Guide to Tuolumne River Stream Data Yosemite, California

Water Years 2002 to 2015
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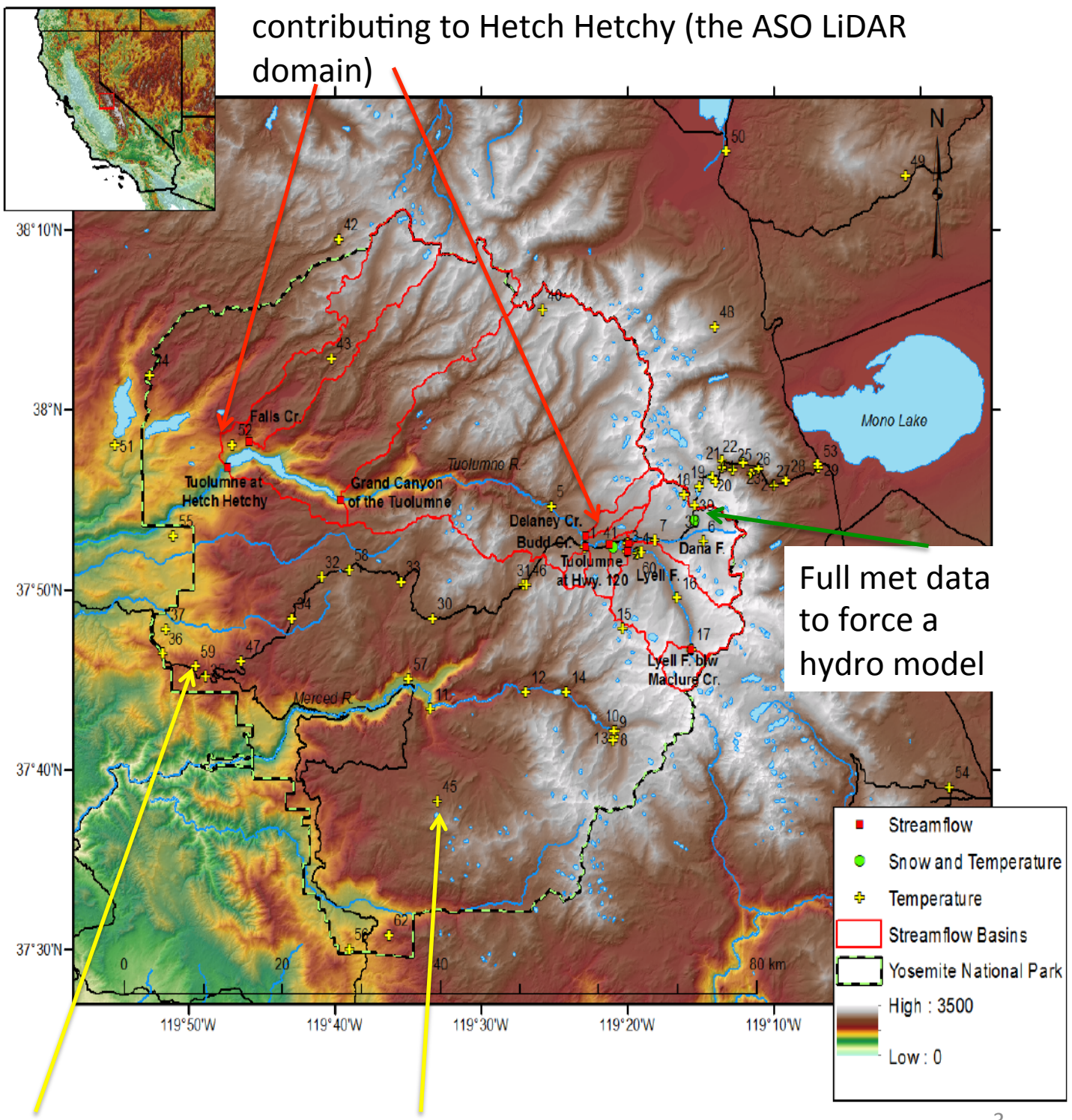
Overview of Yosemite Hydroclimate Dataset

Nested streamflow data for Tuolumne contributing to Hetch Hetchy (the ASO LiDAR domain)

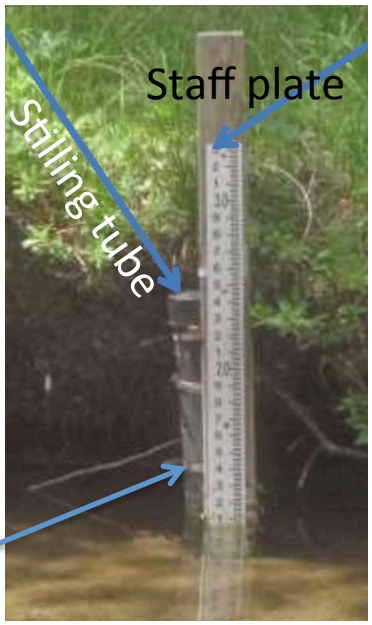


Full met data to force a hydro model

Distributed temperature data from Lundquist and Cayan 2007

Instruments and Installations

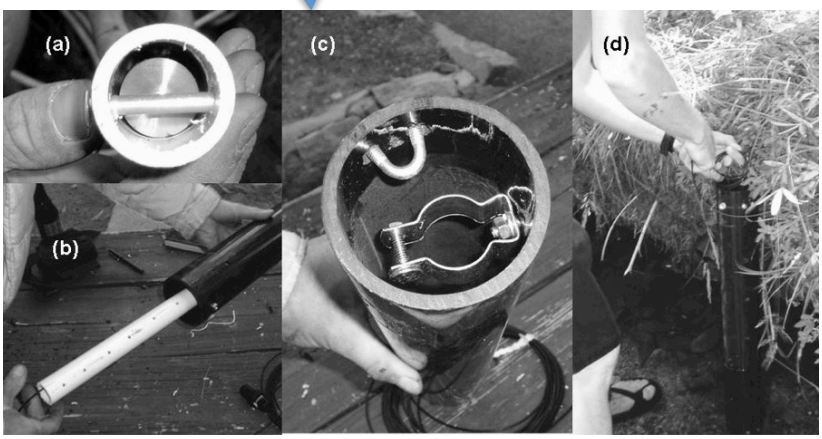
Brief History of "Wilderness Stream Gauging"



Aug 2005: Switch to wilderness stilling tube

Aug 2001: Solinst and Seabird in anchors

2015: Most sites upgraded to vented pressure transducer

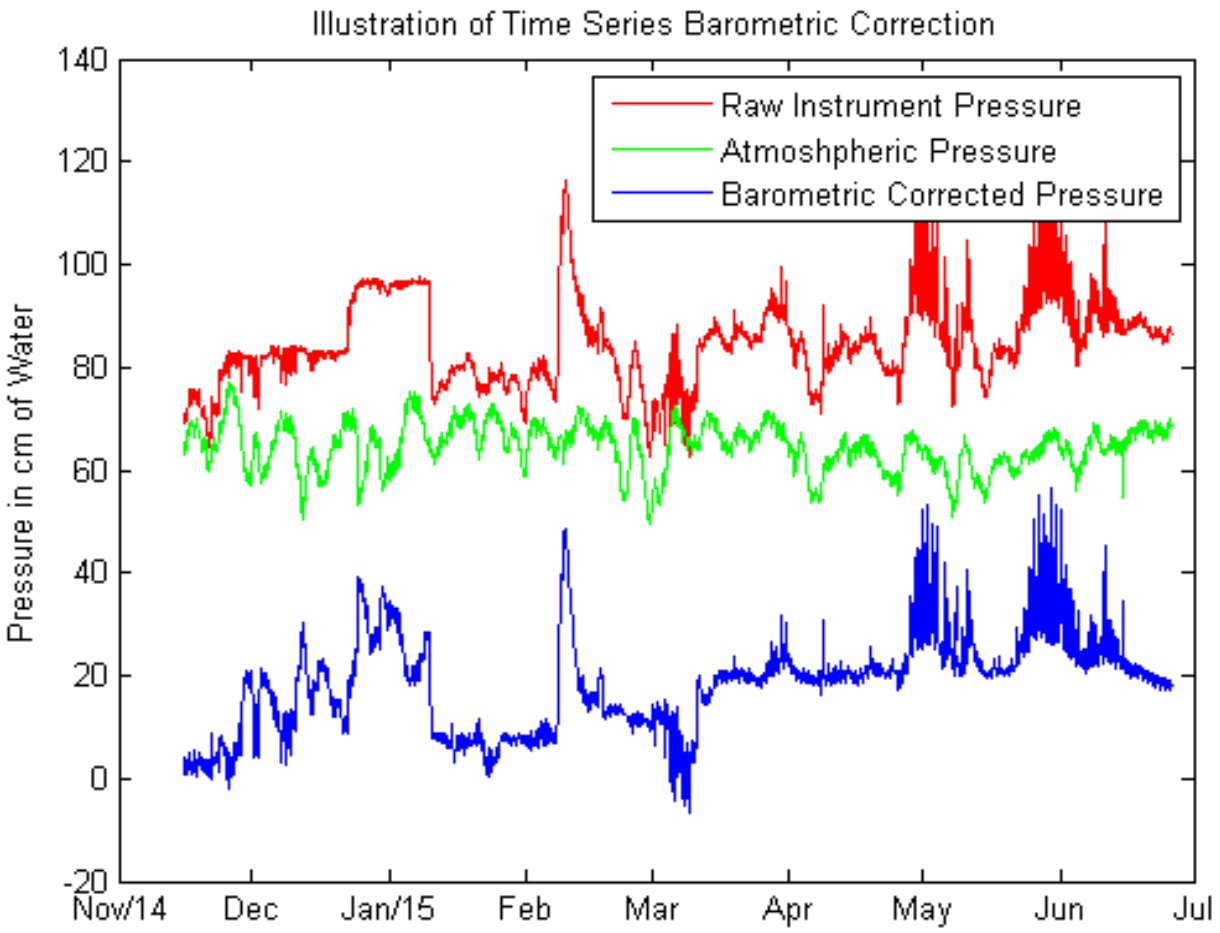


Installation Type	Anchored Solinst	Solinst in Stilling Tube	Vented Pressure Transducer
Description	Instrument in a PVC pipe inside a concrete anchor, which is cabled to a tree, bridge, or culvert.	Instrument in PVC pipe inserted in vertical pipe attached to the streambed and bank with rebar; with cord 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

Processing Steps for Stage

1. Subtract off atmospheric pressure (example from Dana Fork Bug Camp)

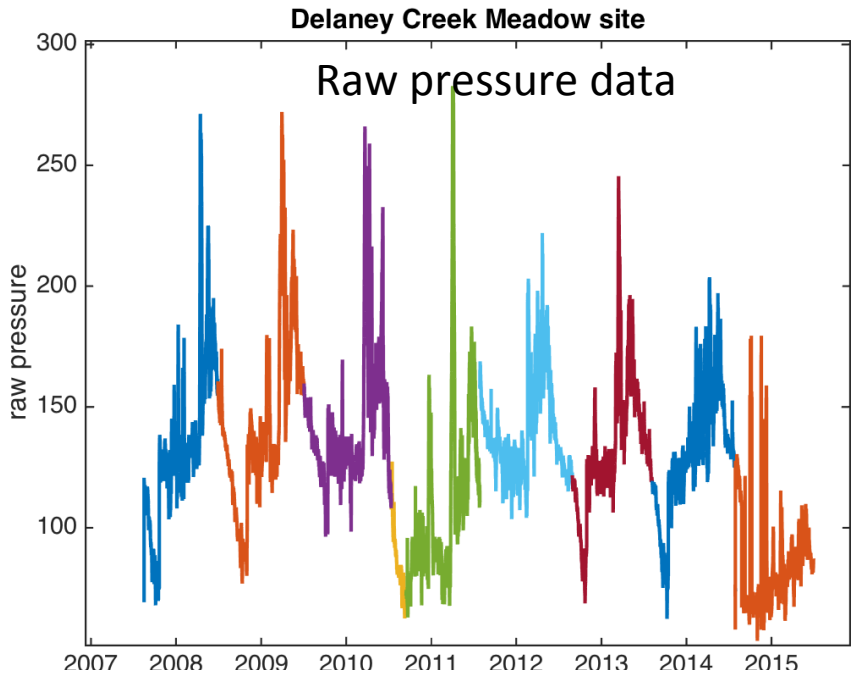


Atmospheric pressure (the green line) is subtracted from the raw instrument pressure (the red line) to obtain pressure due to water overlying the instrument (the blue line).

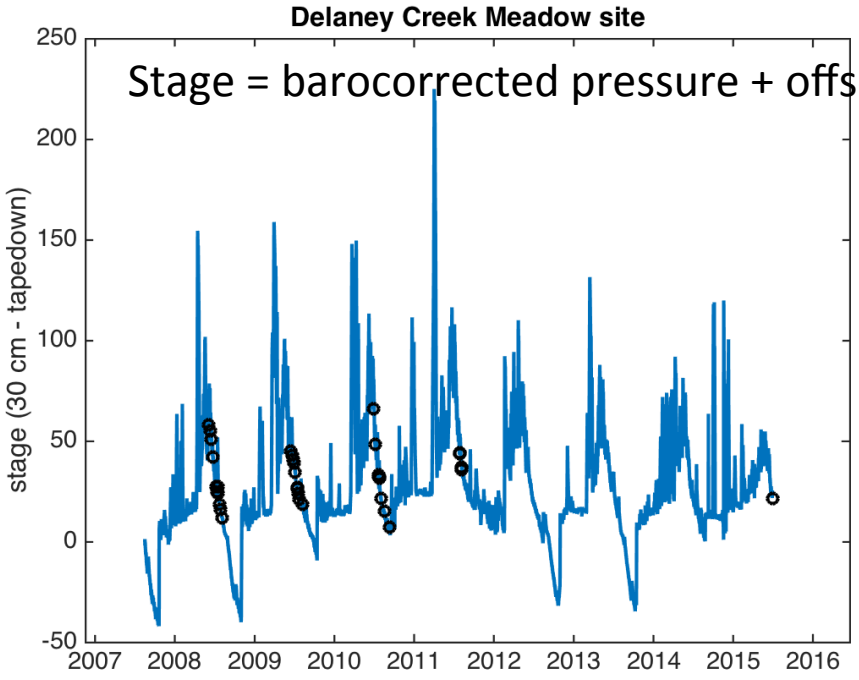
Processing Steps for Stage

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.



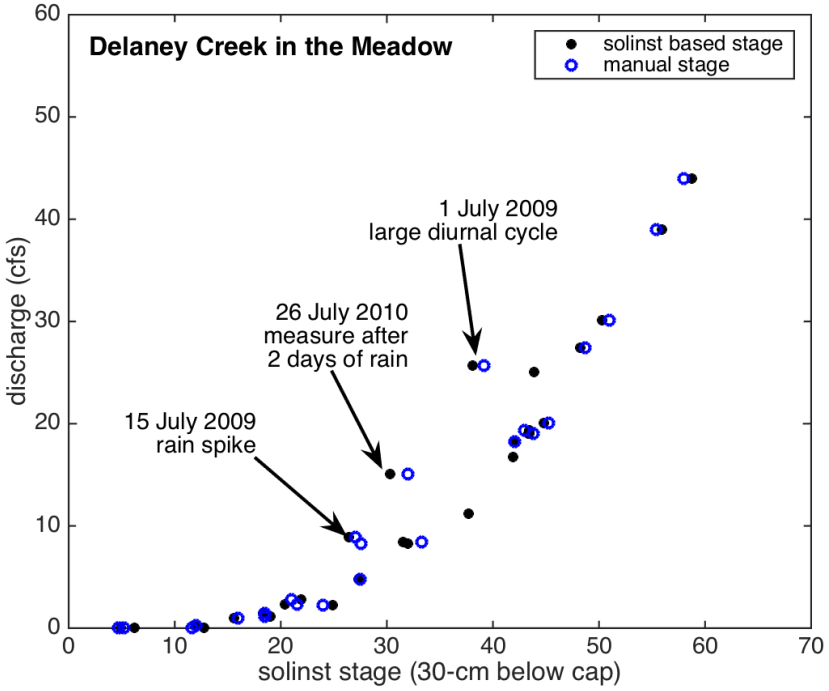
Manual stage measurements (black circles) provide guidance for offsets to adjust the barometrically-corrected water pressure values.



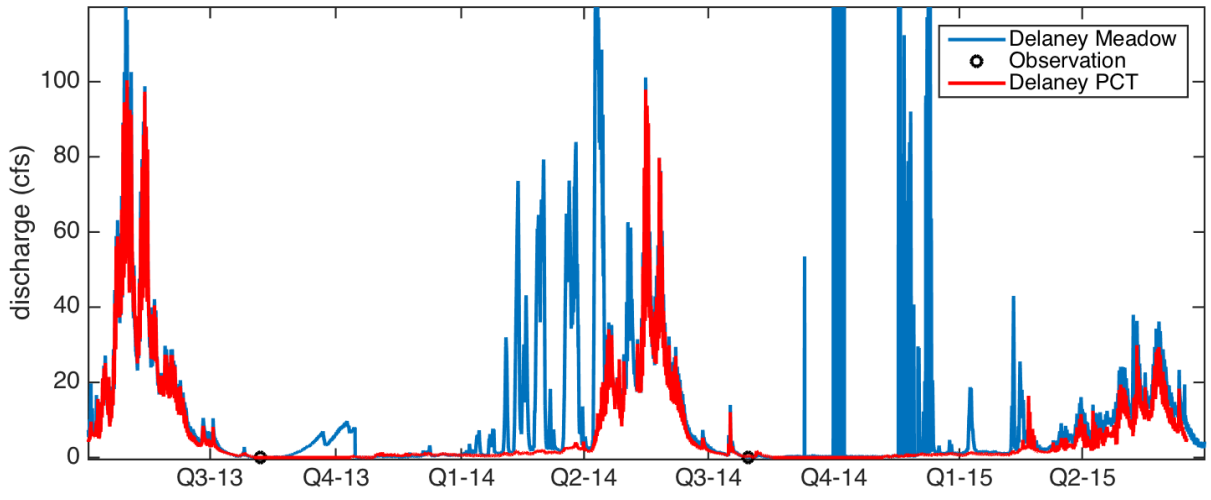
Processing Steps for Stage

4. Develop rating curve (example from Delaney Creek)

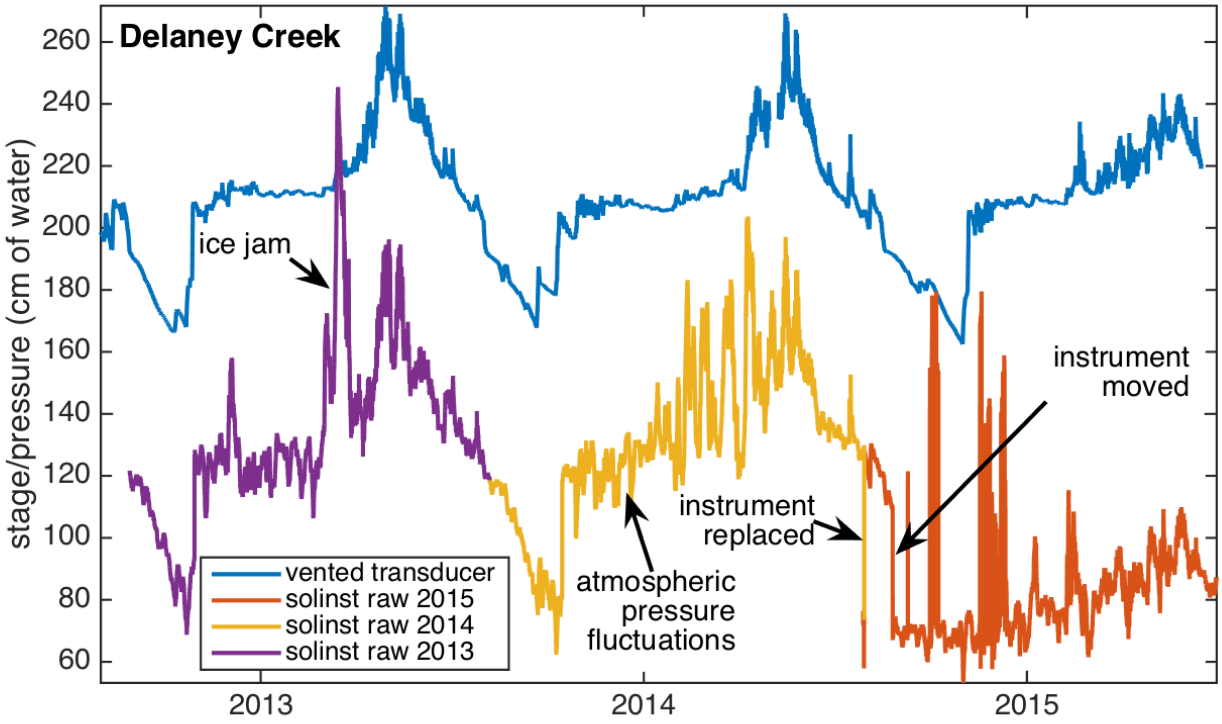
Measurements used to create rating curve (note 3 outliers marked here were not used)



Discharge timeseries: Blue is meadow record provided here; Red is independently generated record from slightly upstream. Meadow (blue) is prone to ice jams.



Data Types:



1) Raw data: pressure recording, including both weight of water in stream and atmosphere; pieced together from multiple instruments to create continuous record in the water
2) Baro-corrected data: Atmospheric pressure subtracted off the raw timeseries
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.

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)

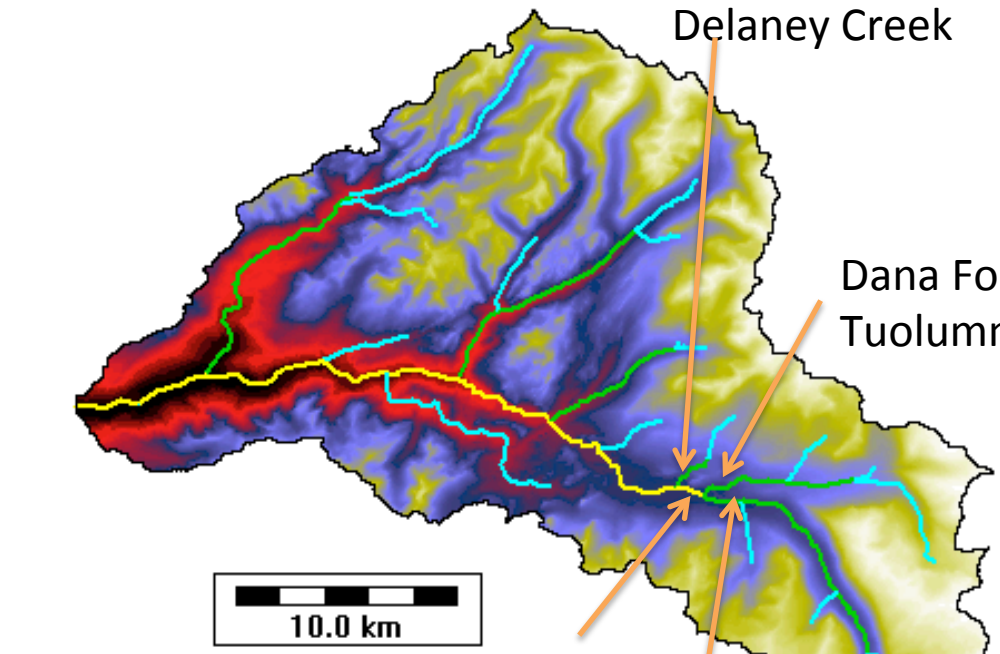
- Use the BaRatin MCMC routine (see LeCoz et al. 2014 and references therein) to use manual stage and discharge observations, along with their estimated uncertainty (10%), to determine the posterior rating curve parameters and control segment breaks to fit the following piecewise power function:

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

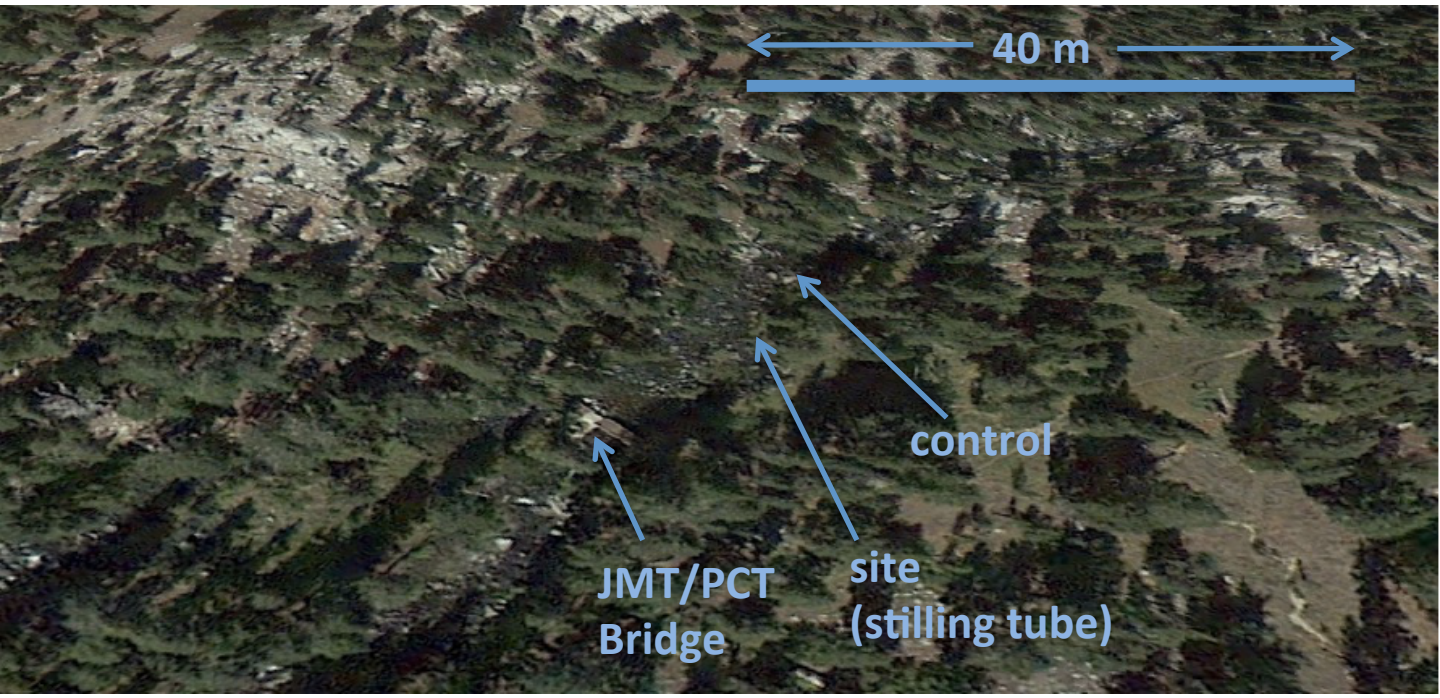
  - Where N_{range} is the number of stage ranges
  - $N_{control}$ is the number of hydraulic controls
  - K_r is the upper water level at stage range *r*
  - M is the hydraulic control matric (M(r,j) = 1 if hydraulic control *j* is active in stage range *r*
  - *h* is stage
  - *a*, *b*, and *c* are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

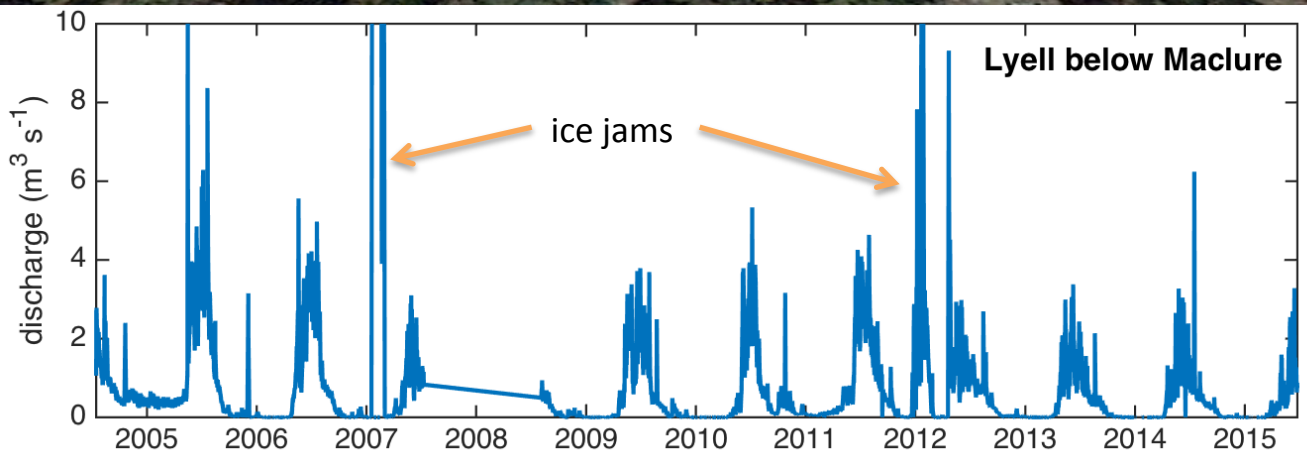
- Outputs include the rating curve equation for each stage range, as well as a look up table of values for the upper and lower limits of 95% confidence intervals (which vary by stage and are determined as part of the MCMC process)
- These are illustrated for each site in the pages that follow.
- For 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

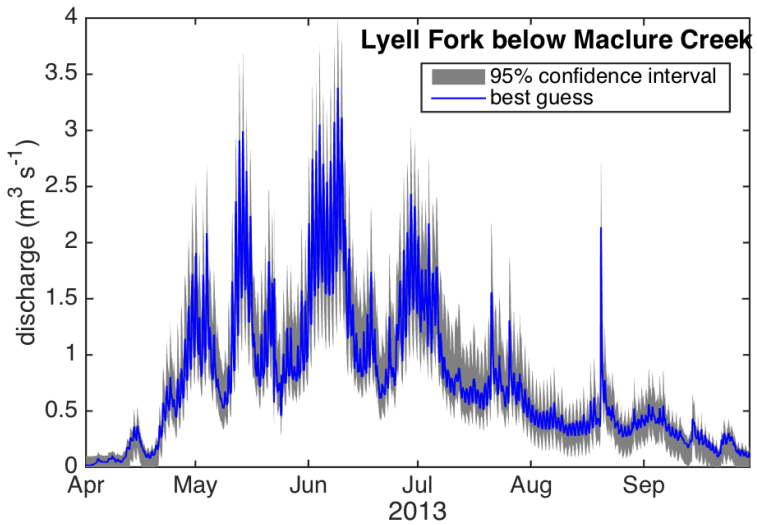
Specific Sites:



Lyell Fork below Maclure



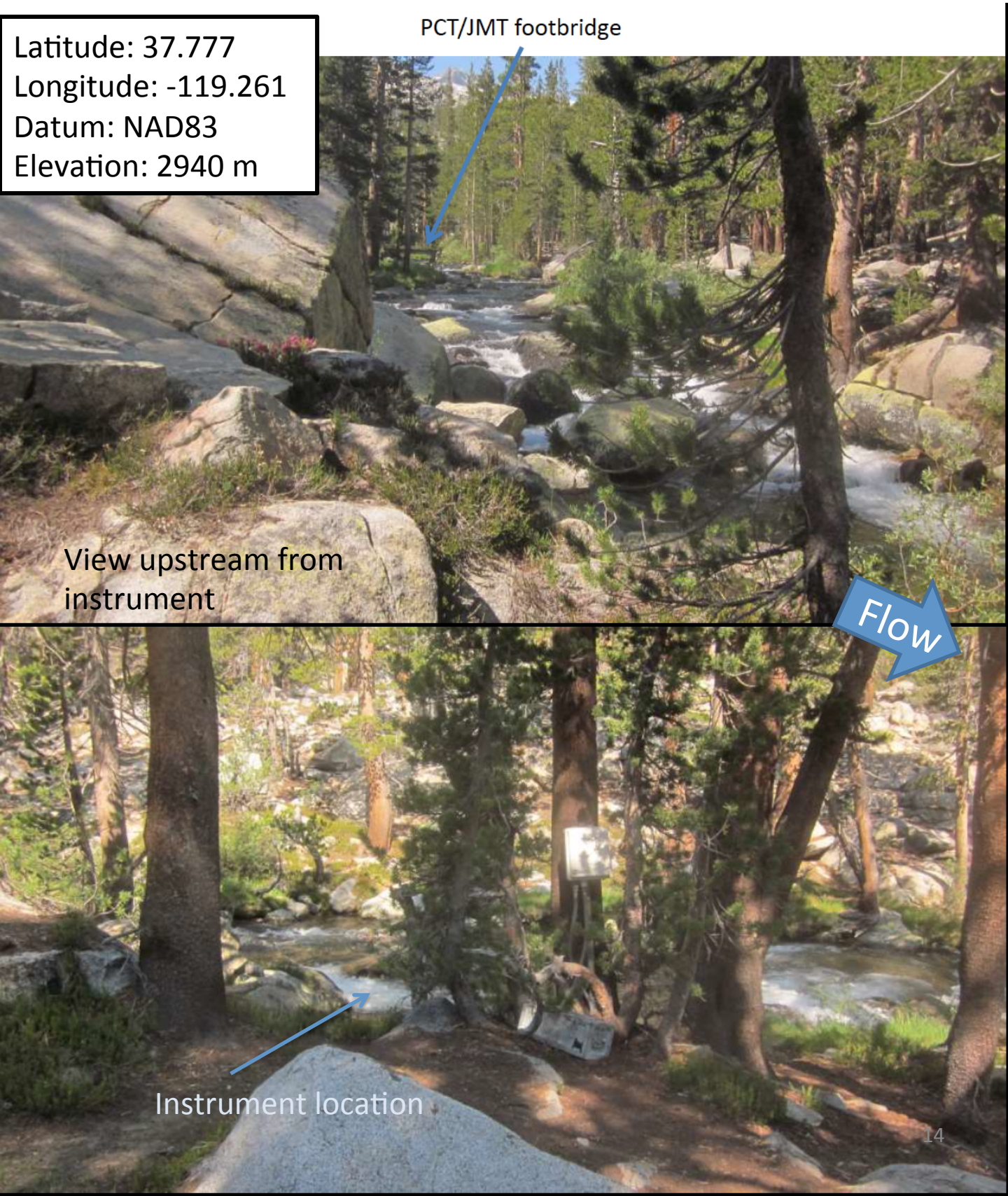




Overall, rating curve is good, but there is greater uncertainty in the datum before 2008, and there are occasional ice jams.

Lyell Fork below Maclure

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



Lyell Fork below Maclure Creek

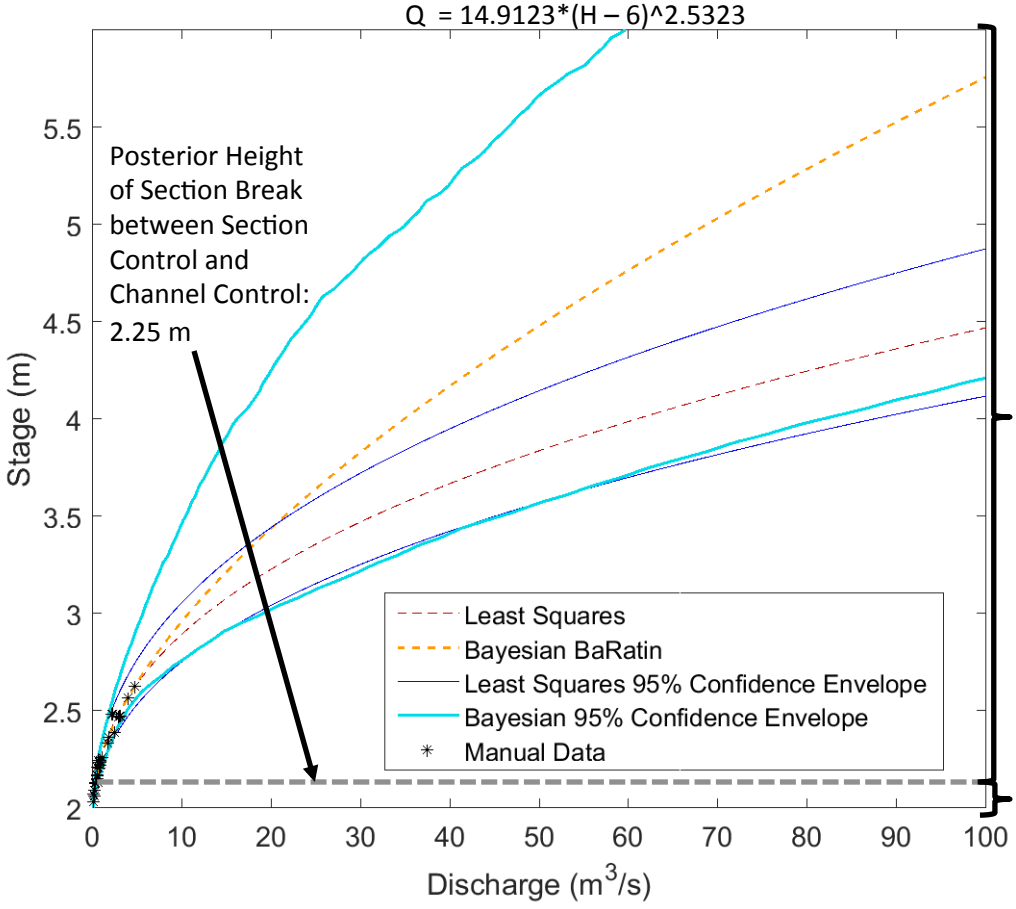
Based on photographs estimate two cross-sections:

- 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

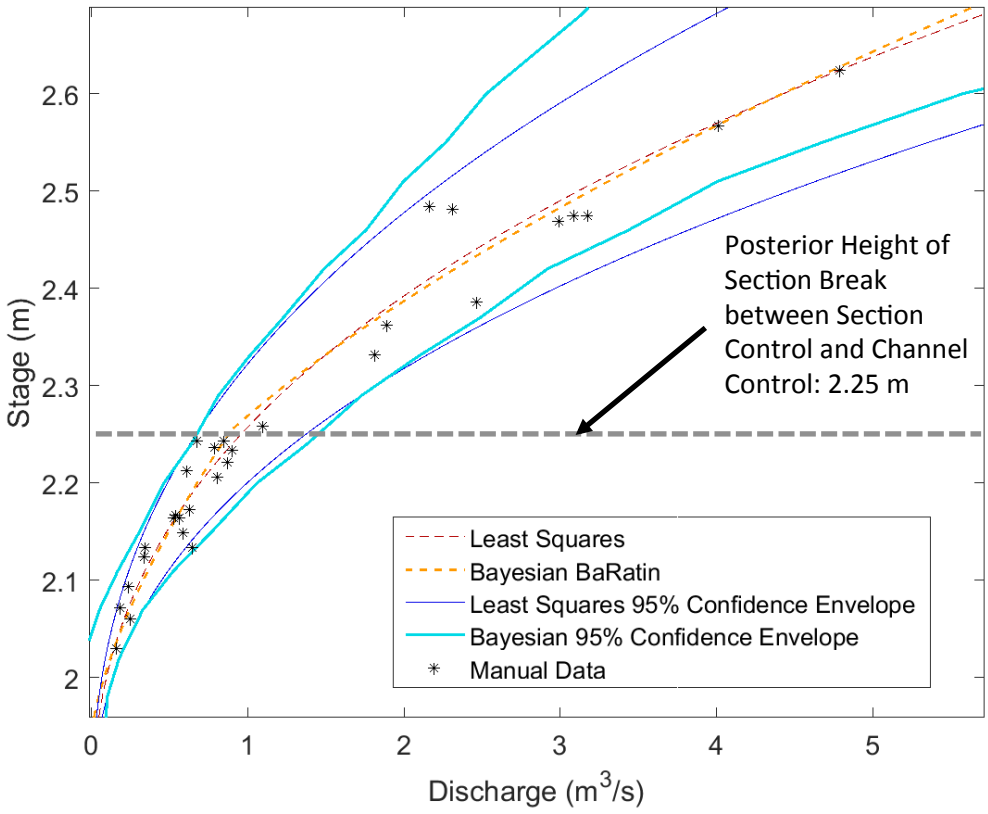
Least Squares (stage in ft, Q in cfs):
Q = 14.9123*(H – 6)^2.5323

BaRatin (stage in m, Q in cms):



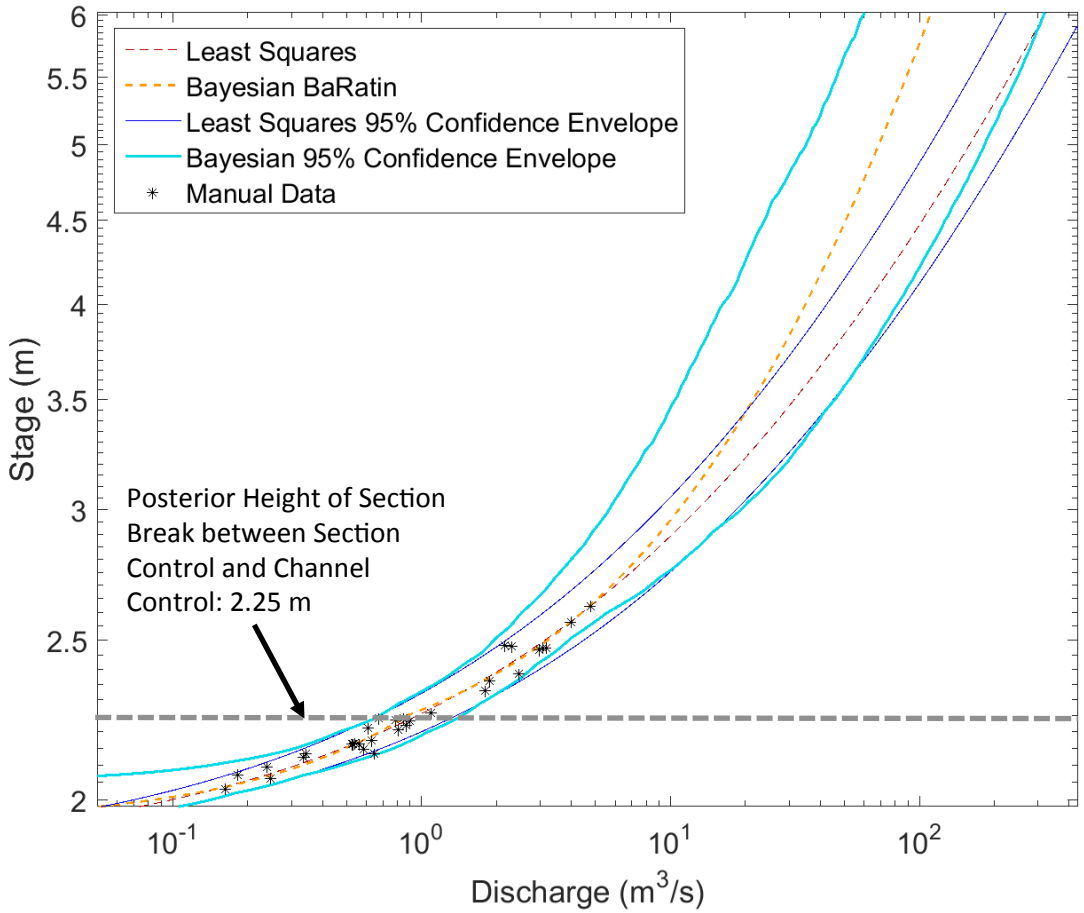
2.25m < H <= 6.044m
Q = 11.609*(H –2.0443)^1.6415

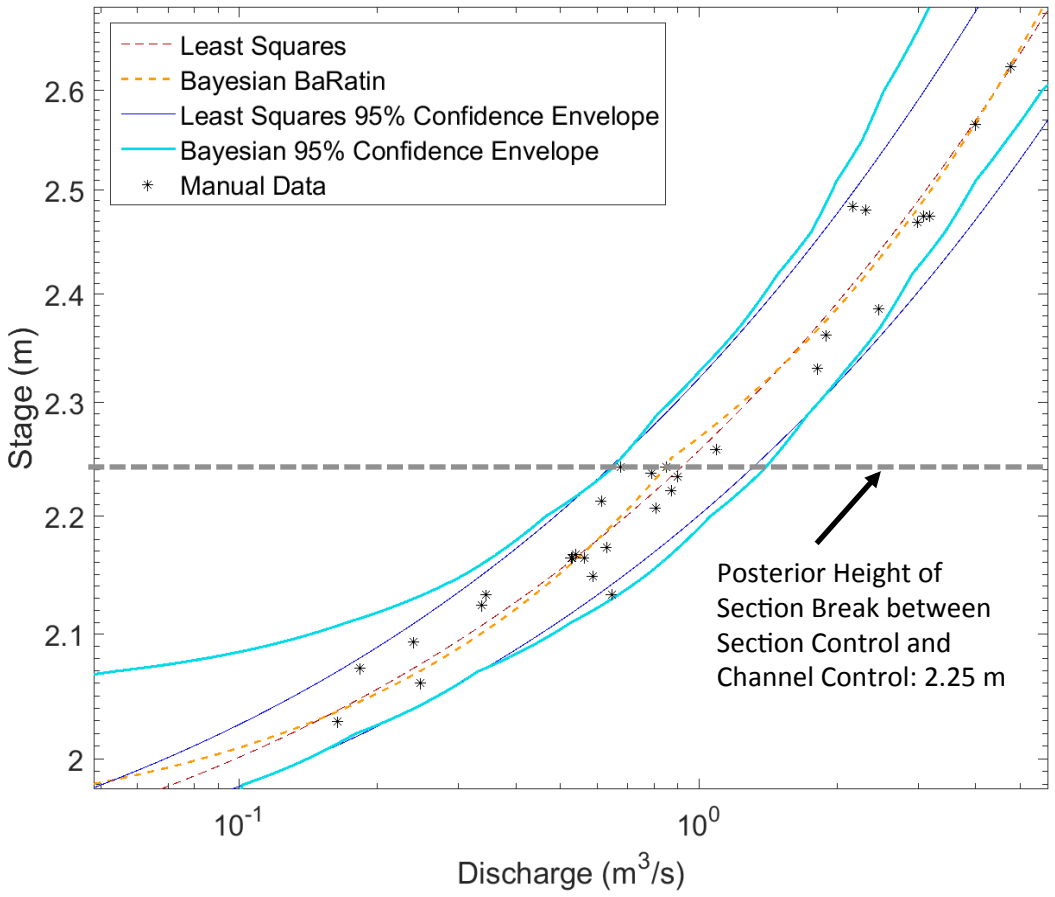
H <2.25
Q =4.9324*(H – 1.9357)^1.4917



Log-Log View

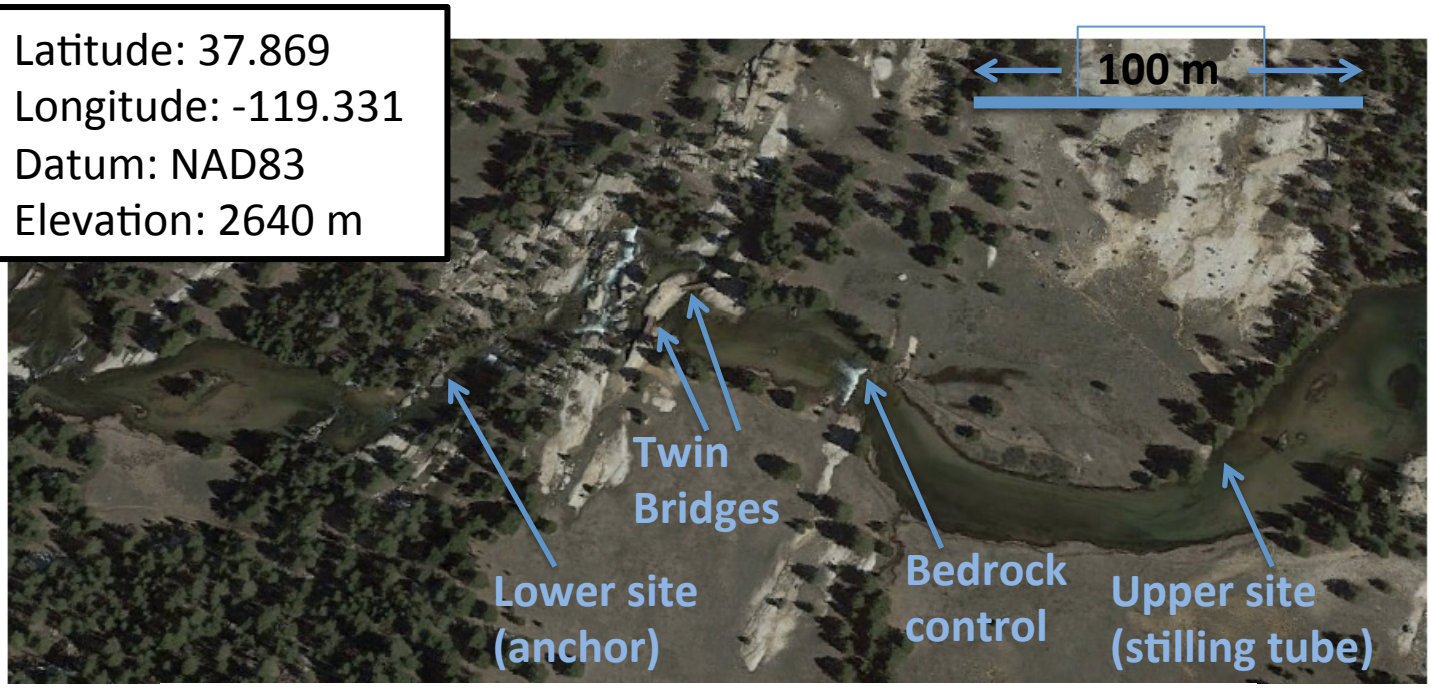
Lyell Fork below Maclure Creek

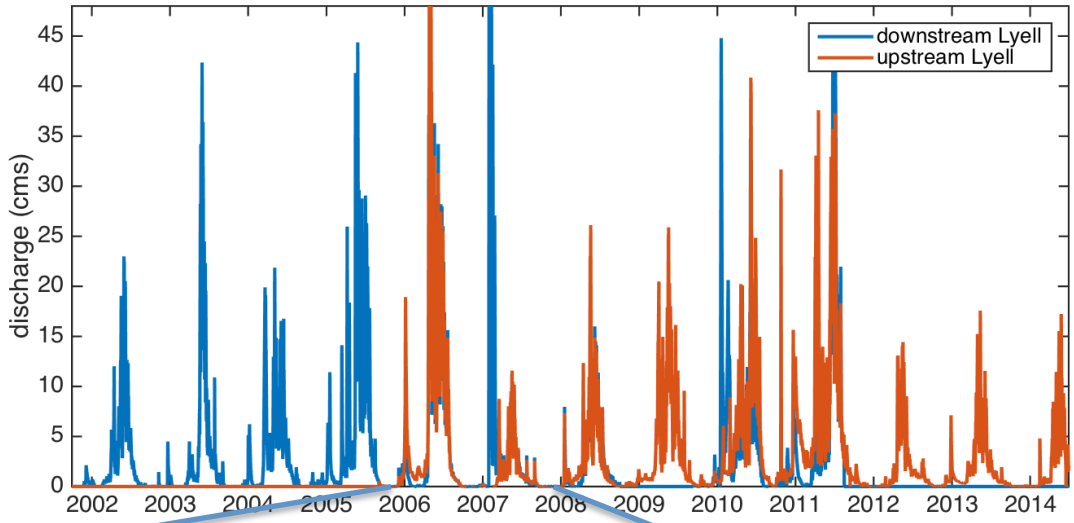


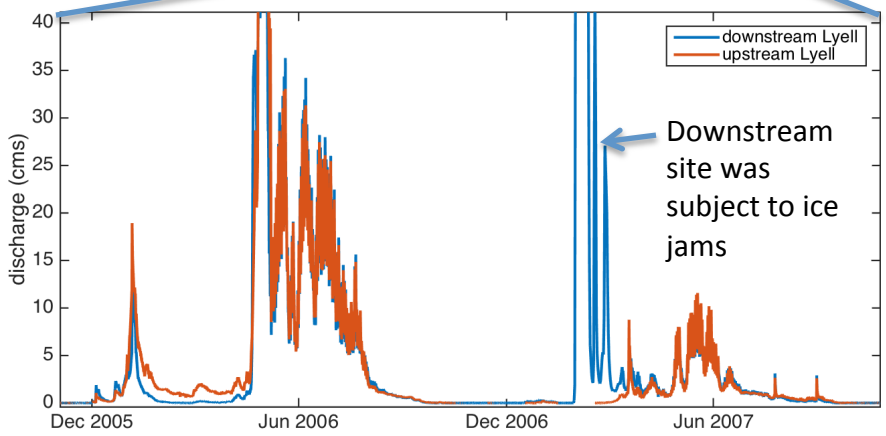


Lyell Fork at Twin Bridges

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



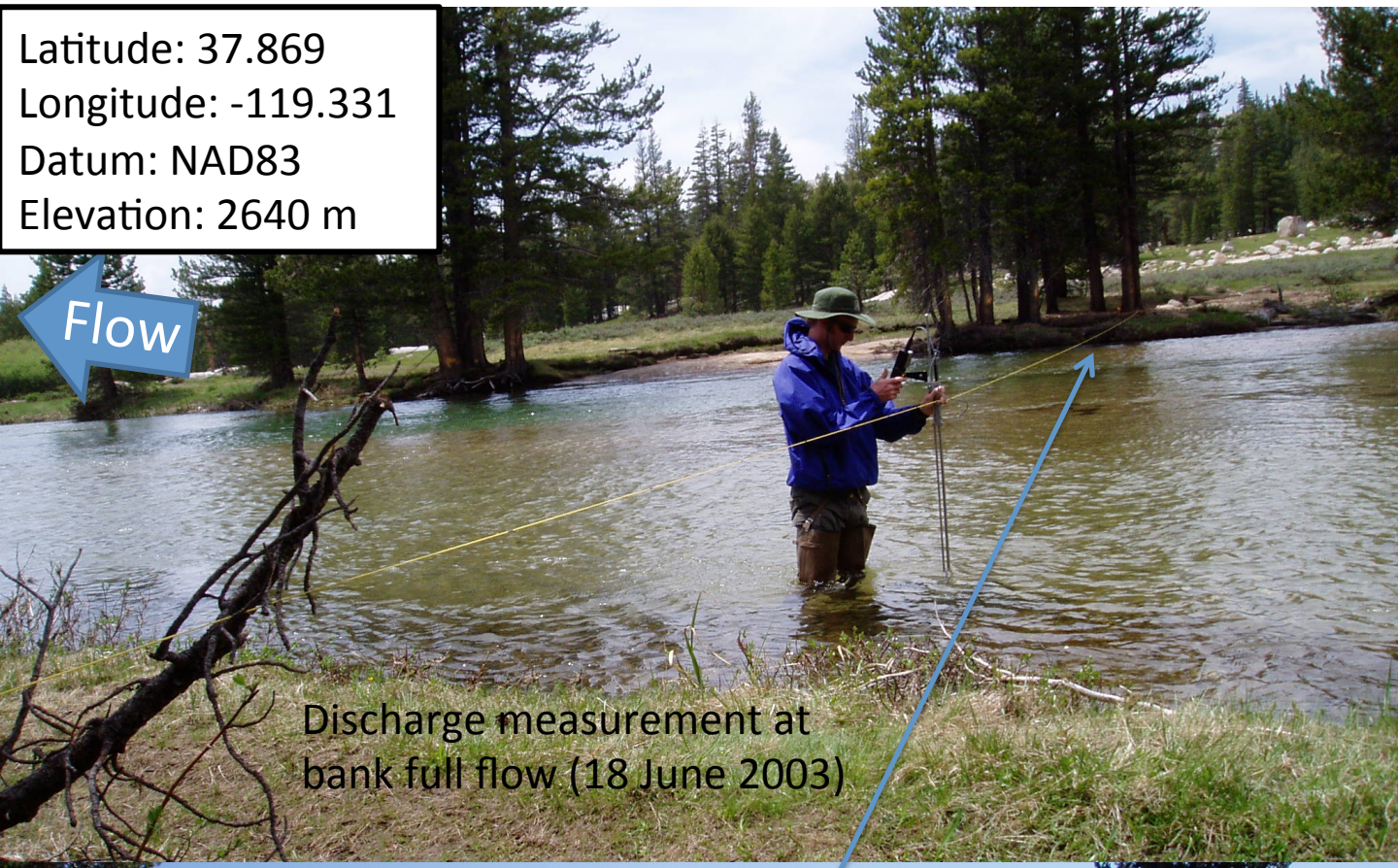


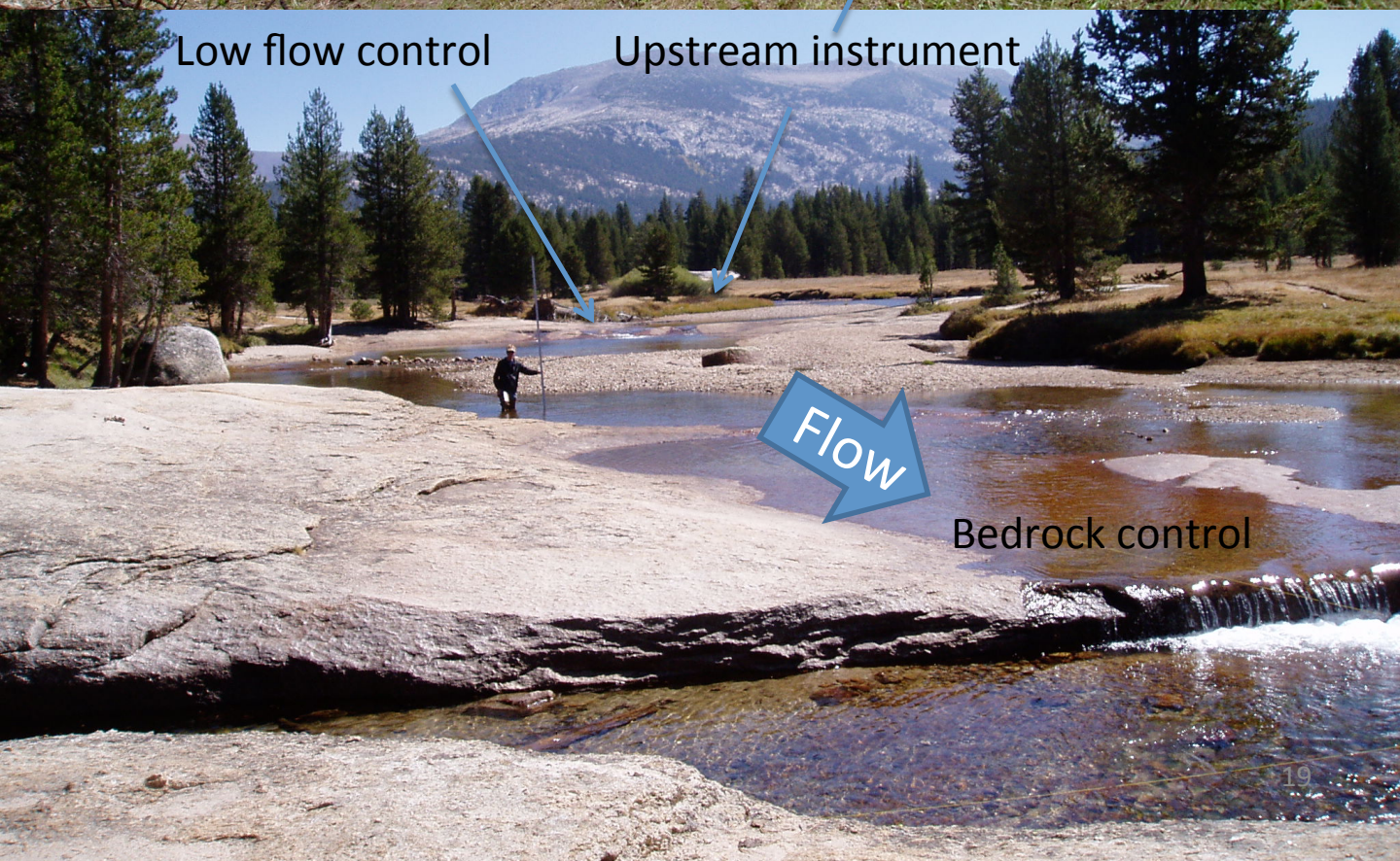


The downstream site was installed first (WY 2002), with the upstream site designed to replace it starting WY 2006. Calculated discharge agrees very well during the 2006-08 period of overlap, with the exception of winter and early spring ice jams. For 2009 on, the downstream site was less frequently maintained,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

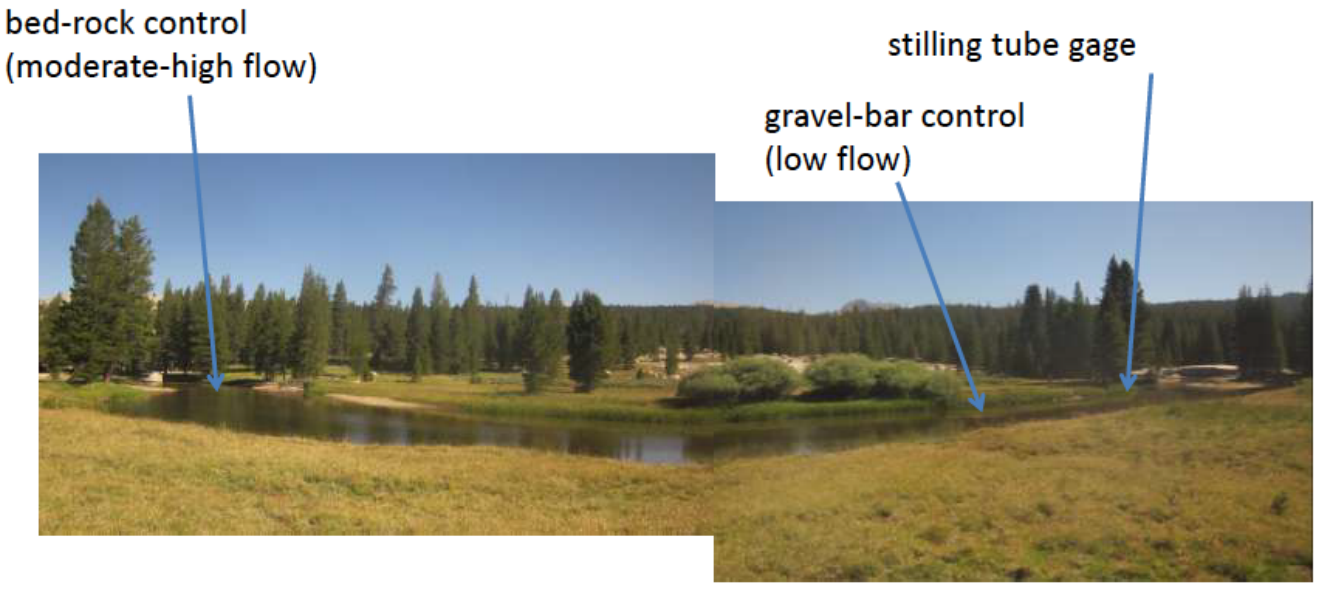
Lyell Fork abv Twin Bridges

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





Lyell Fork above Twin Bridges

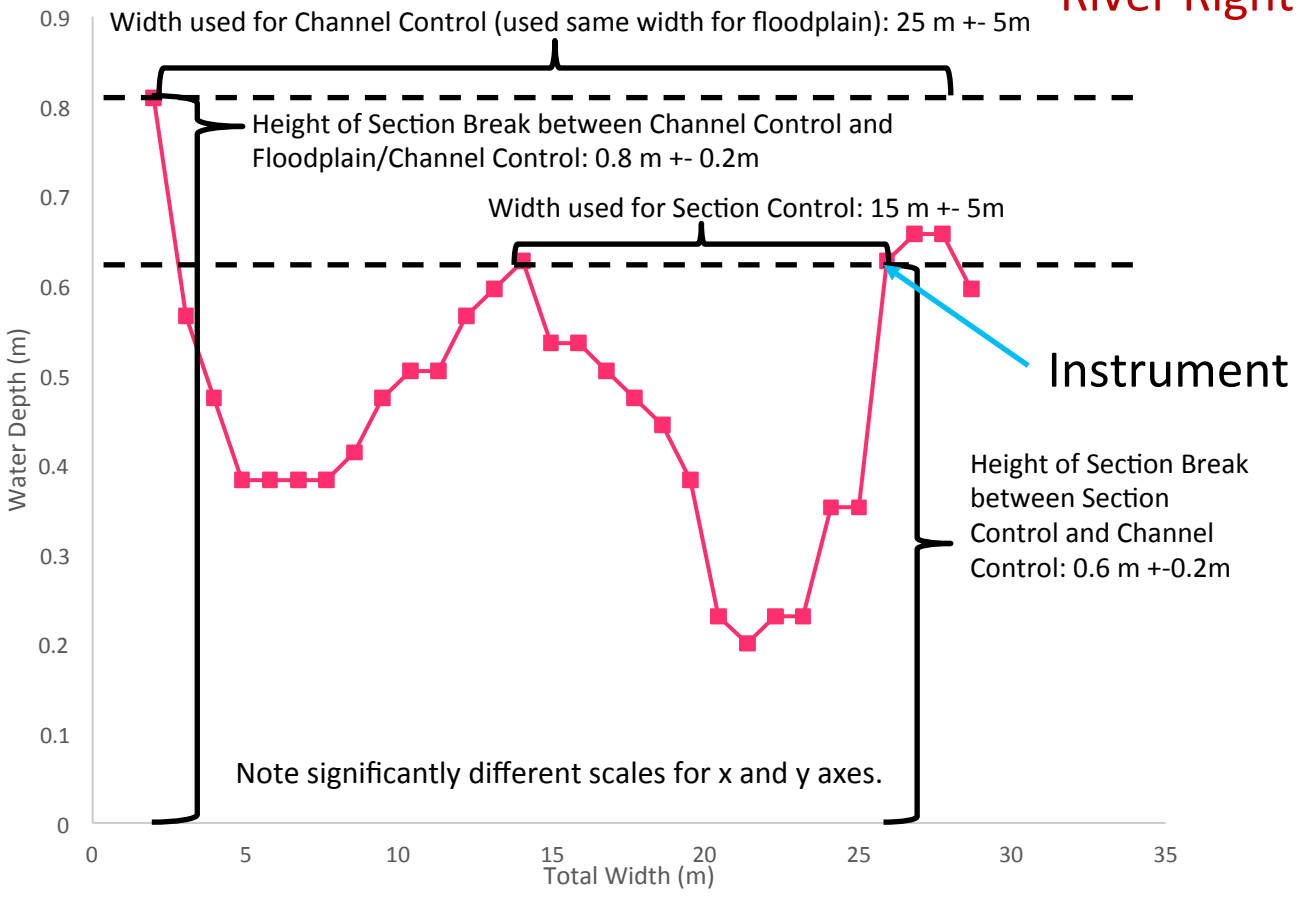


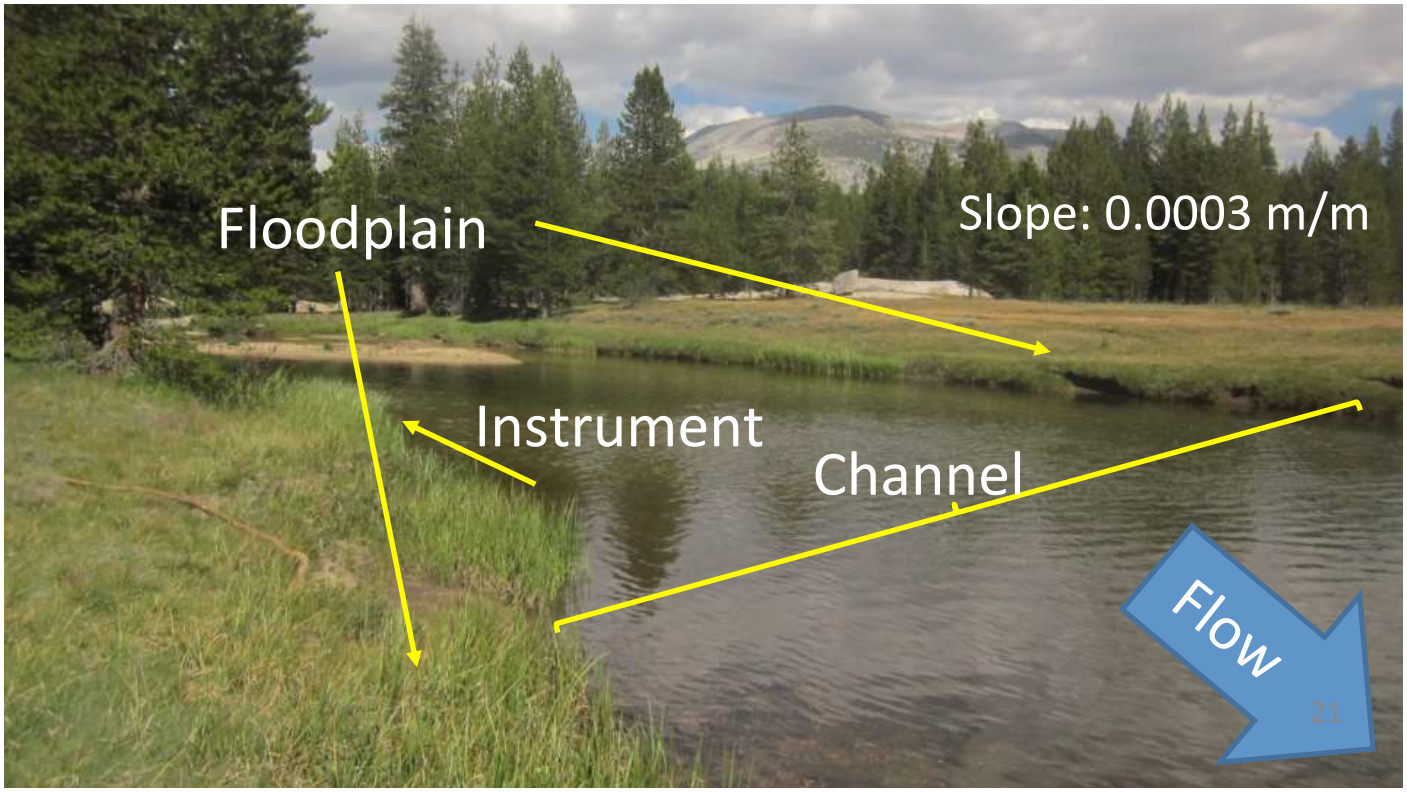
Note: On 17 July 2015 at 9:15 am local time, the depth of water over the bed-rock control was 0.68 ft and over the gravel-bar control was 1.50 ft. Gauge height measured as 10 ft – distance from top of stilling tube to water (0.78 ft) at that time was 9.22 ft; making gauge height 8.54 ft when bedrock control matters and 7.72 ft when gravel-bar control matters – need to check new references to my stage measurements. Stage reference has been hard here.

Lyell Fork above Twin Bridges

Cross-Section at Instrument Site with Stage Measurement Datum

River Right

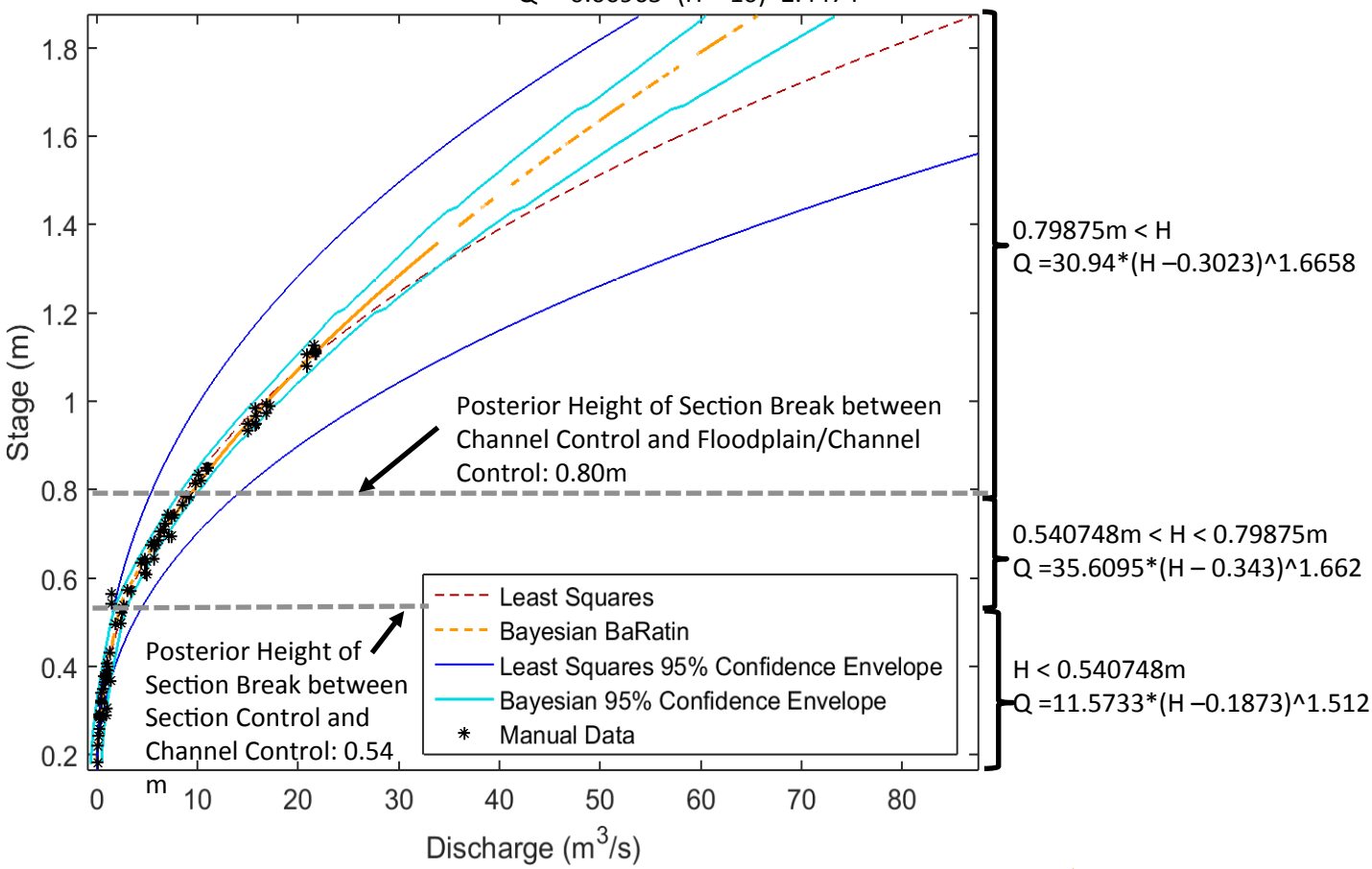


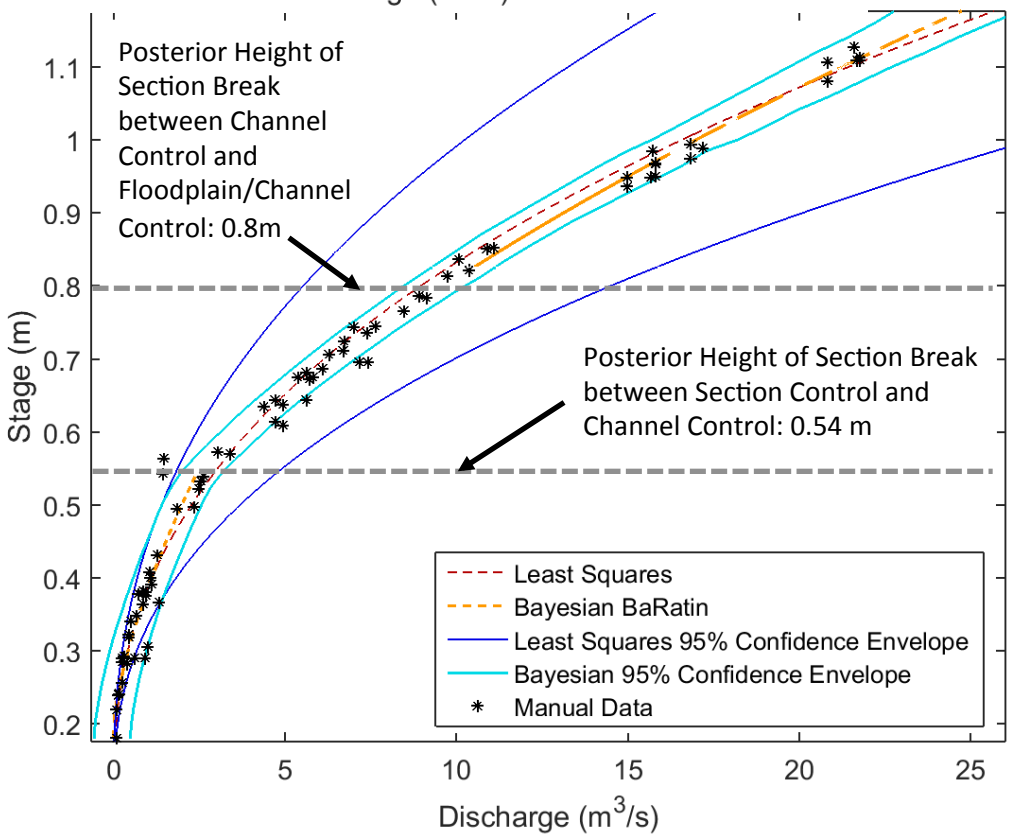


Lyell Fork above Twin Bridges

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

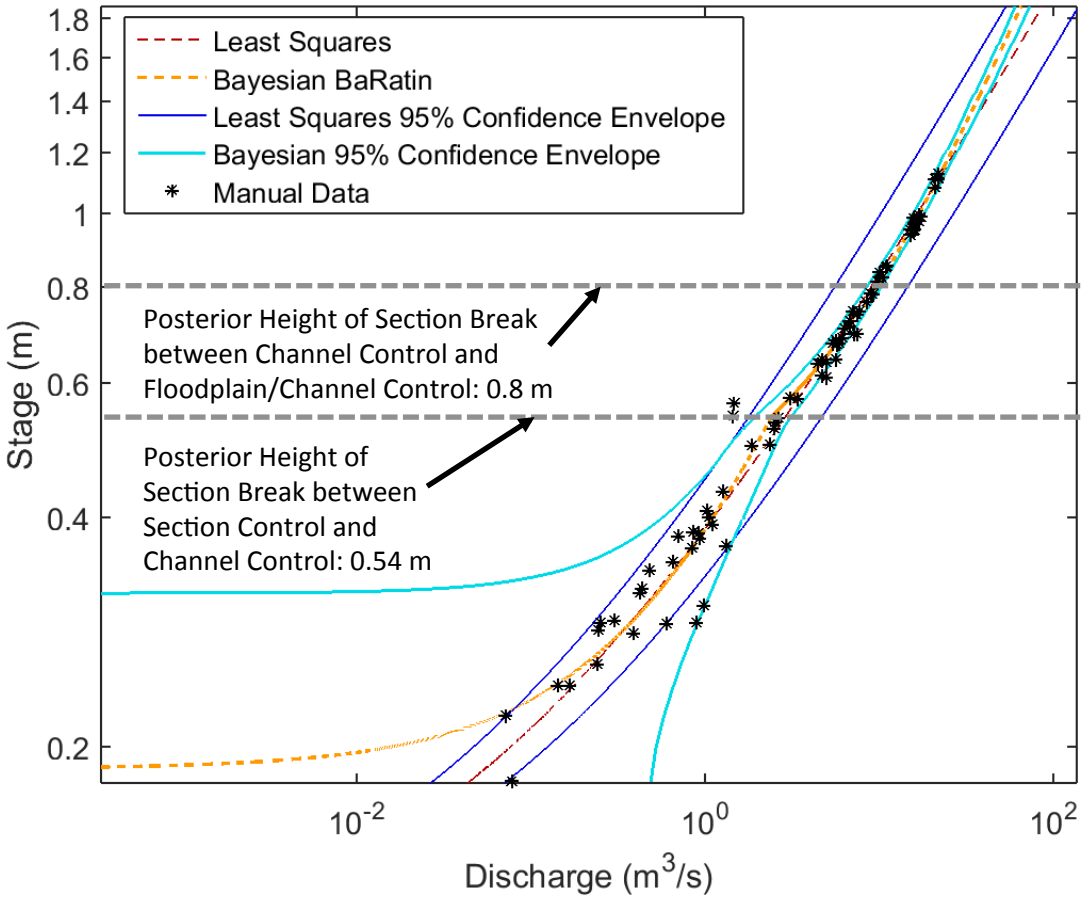
BaRatin (stage in m, Q in cms):

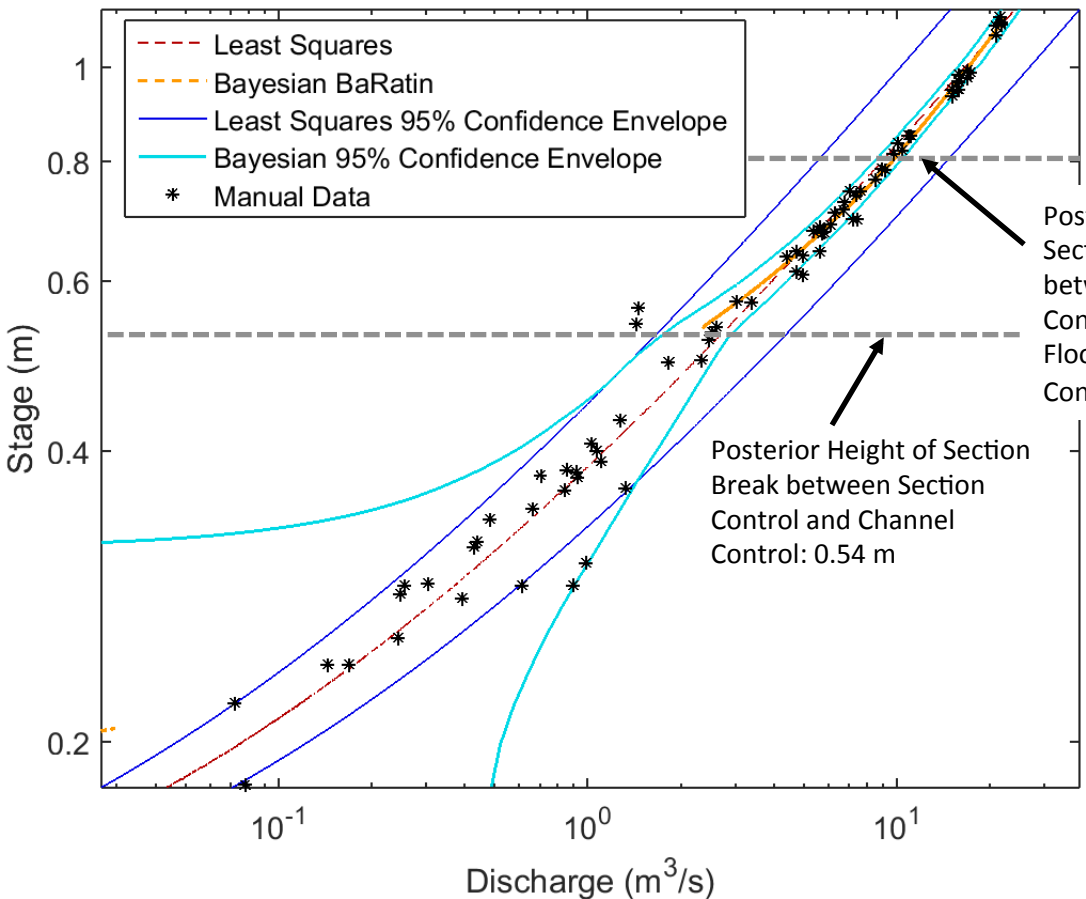




Log-Log View

Lyell Fork above Twin Bridges





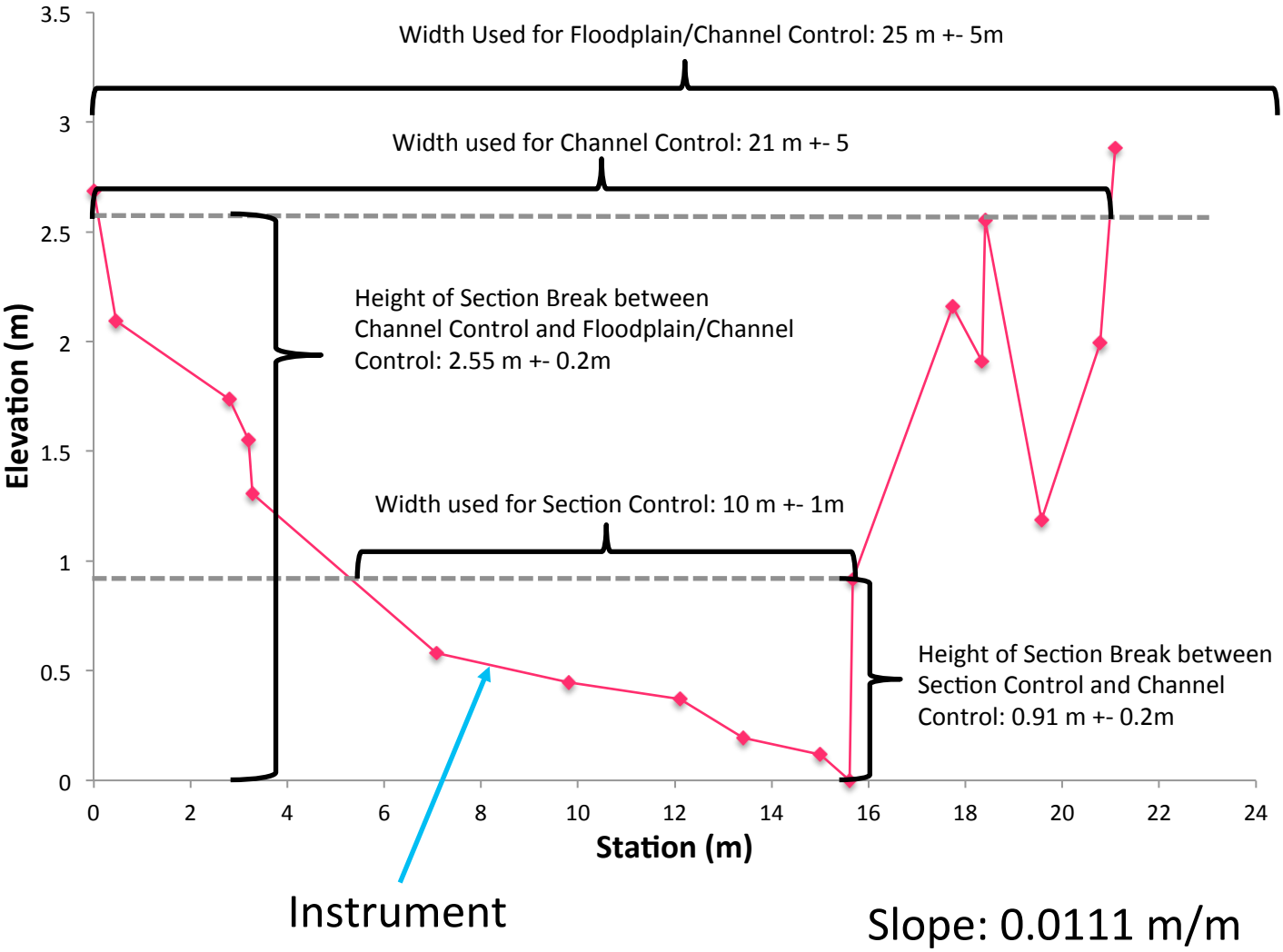
Lyell Fork blw Twin Bridges

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.

River Right



Instrument

Slope: 0.0111 m/m

Lyell Fork below Twin Bridges

Height above which rating curve does not apply (ice jam): 2.5m

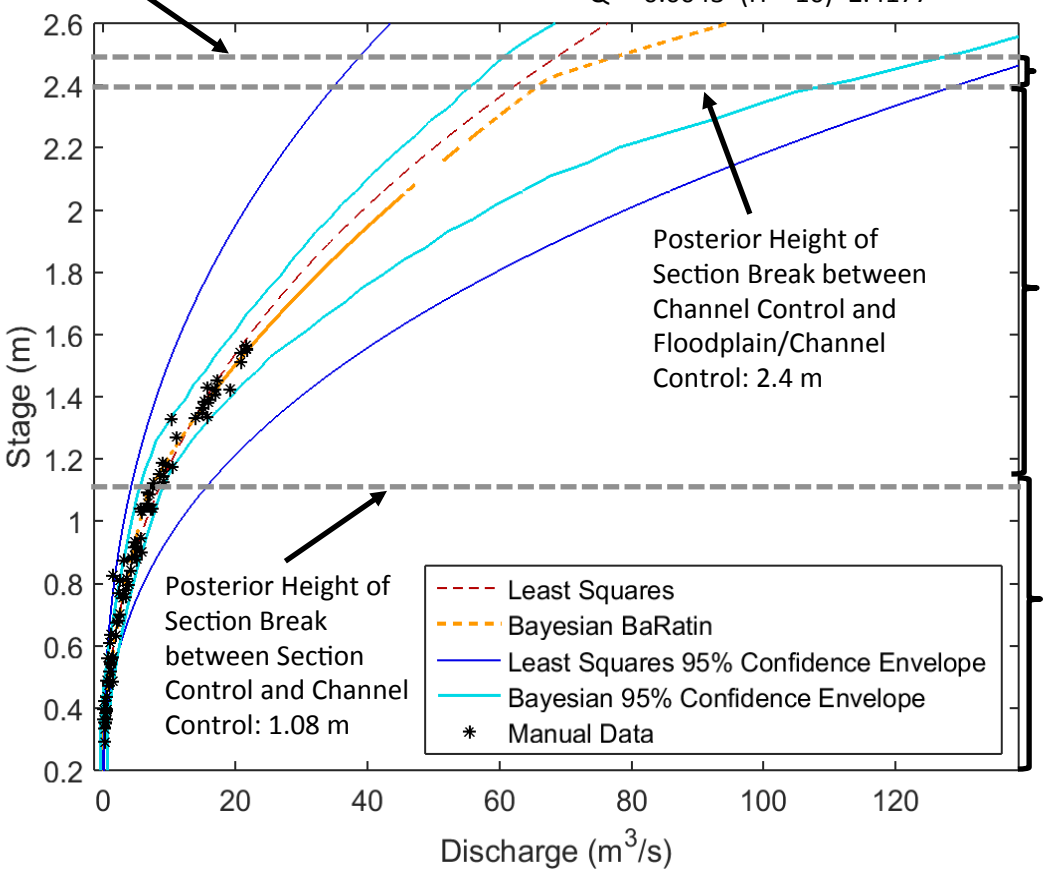
Least Squares (stage in cm, Q in cfs):
Q = 0.0043*(H – 10)^2.4177

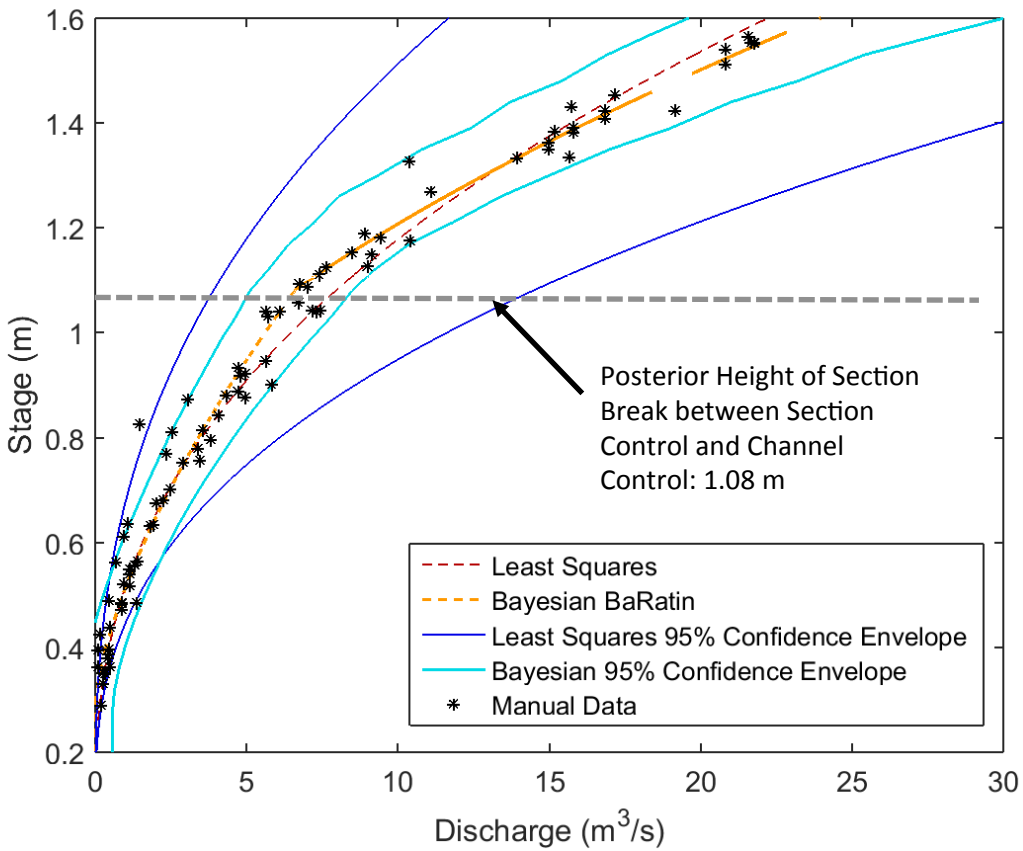
BaRatin (stage in m, Q in cms):

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

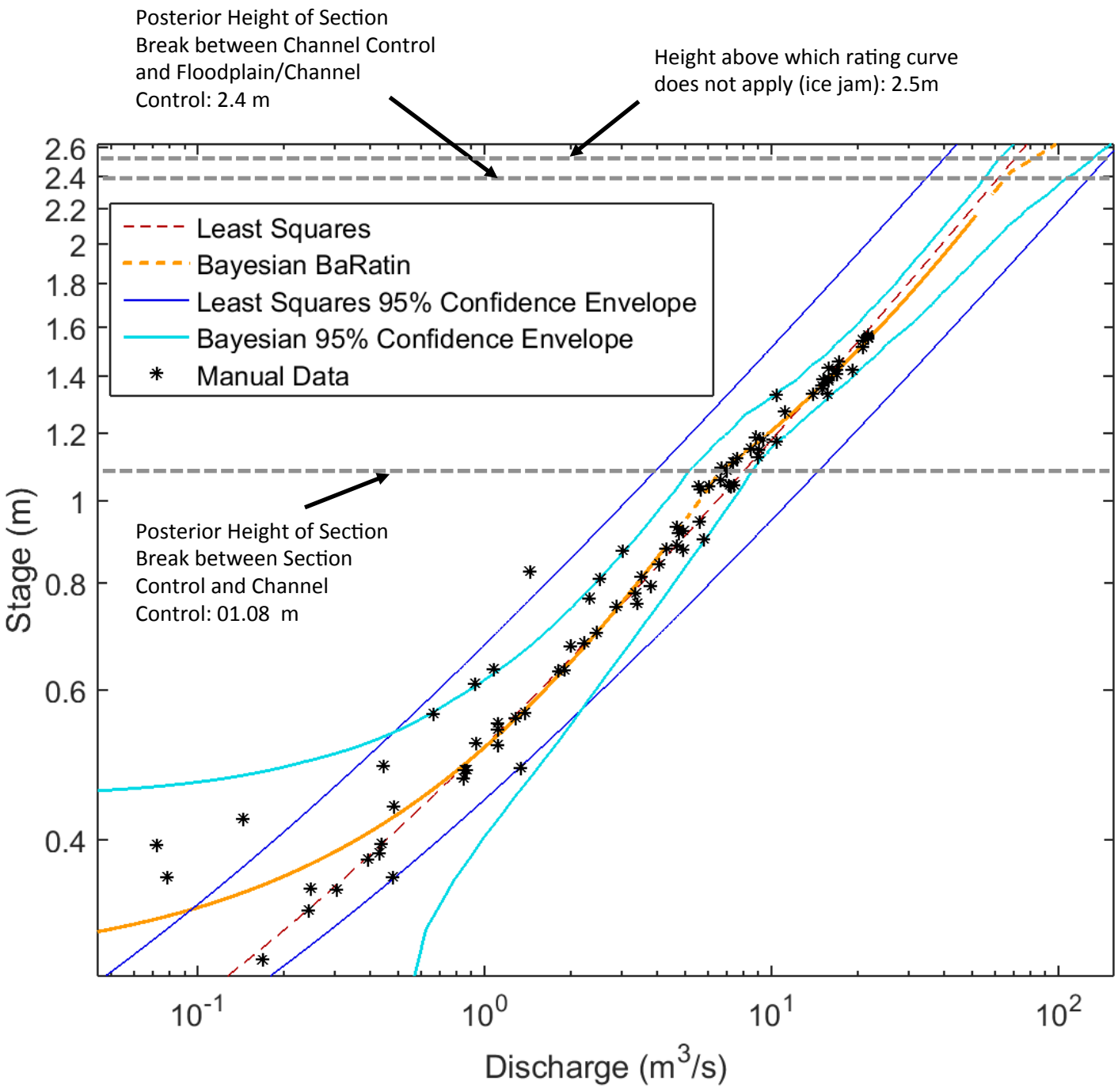
H < 1.08171m
Q =9.3003*(H – 0.28214)^1.526



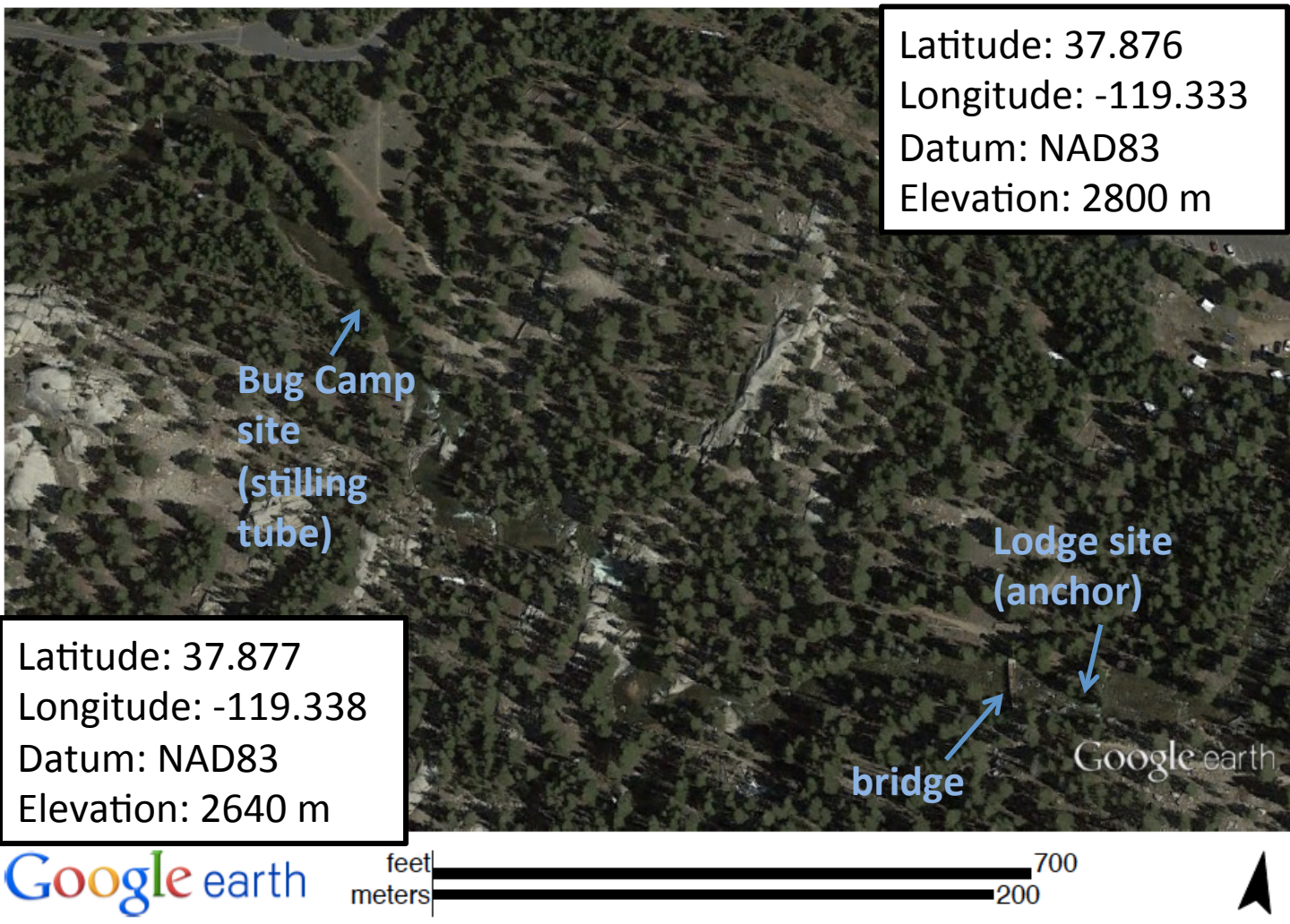


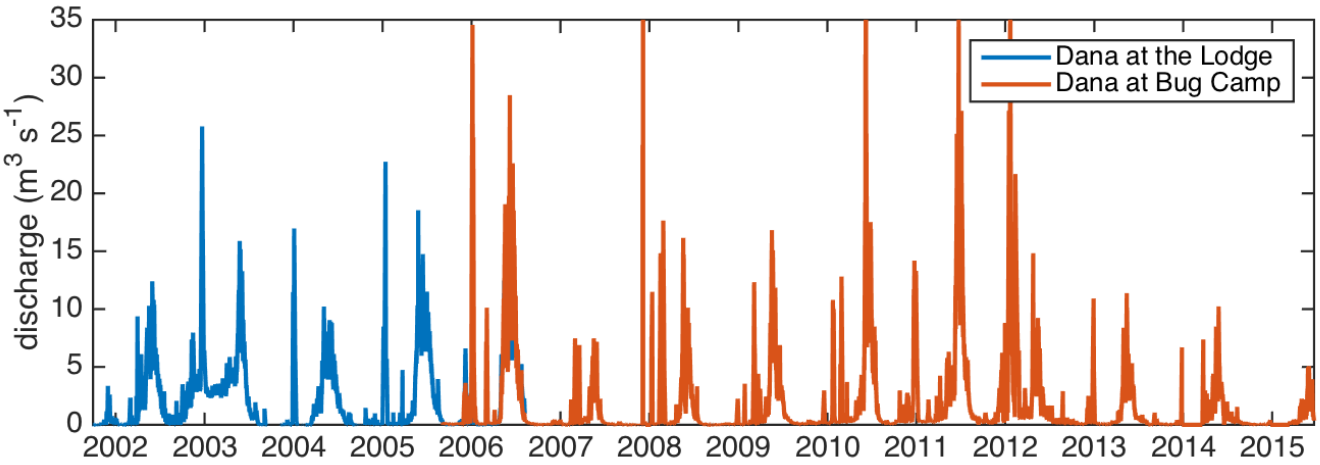
Log-Log View

Lyell Fork below Twin Bridges



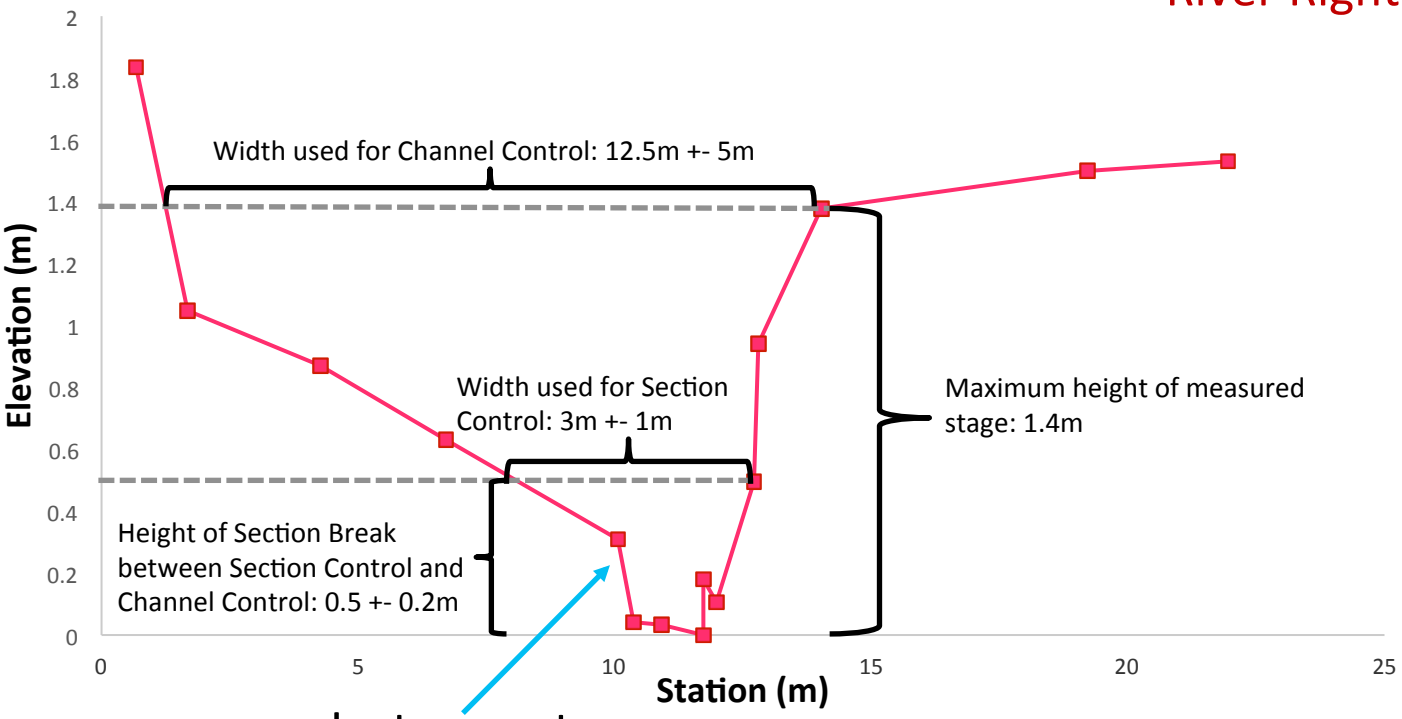
Dana Fork, Tuolumne Lodge and Bug Camp





Dana Fork near Tuolumne Lodge

River Right



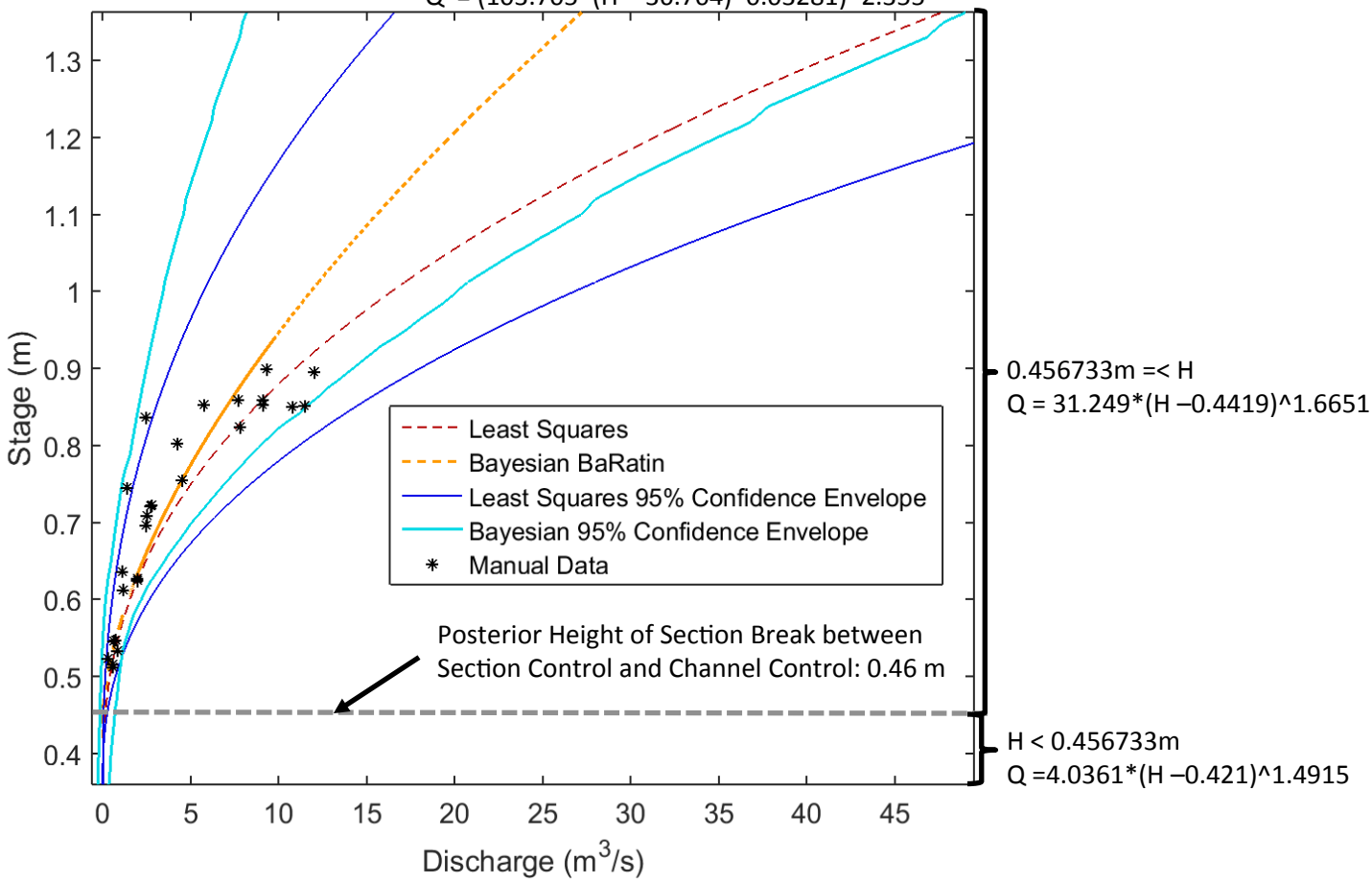
Instrument

Note significantly different scales for x and y axes.

Dana Fork near Tuolumne Lodge

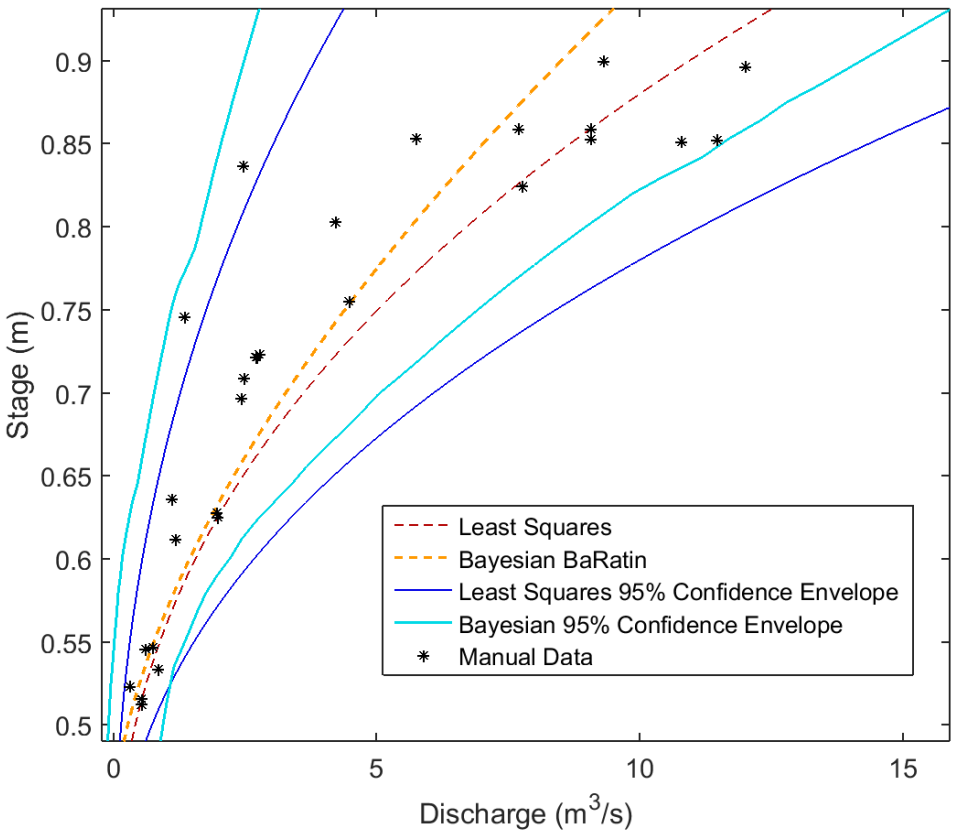
Least Squares (stage in ft, Q in cfs):
Q = (103.705*(H – 36.704)*0.03281)^2.355

BaRatin (stage in m, Q in cms):



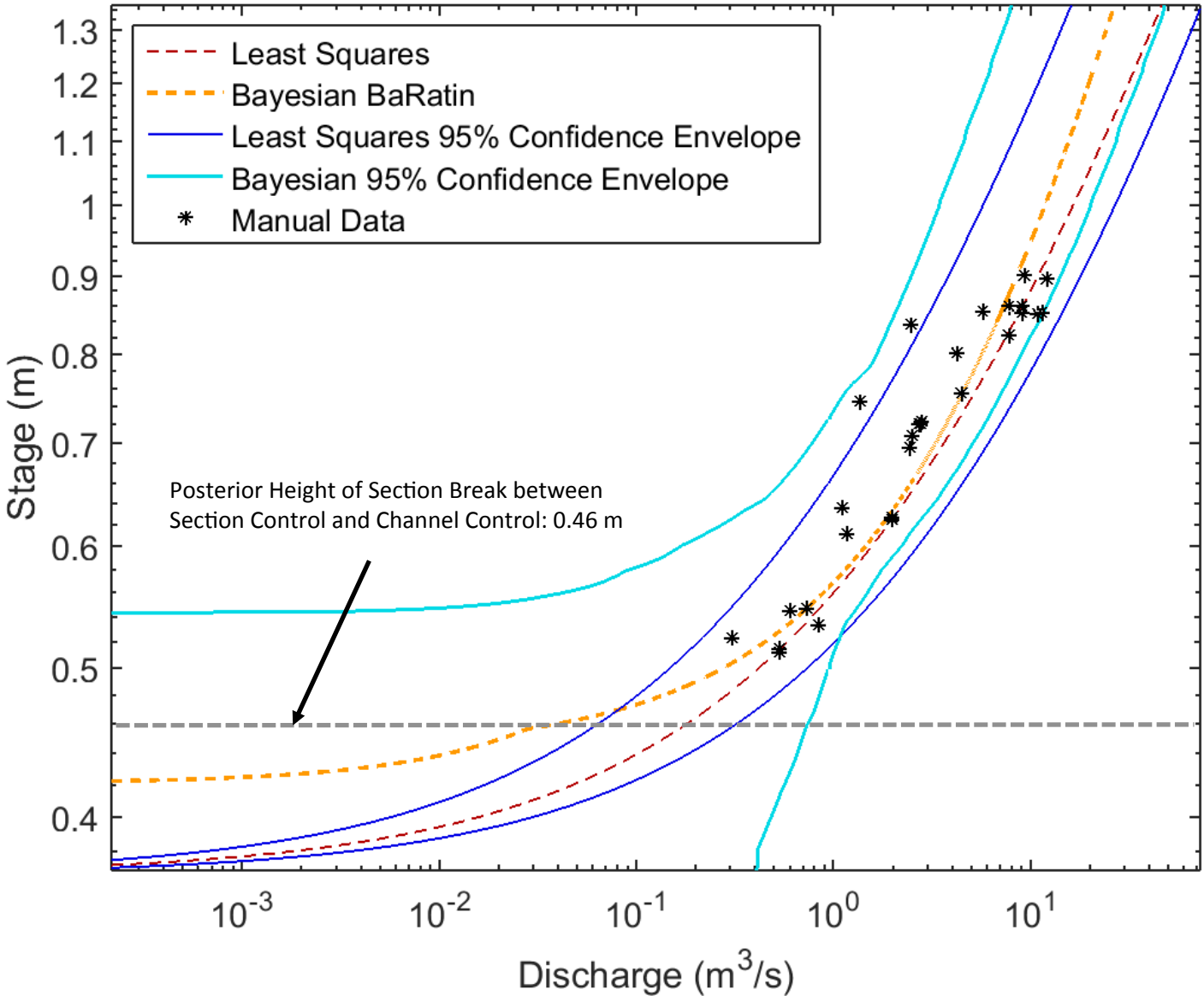
0.456733m =< H
Q = 31.249*(H –0.4419)^1.6651

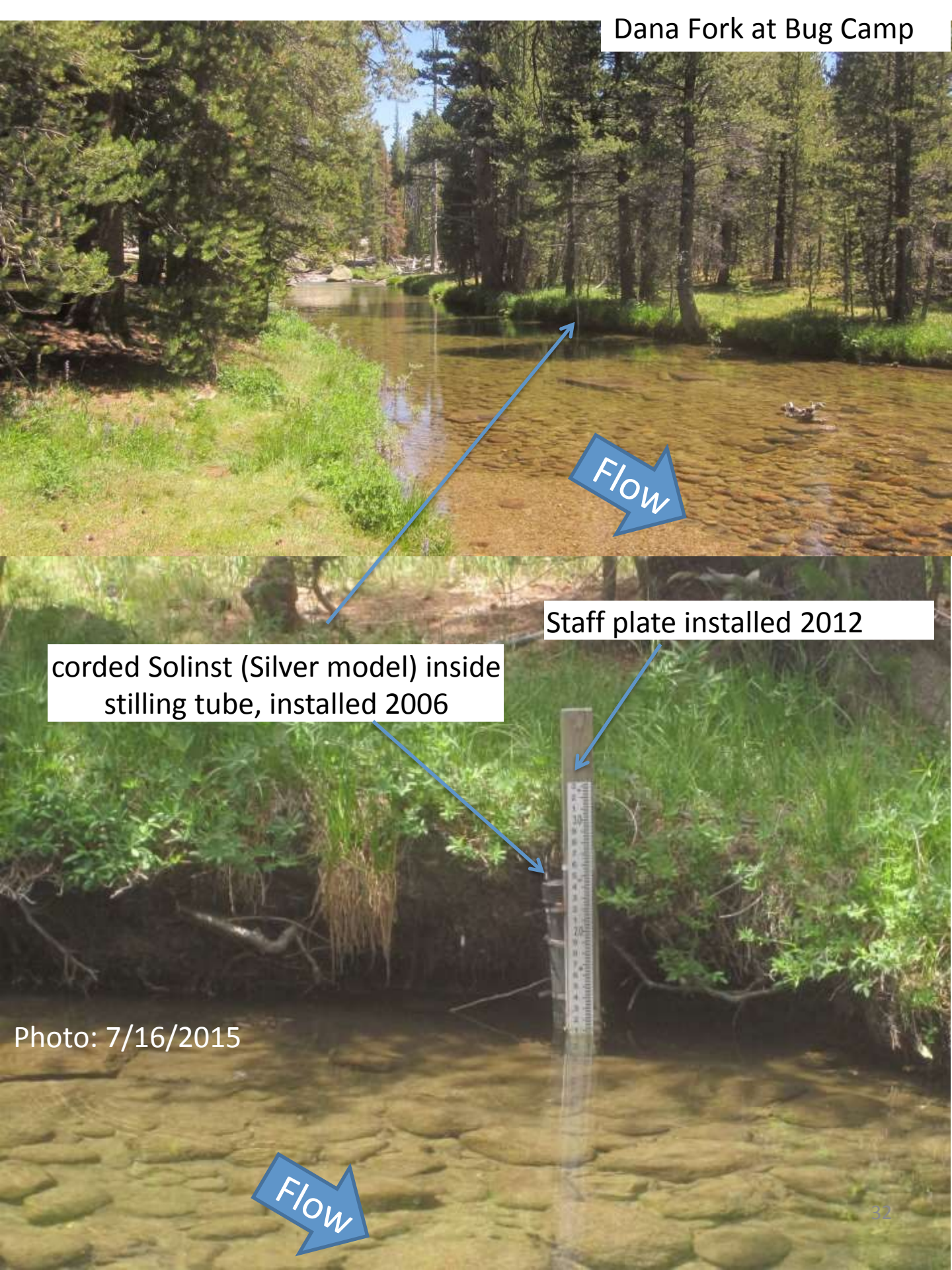
H < 0.456733m
Q =4.0361*(H –0.421)^1.4915



Log-Log View

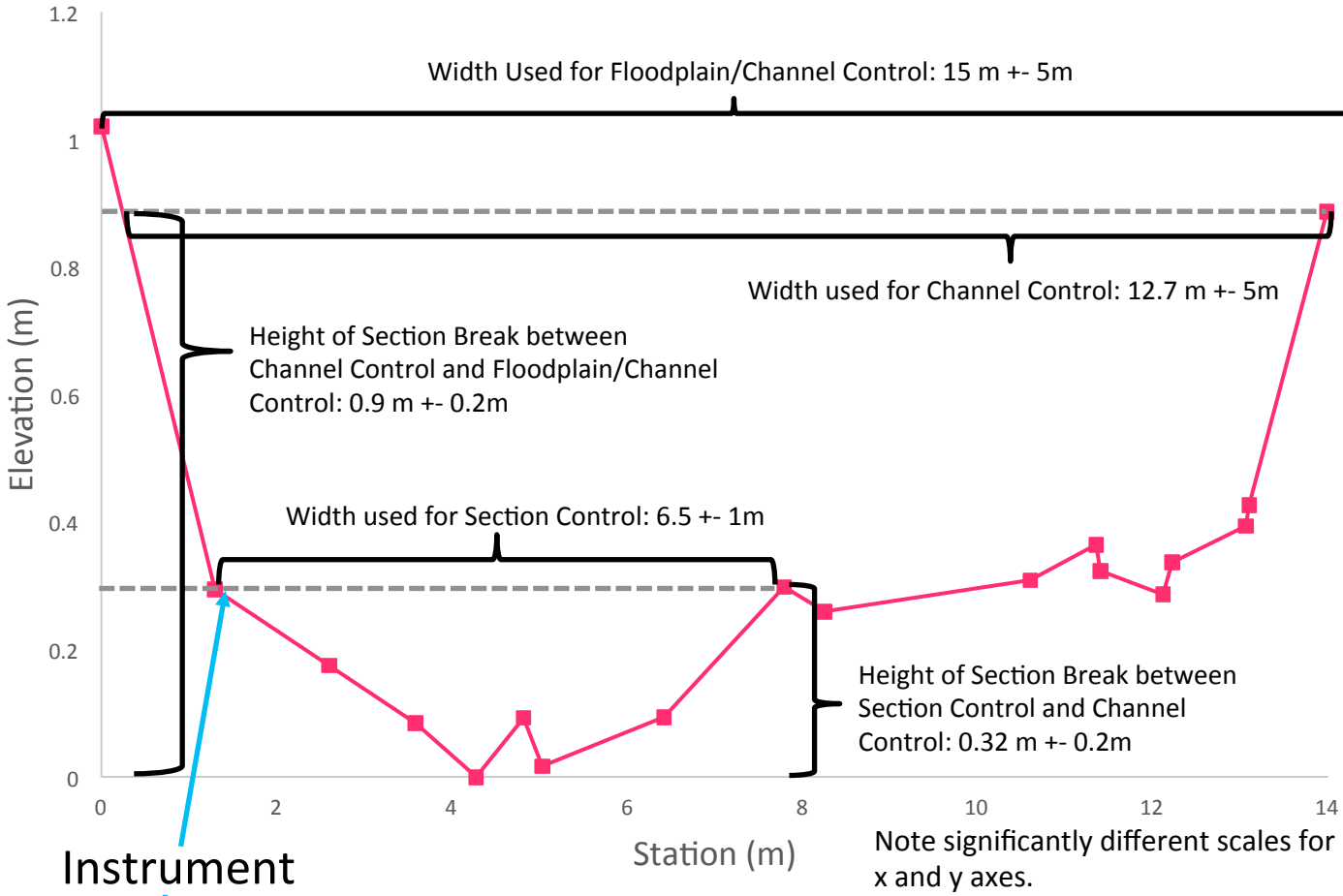
Dana Fork near Tuolumne Lodge



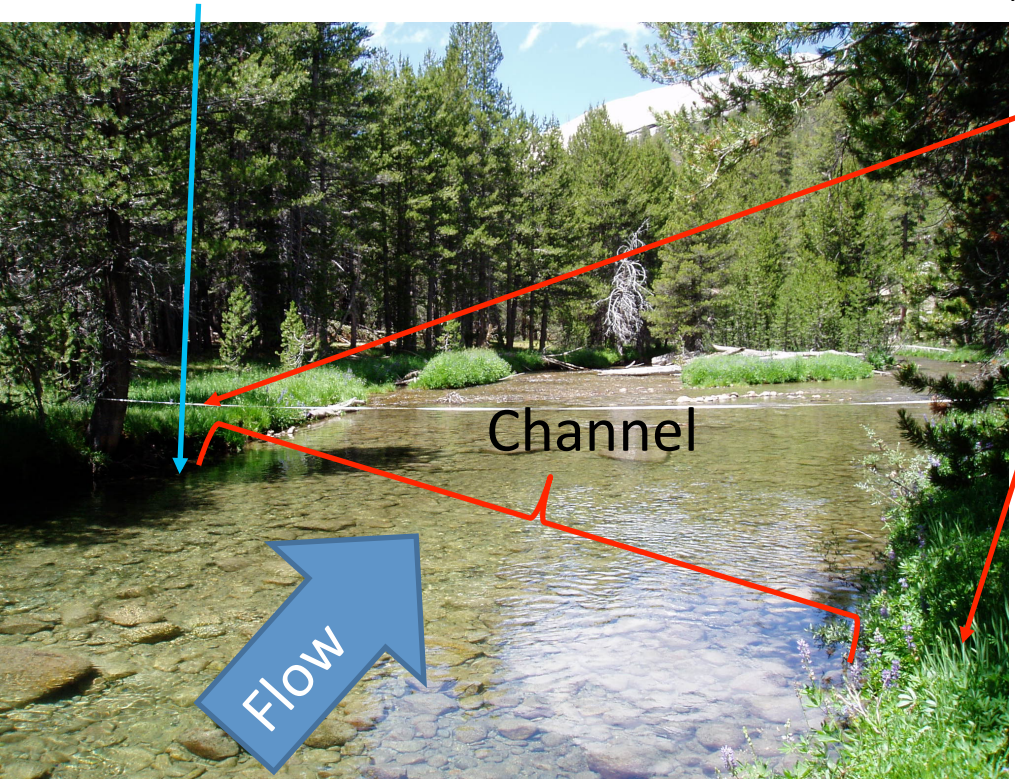

Dana Fork at Bug Camp
Flow
Staff plate installed 2012
corded Solinst (Silver model) inside stilling tube, installed 2006
Photo: 7/16/2015
Flow

Dana Fork at Bug Camp

River Right



Note significantly different scales for x and y axes.

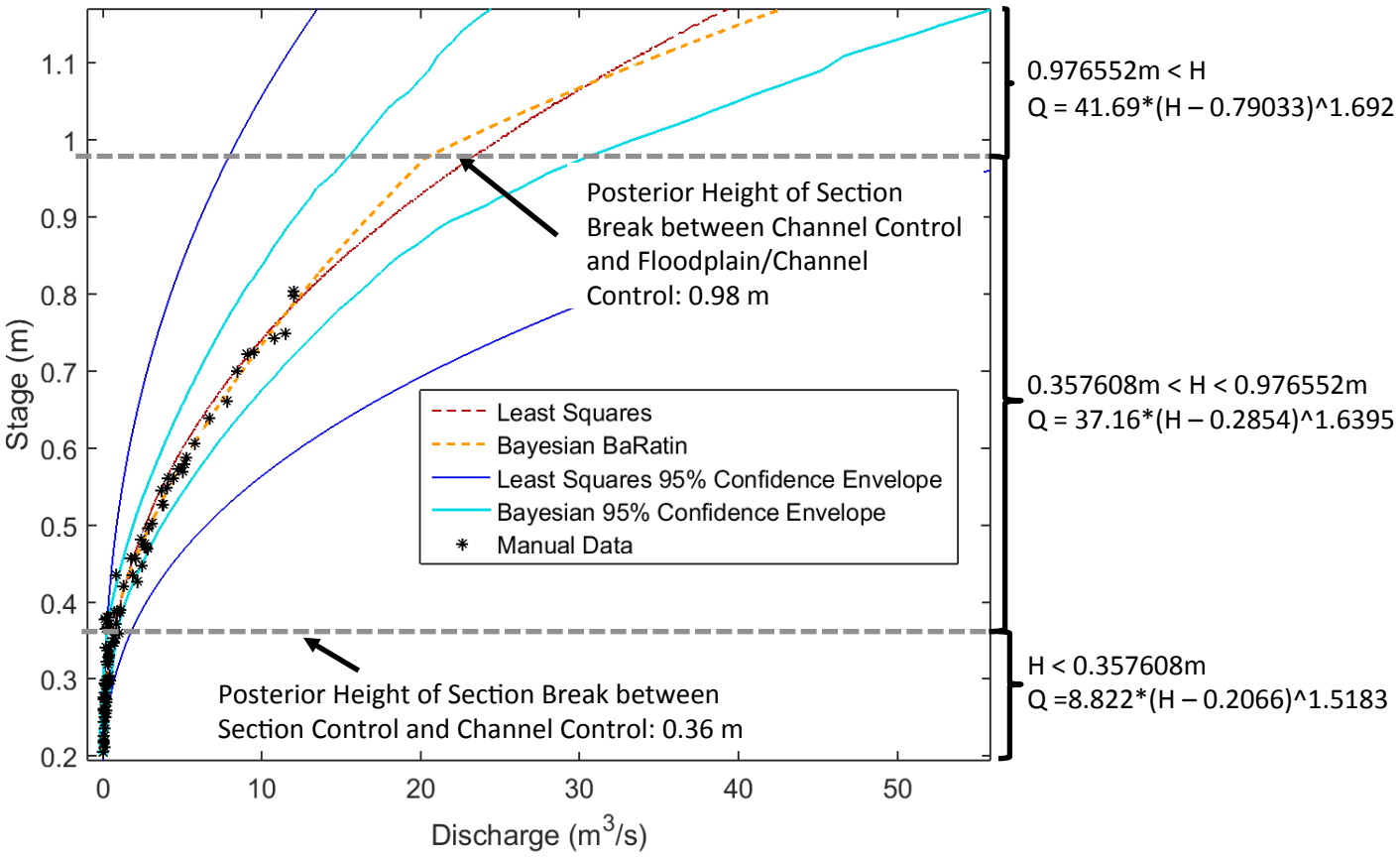


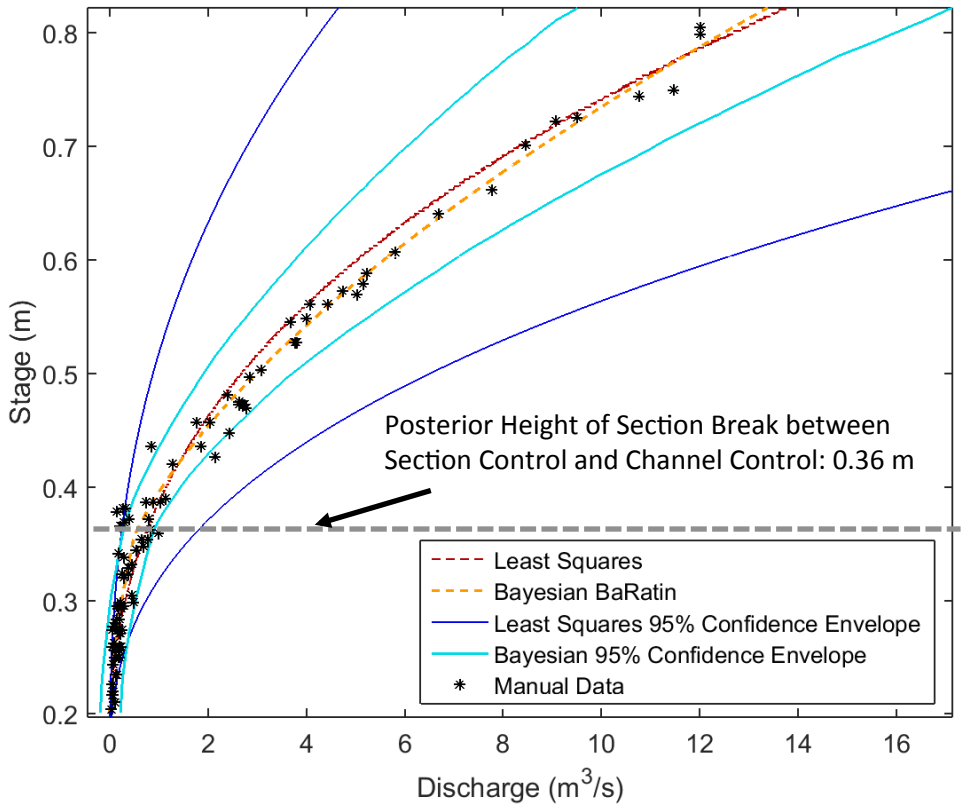
Slope: 0.033 m/m

Dana Fork at Bug Camp

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

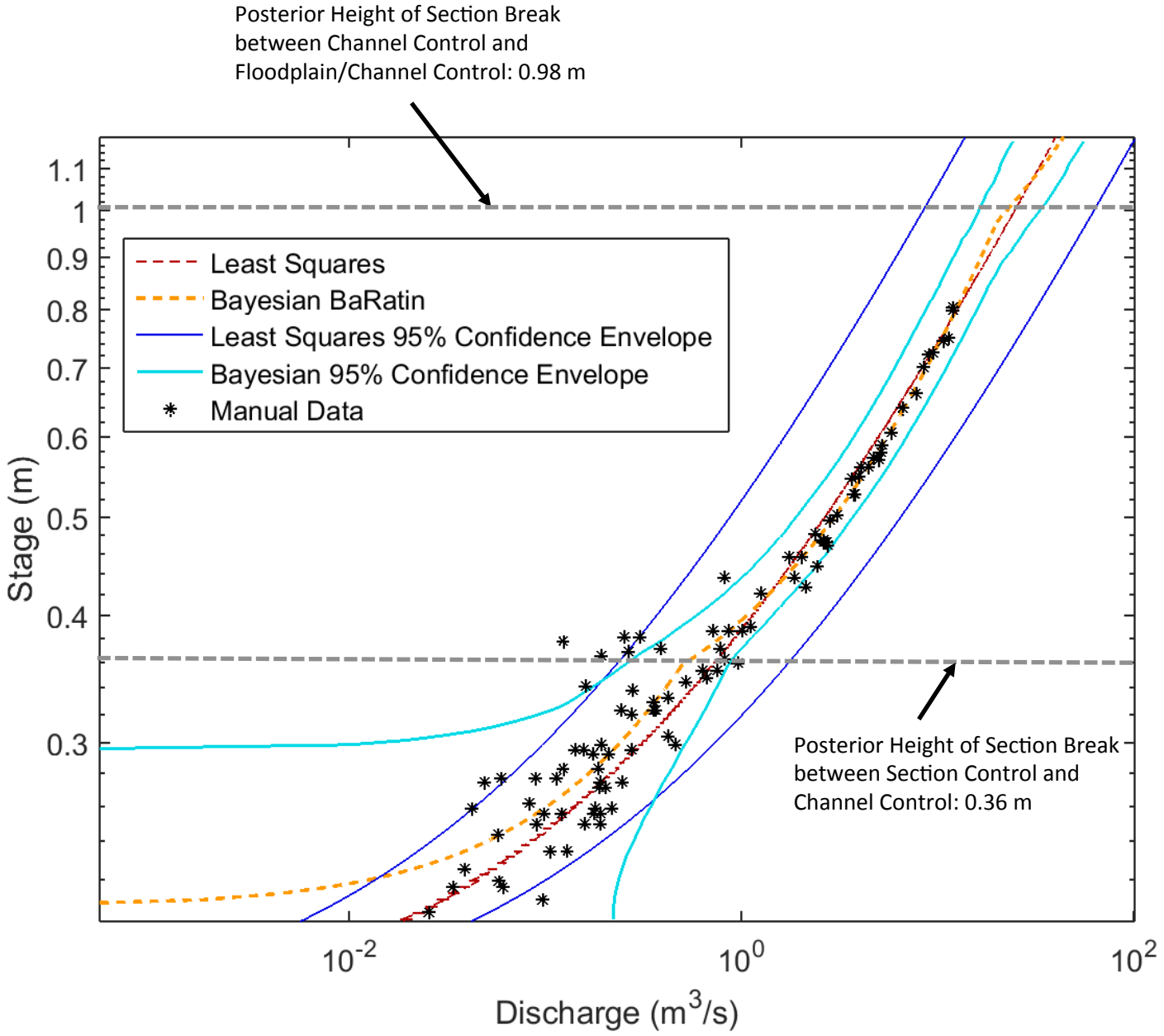
BaRatin (stage in m, Q in cms):

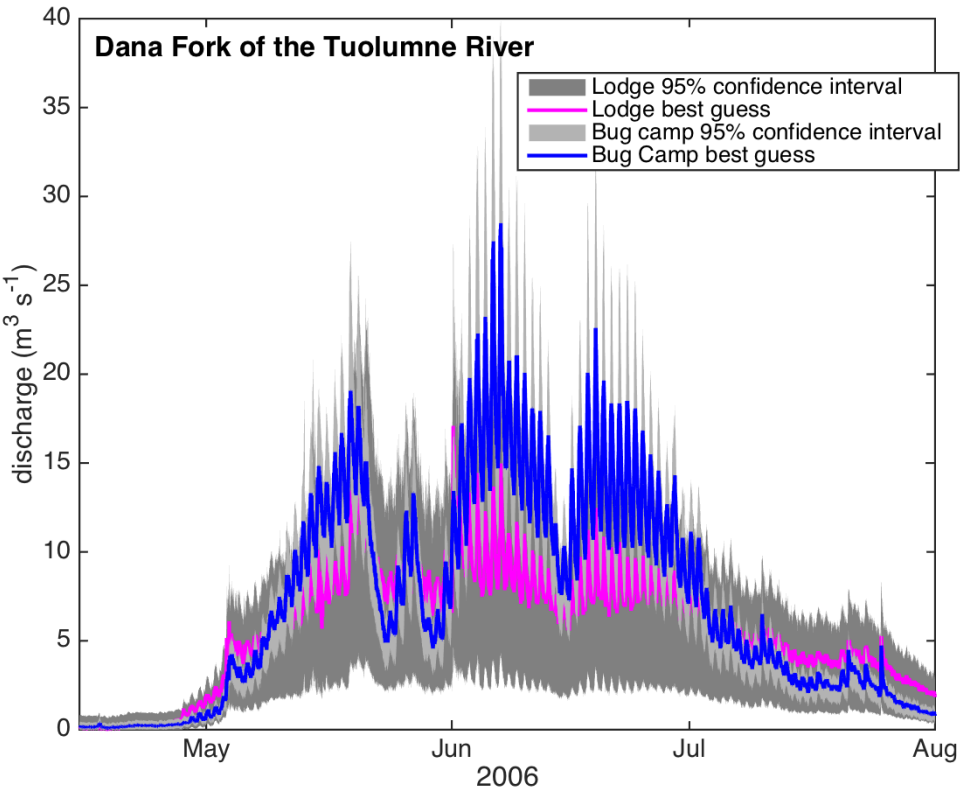




Log-Log View

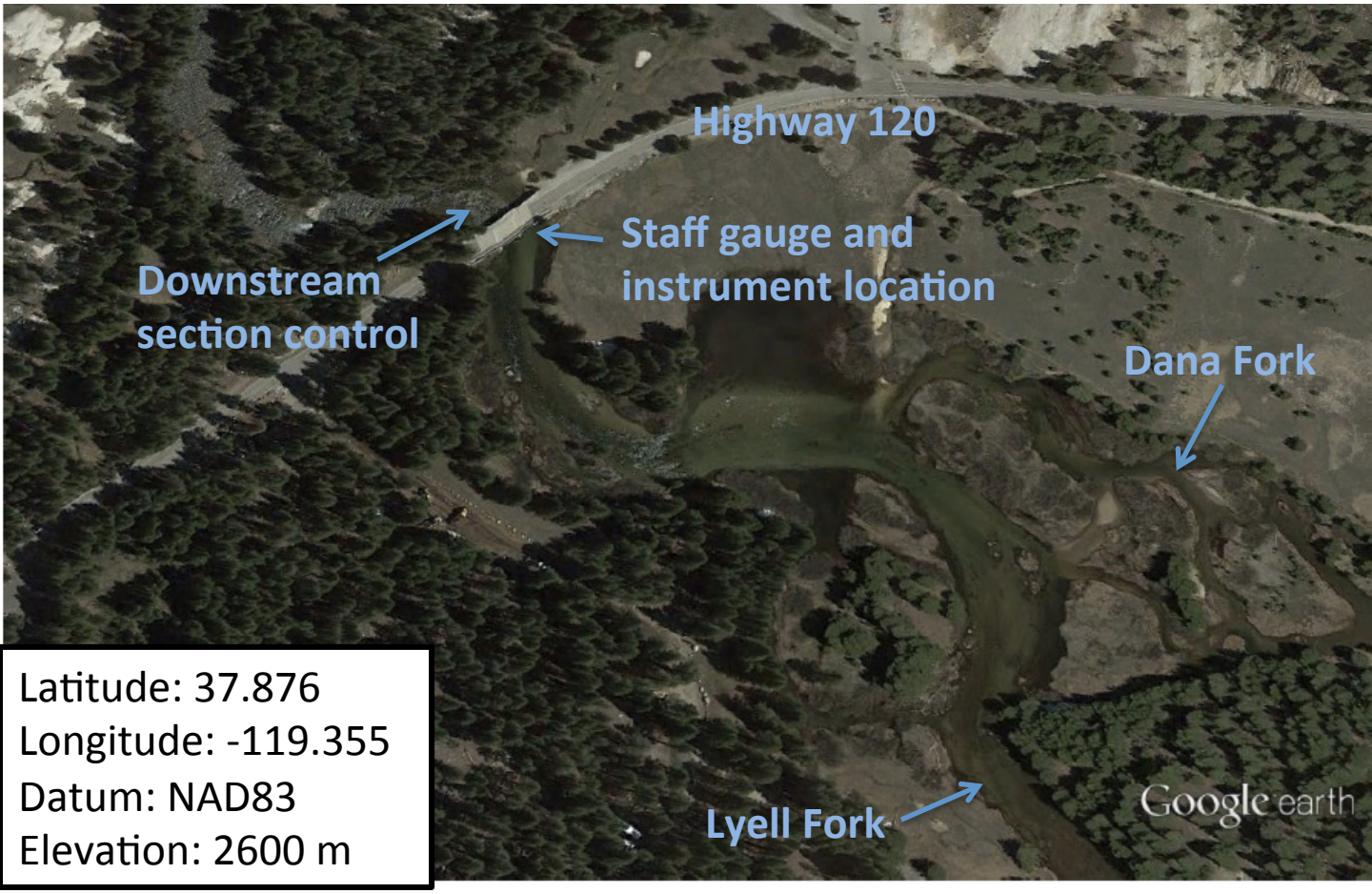
Dana Fork at Bug Camp





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

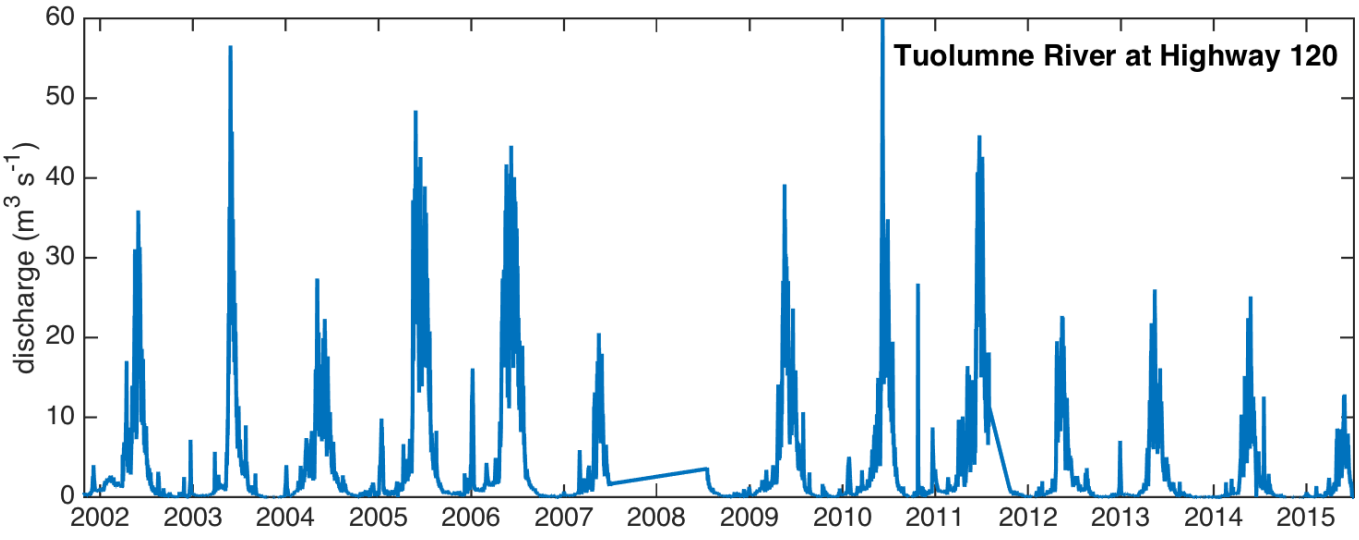
Tuolumne at Highway 120



Latitude: 37.876
Longitude: -119.355
Datum: NAD83
Elevation: 2600 m

Google earth

feet 800
meters 200



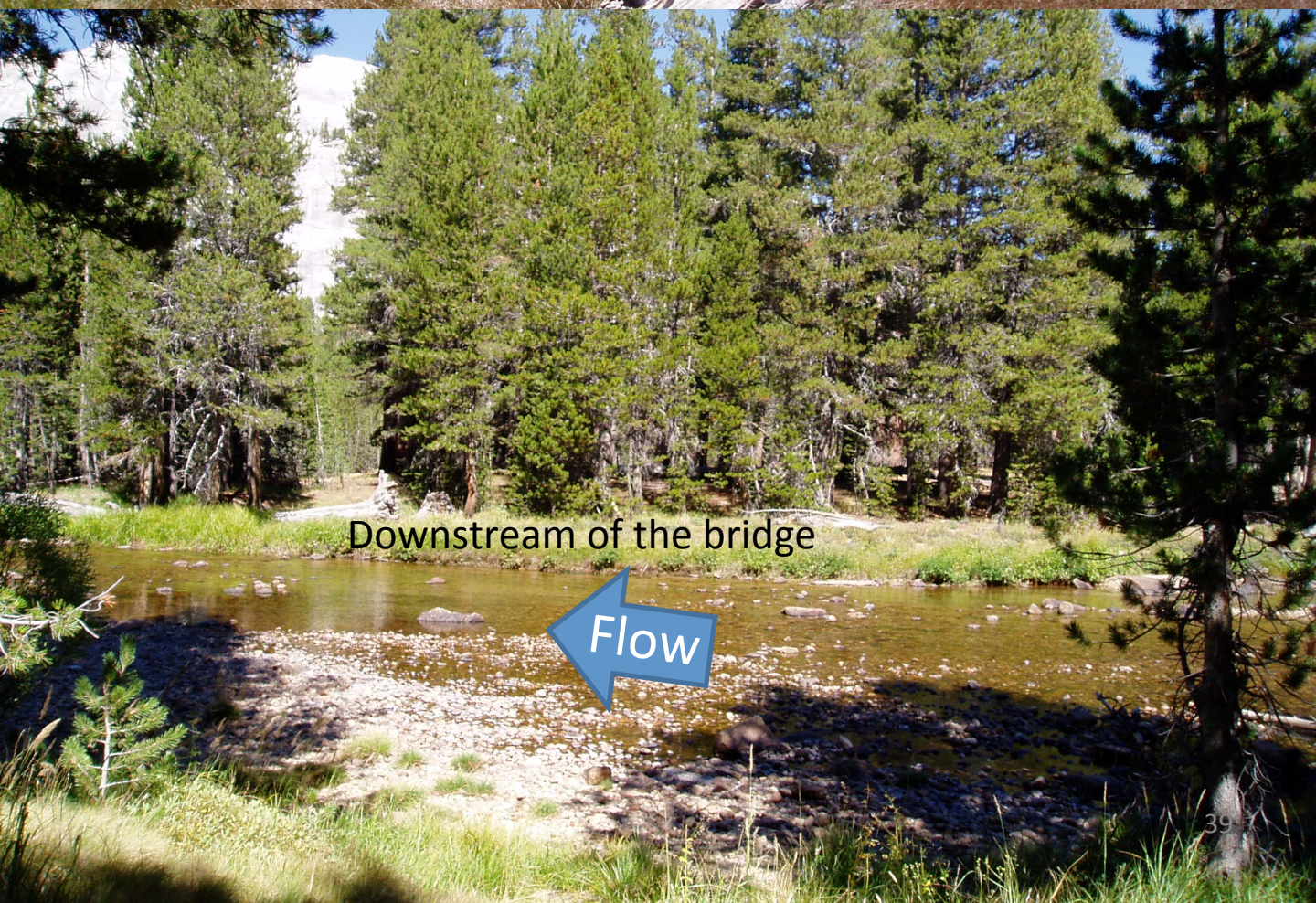
Tuolumne River at Highway 120

Staff gauge, installed in 2006

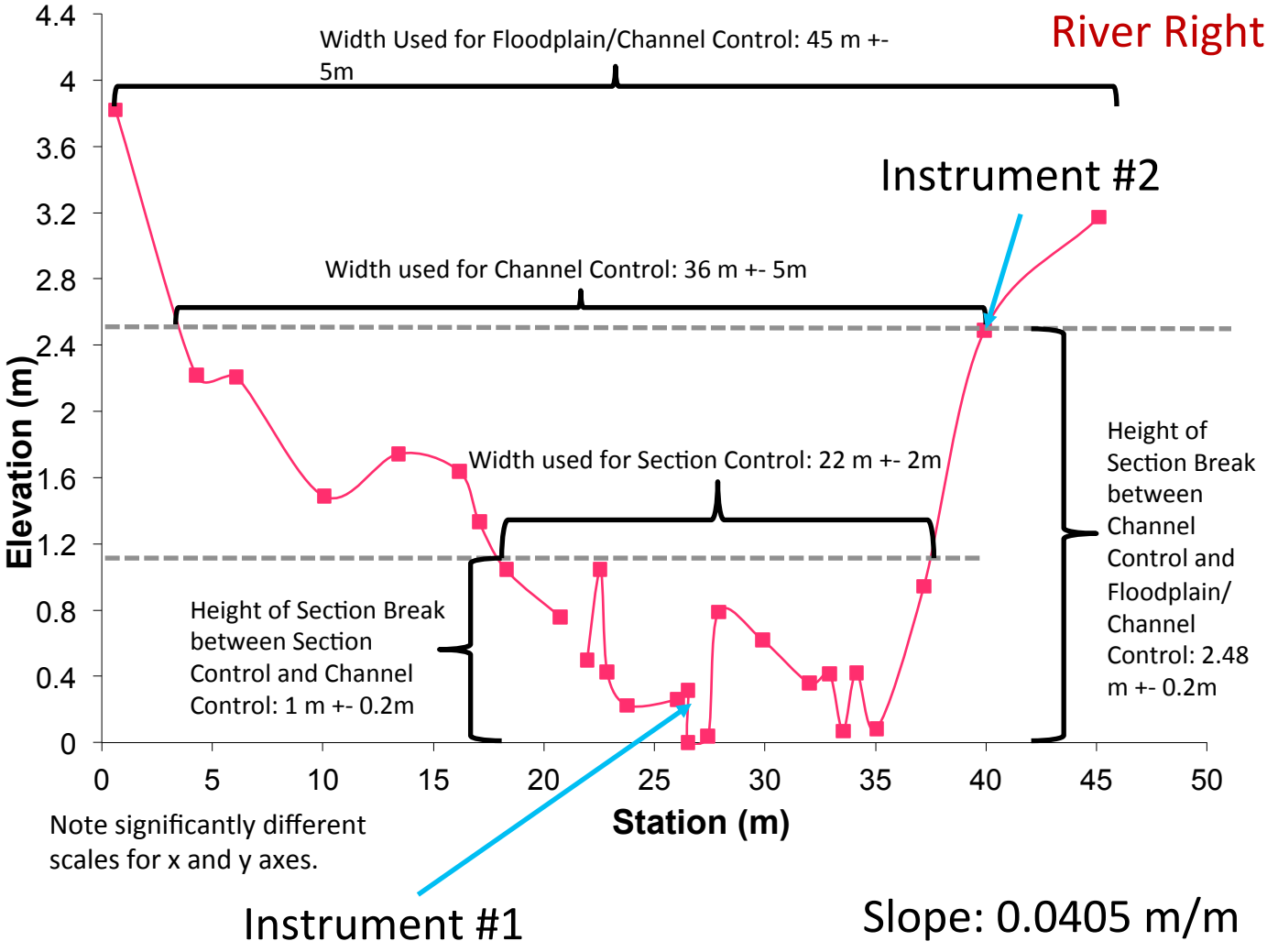
Corded pressure transducer, installed in 2006

Original install in 2001, anchored solinst and/or Seabird at the base of this abutment.

Tuolumne River at Highway 120



Tuolumne River at Highway 120

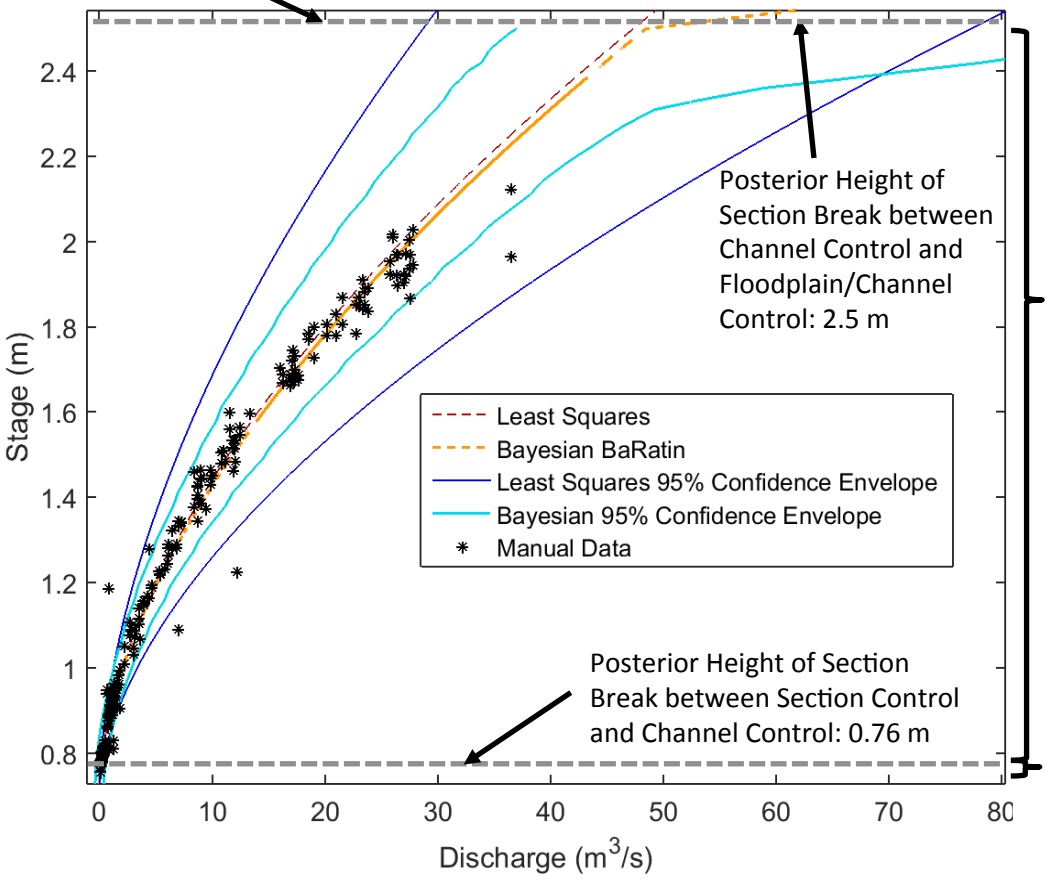


Tuolumne River at Highway 120

Height above which rating curve does not apply (ice jam): 2.5 m

Least Squares (stage in cm, Q in cfs):
Q = 0.188488*(H – 70)^1.75063

BaRatin (stage in m, Q in cms):

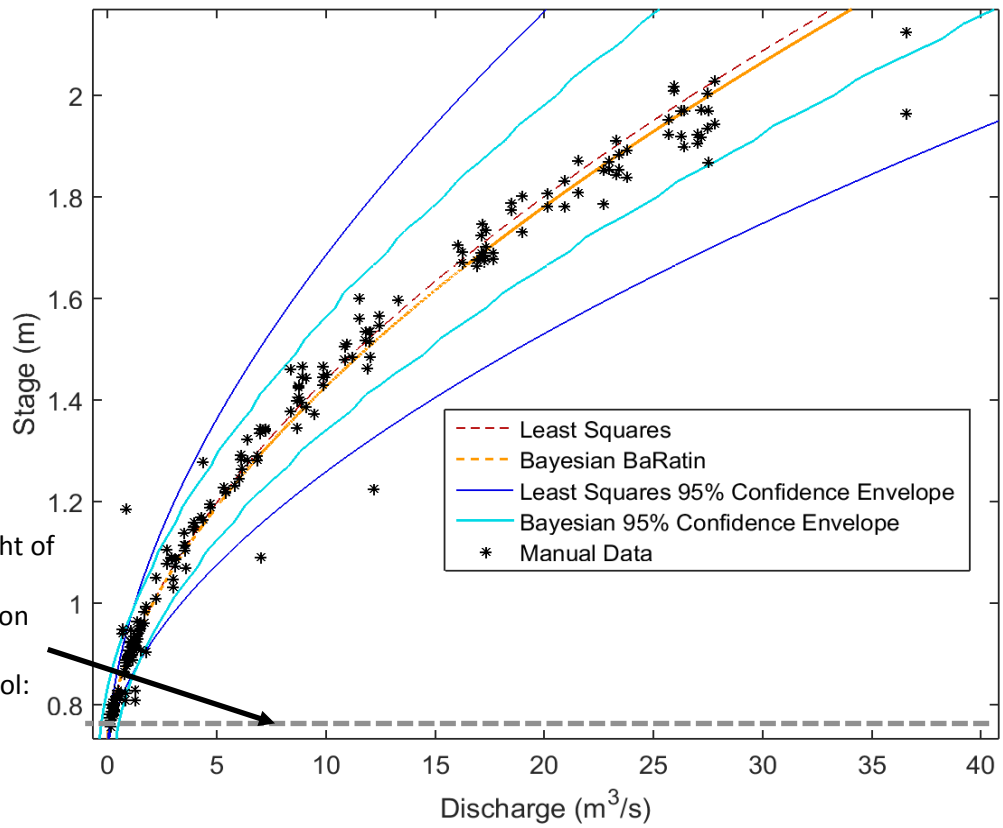


Posterior Height of Section Break between Channel Control and Floodplain/Channel Control: 2.5 m

0.764609m < H <= 2.499m
Q = 18.007*(H – 0.7169)^1.713

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

H < 0.764609m
Q = 34.099*(H – 0.7460)^1.468



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

Log-Log View

Tuolumne River at Highway 120

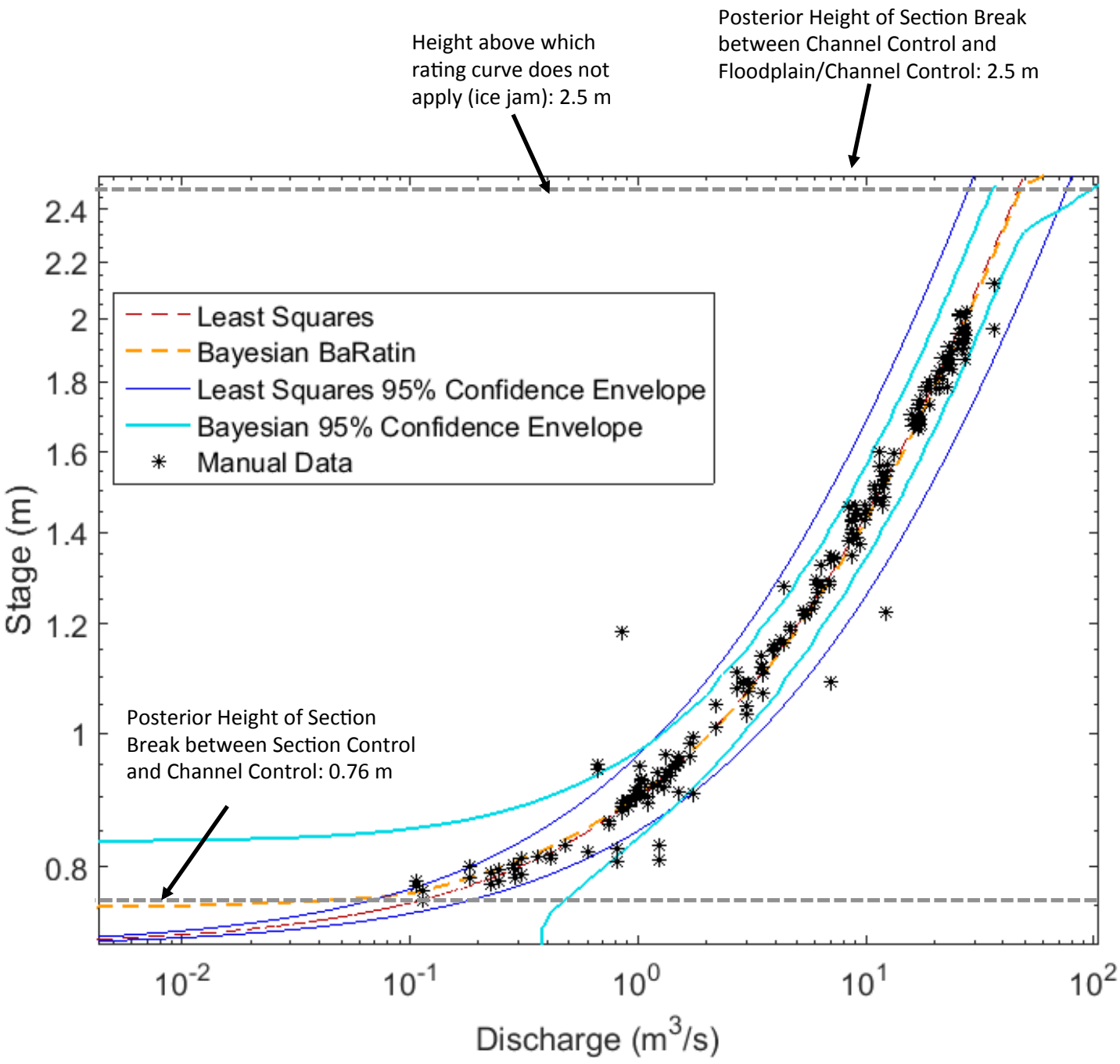
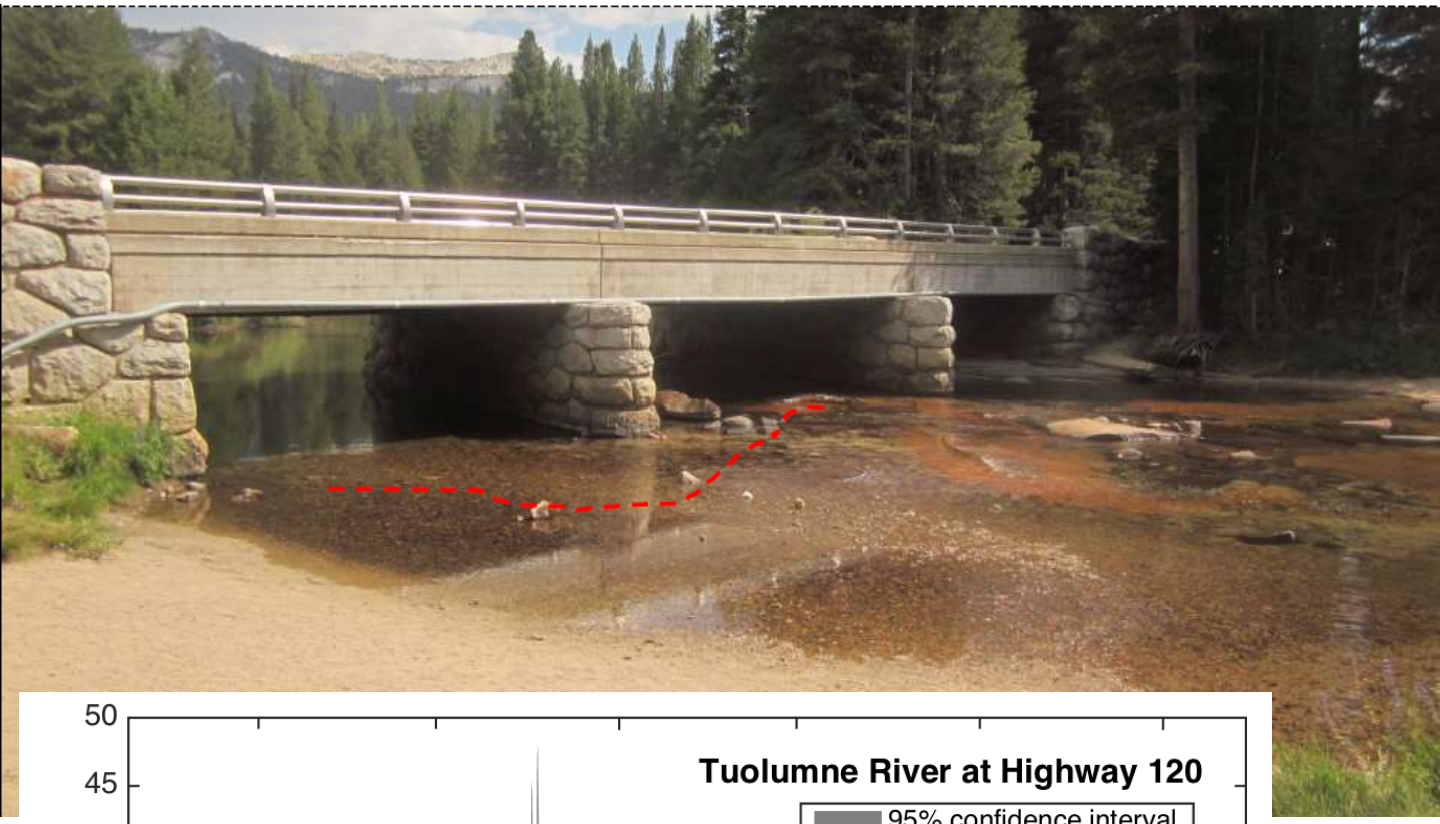
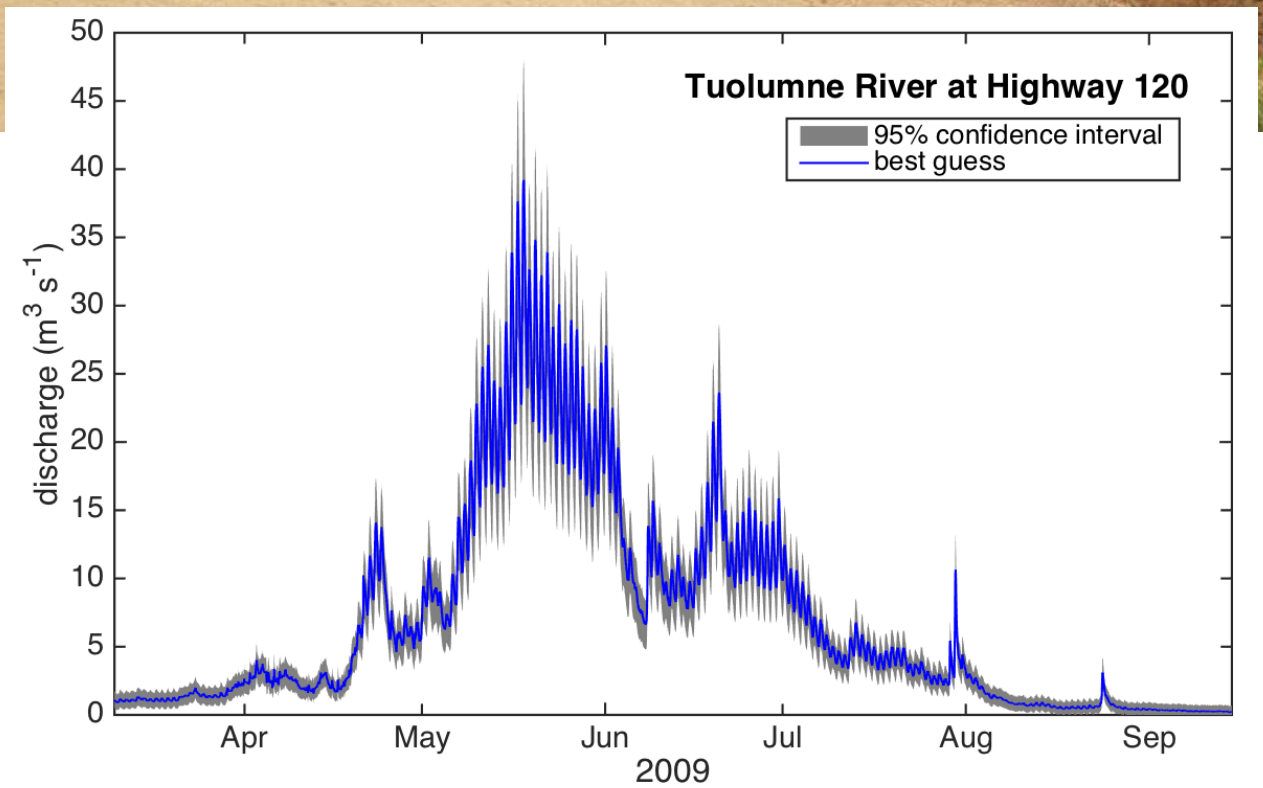


Photo on 29 July 2015; red shows gravel bar section control.
16:00 on 29 July 2015: Gage height of zero flow 2.79 ft – 0.86 ft = 1.93 ft

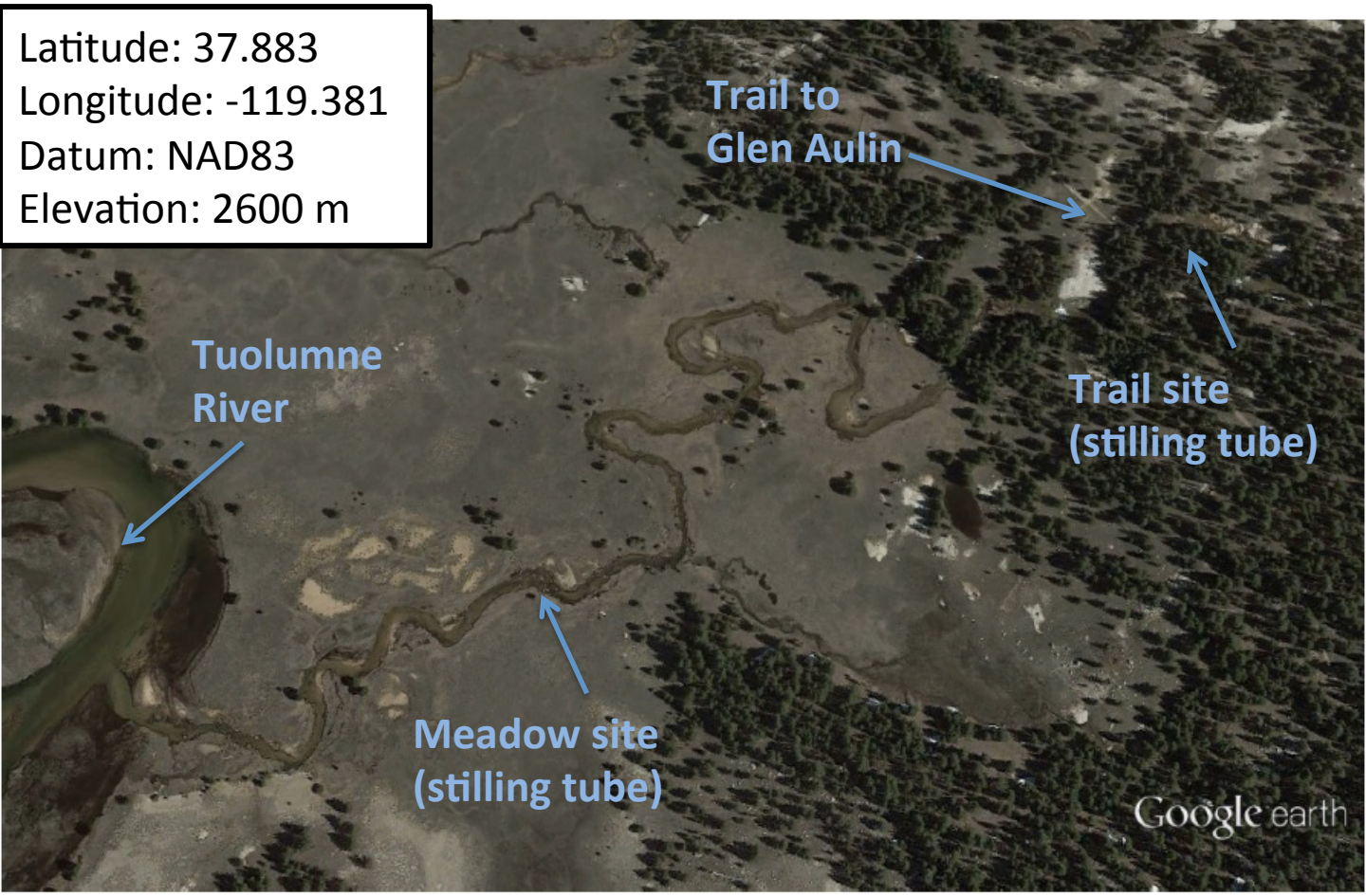




The rating curve at this location has greater confidence than at many of the other sites.

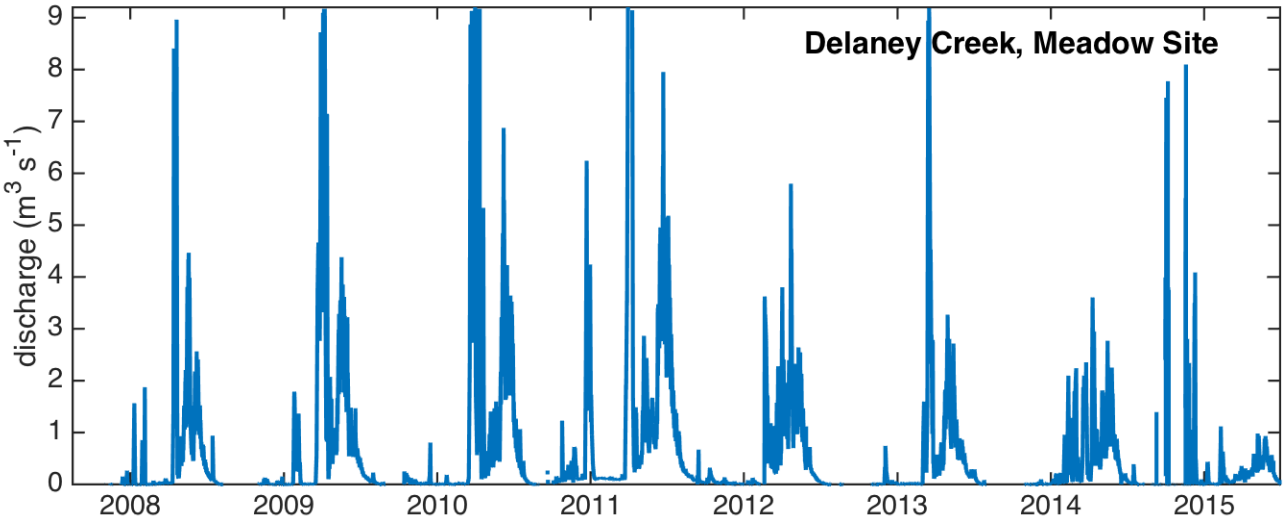
Delaney Creek

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



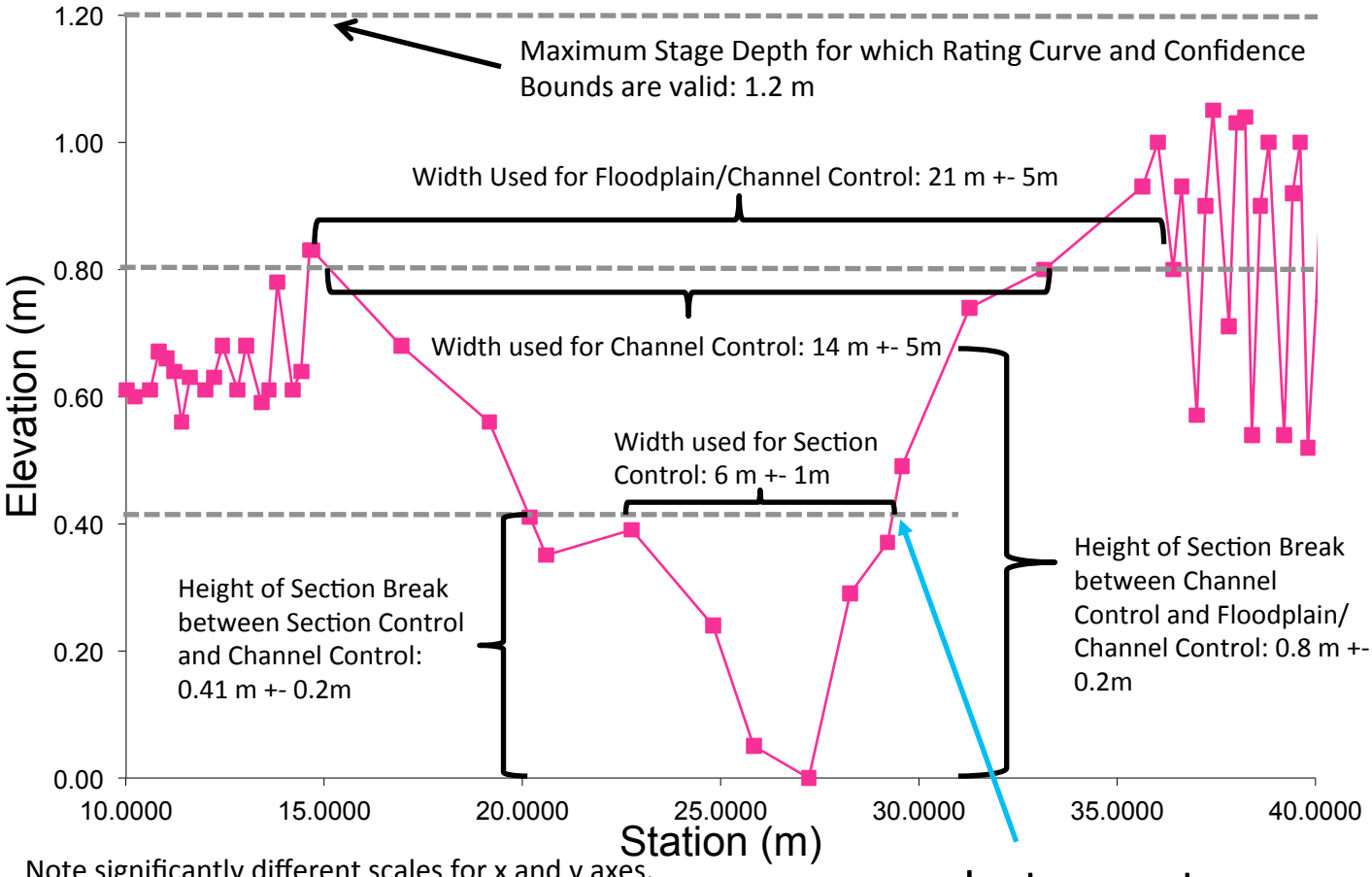
Google earth

feet 1000
meters 300

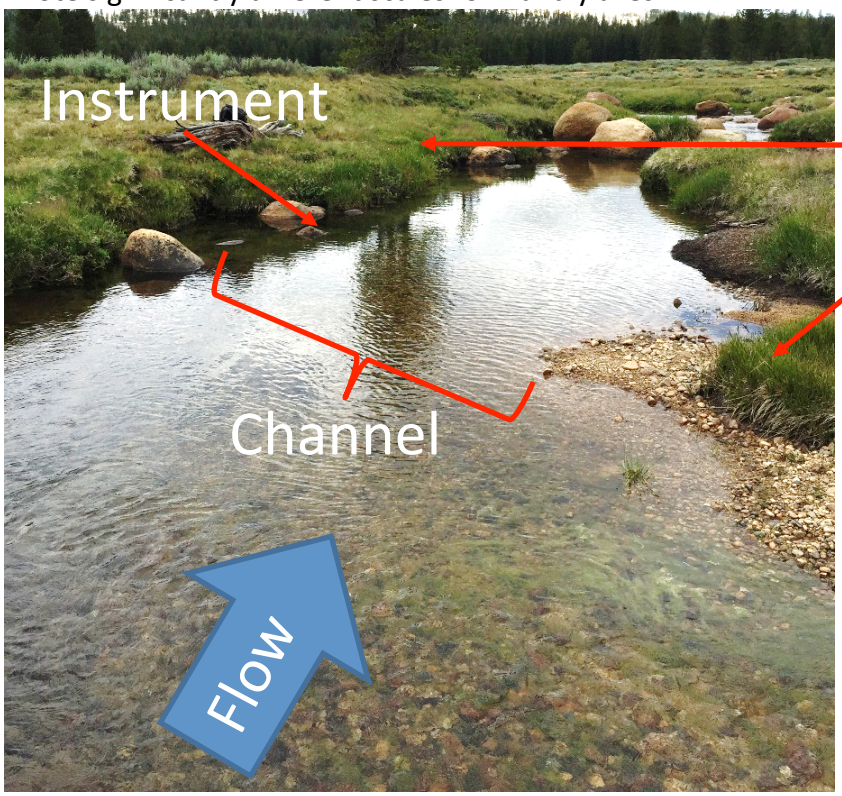


Meadow site only is available at this time. Notice frequency of ice jams.

River Right



Note significantly different scales for x and y axes.



Floodplain

Slope: 0.00422 m/m

Delaney Creek

Height above which rating curve does not apply (ice jam): 1.2 m

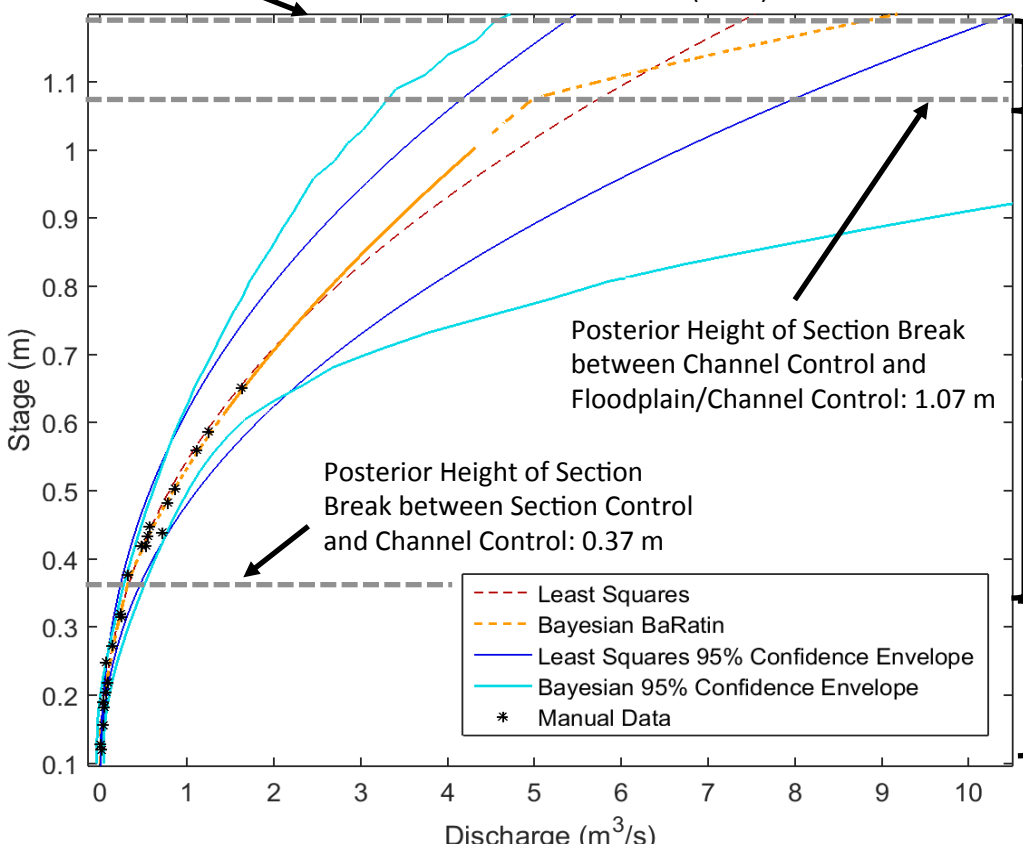
Least Squares (stage in cm, Q in cfs):
Q = 0.0037*(H – 6)^2.3618

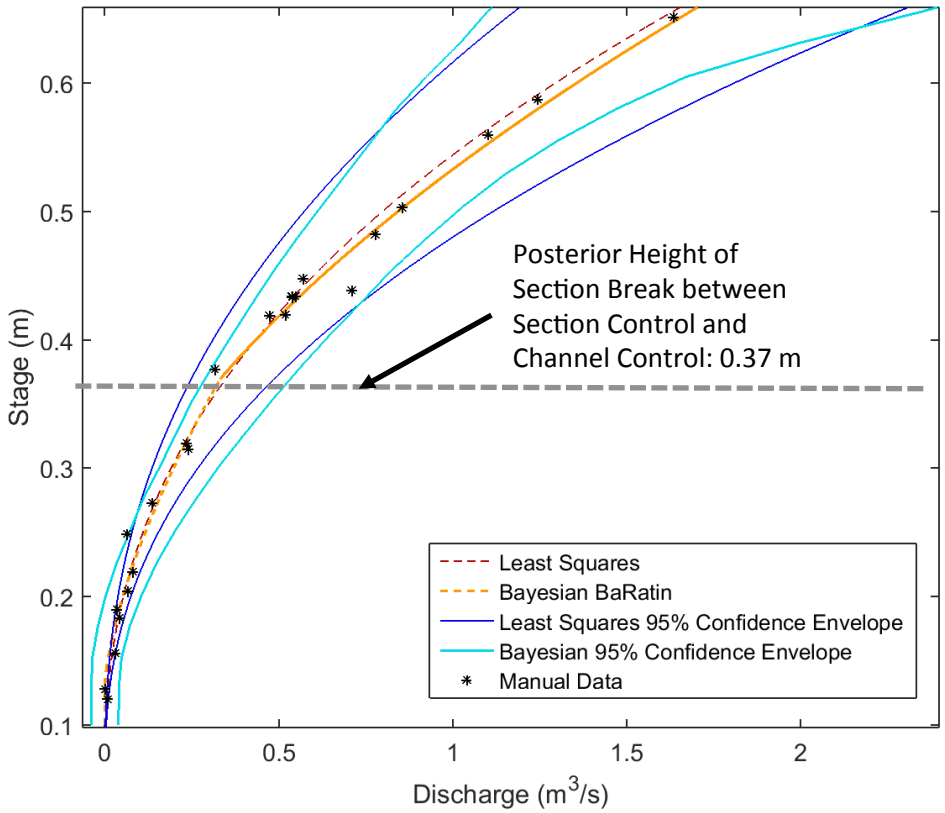
BaRatin (stage in m, Q in cms):

1.07m < H <= 1.2m
Q = 41.69*(H – 0.79033)^1.692

0.369561m < H < 1.07m
Q = 6.157*(H – 0.19283)^1.685

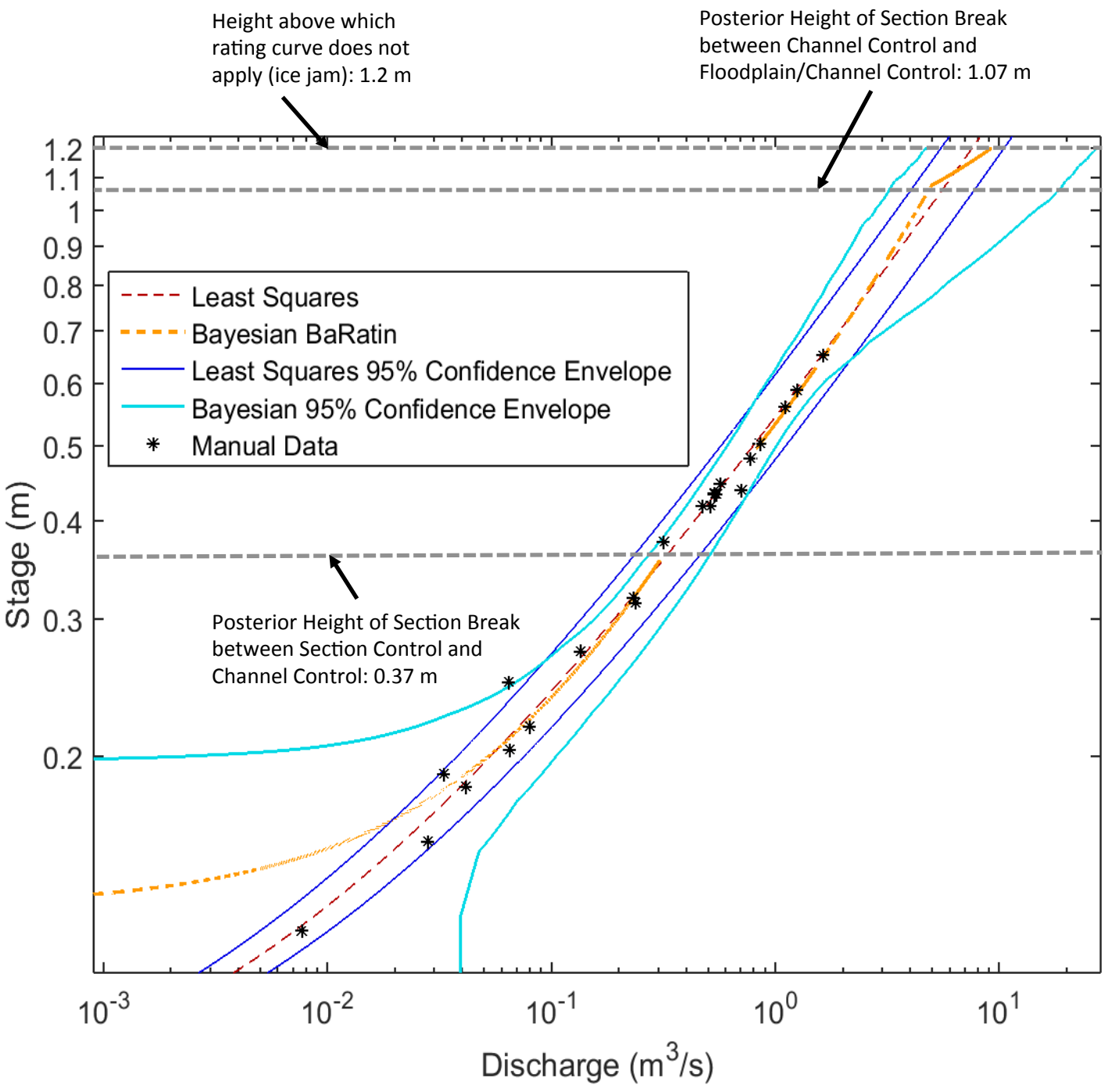
H < 0.369561m
Q = 2.903*(H – 0.12934)^1.525





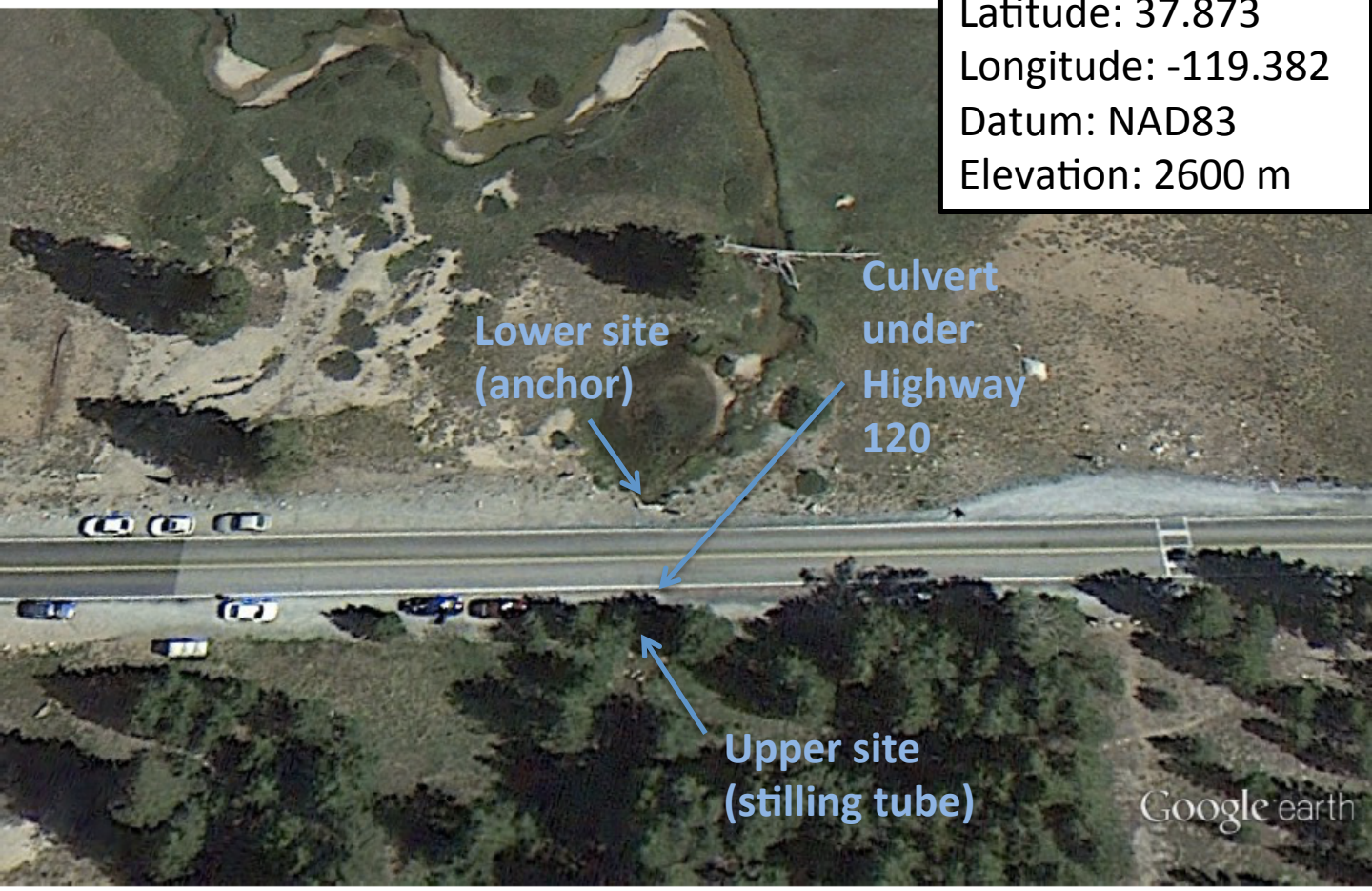
Log-Log View

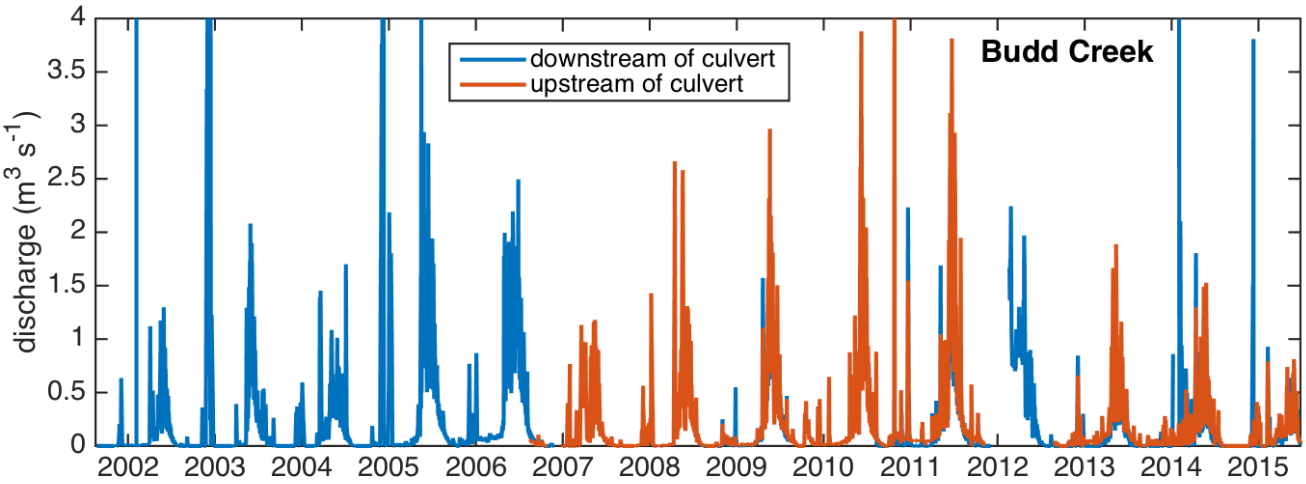
Delaney Creek

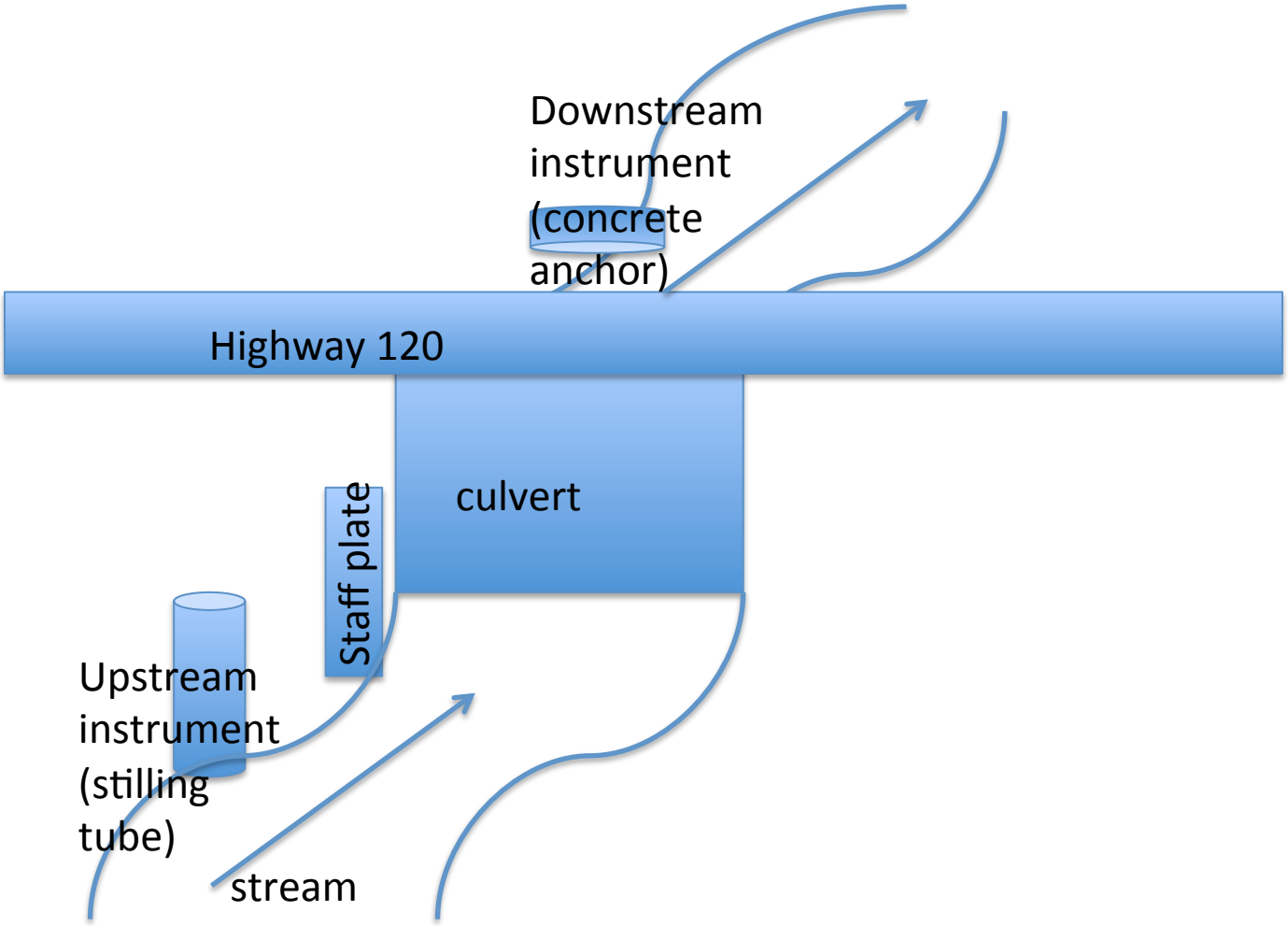


Budd Creek

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

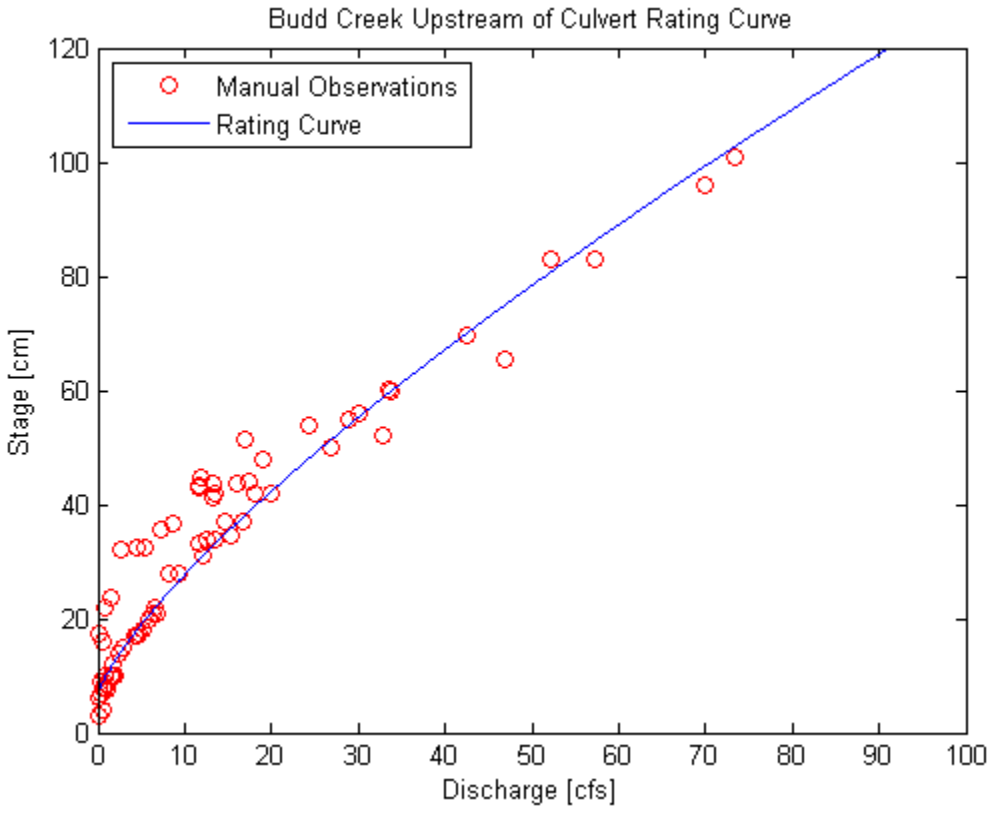
The upstream site serves as the principal record, except in the case of known ice jams or backwater affects. Occasionally water levels rise above the top of the culvert, therefore initiating higher recorded stage values which may not agree with rating curve estimated discharge values. In the event of 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.

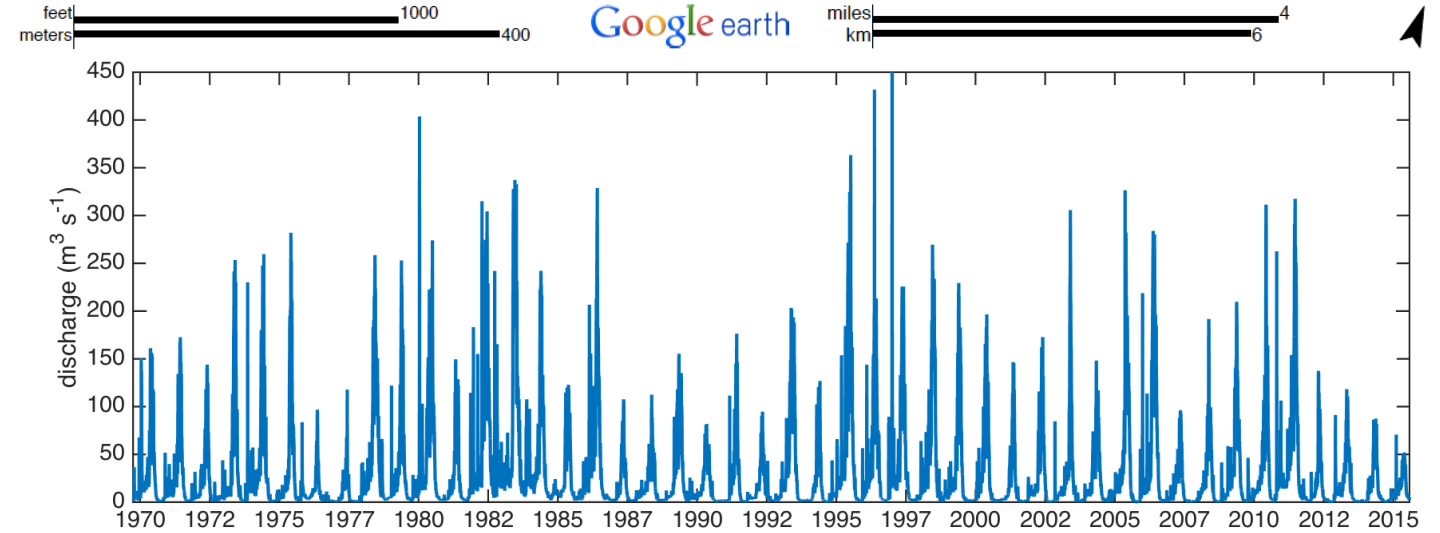
Downstream of culvert

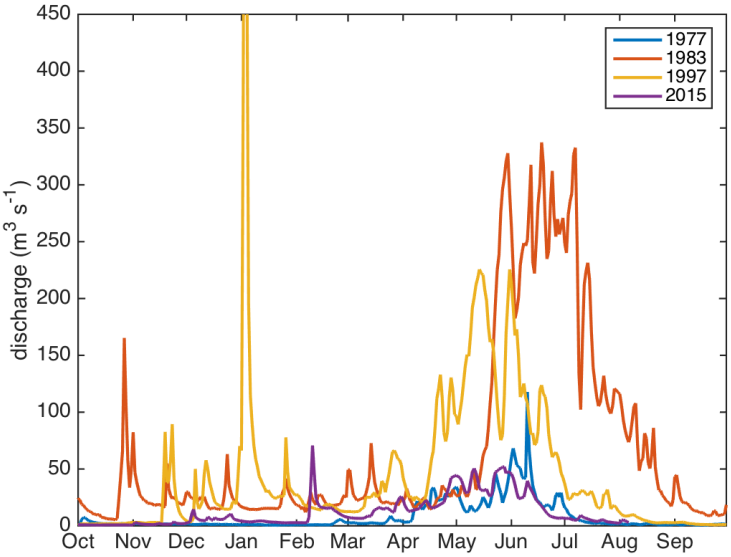
The downstream Solinst pressure transducer is located in concrete anchor. The anchor occasionally is moved during high flows, thus requiring an estimated offset in order to provide a consistent record. The upstream of culvert site therefore provides a preferred record for Budd Creek.



Rating curve for Budd Creek upstream of culvert. Q=.182(stage-6.5)^ 1.3139. The rating curve for downstream of the culvert is 0.0245*(stage -10).^1.7951.

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.