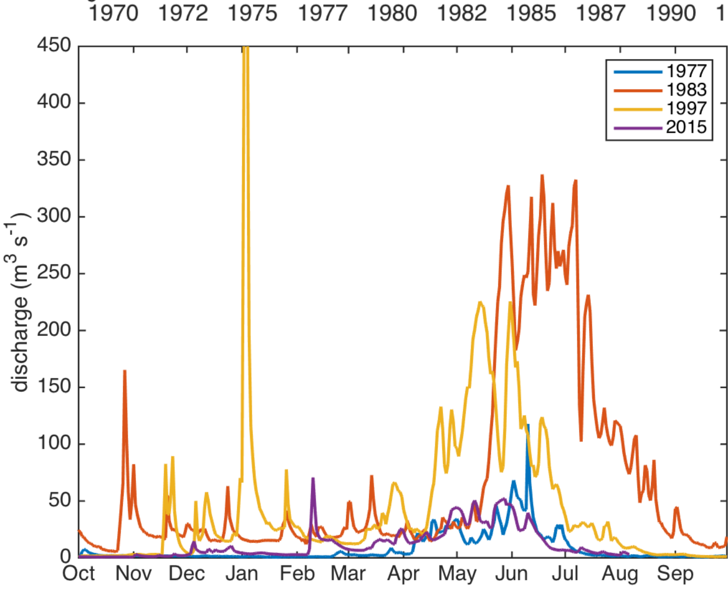
The rating curve for downstream of the culvert is Q=0.0246*(stage-10)^1.7963, where the stage, barocorrected_pressure +offset, is in cm, and the discharge is in cubic feet per second. Note the large uncertainty in measurements at high flows.



Q07: Hetch Hetchy Reservoir Full Natural Flows







Latitude: 37.9708
Longitude: -119.7883
Datum: NAD83
Elevation: 1162 m

Daily average inflows were estimated from reservoir water levels and releases.

References

Bohn, T. J., B. Livneh, J. W. Oyler, S. W. Running, B. Nijssen, and D. P. Lettenmaier (2013), Global evaluation of MTCLIM and related algorithms for forcing of ecological and hydrological models, *Agric. For. Meteorol.*, *176*, 38-49, doi:10.1016/j.agrformet.2013.03.003.

Lapo, K. E., L. M. Hinkelman, C. C. Landry, A. K. Massmann, and J. D. Lundquist (2015), A simple algorithm for identifying periods of snow accumulation on a radiometer, *Water Resour. Res.*, *51*, 7820-7828 doi: 10.1002/2015WR017590.

LeCoz, J., B. Renard, L. Bonnifait, F. Branger, and R. Le Boursicaud (2014), Combining hydraulic knowledge and uncertain gaugings in the estimation of hydrometric rating curves: A Bayesian approach, *J. Hydrol.*, *509*, 573-587. doi: http://dx.doi.org/10.1016/j.jhydrol.2013.11.016

Lundquist, J. D. and D. R. Cayan (2007), Surface temperature patterns in complex terrain: Daily variations and long-term change in the central Sierra Nevada, California, *J. Geophys. Res.*, *112*, D11124, doi:10.1029/2006JD007561.

Rantz, S. E. et al. (1982), Measurement and computation of streamflow, Measurement of Stage and Discharge, vol. 1, *U.S. Geol. Surv. Water Supply Pap. 2175*, 284 pp., U.S. Gov. Print. Off., Washingto, D. C.