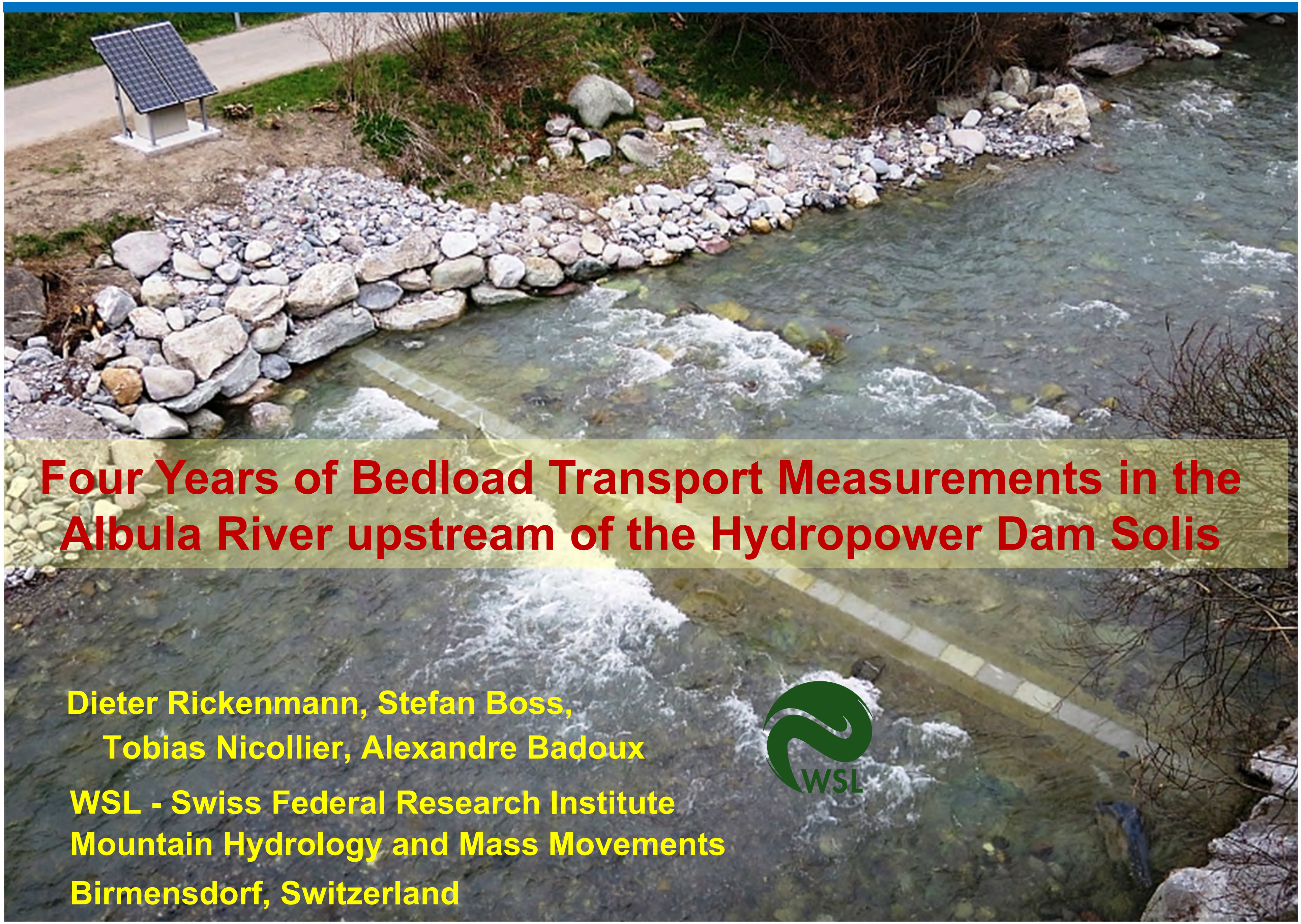

Four Years of Bedload Transport Measurements in the Albula River upstream of the Hydropower Dam Solis

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WSL - Swiss Federal Research Institute Mountain Hydrology and Mass Movements

Birmensdorf, Switzerland

Content

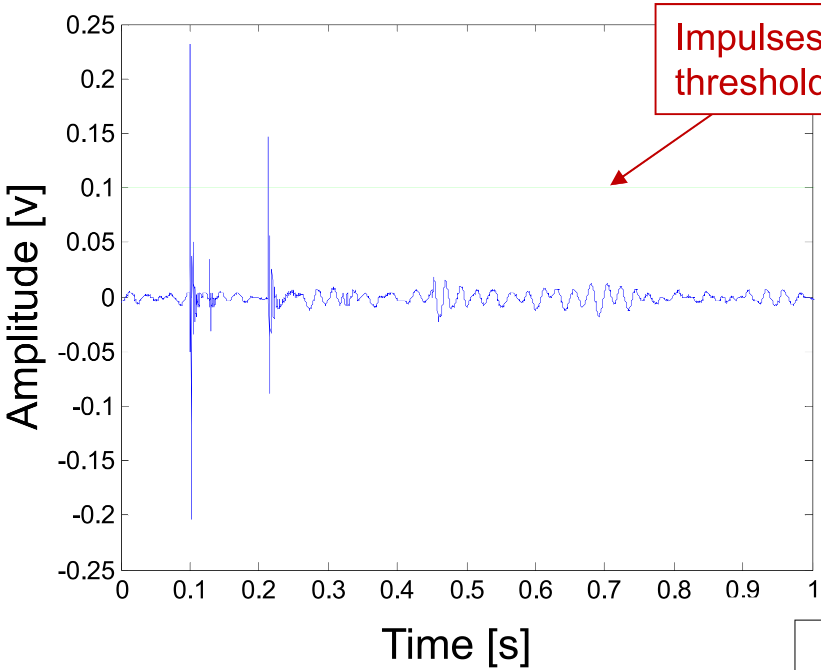
Swiss plate geophone (calibration) measurements at various sites

Stream	Location	Drainage area [km^2]	Operation period (sensor type)	Calibration
Erlenbach (basin)	Alptal, Schwyz, CH	0.7	1986-1999 (PBIS), 2000+ (GS)	yes
Erlenbach (bridge)	Alptal, Schwyz, CH	0.5	1995-1997 (PBIS), 2002+ (GS)	–
Vogelbach	Alptal, Schwyz, CH	1.6	1999+ (GS)	–
Pitzbach	Pitztal, Tyrol, AT	27	1994-1995 (PBIS)	yes
Spissibach	Leissigen, Berne, CH	2.5	1998-2010 (PBIS)	yes
Rofenache	Vent, Tyrol, AT	98	2000+ (GS)	yes
Drau	Lienz, Tyrol, AT	1876	2002+ (GS)	yes
Drau	Dellach, Carynthia, AT	2300	2006+ (GS)	yes
Isel	Lienz, Tyrol, AT	1199	2006+ (GS)	yes
Schweibbach	Eisten, Valais, CH	9.7	2007+ (GS)	–
Fischbach	Mühlau, Tyrol, AT	71	2008+ (GS)	yes
Ruetz	Mutterbergalm, Tyrol, AT	28	2008+ (GS)	yes
Riedbach	Grächen, Valais, CH	18.7	2009+ (GS)	yes
Nahal Eshtemoa	Negev Desert, Israel	119	2009+ (GS)	yes
Elwha River	Washington, USA	833	2009+ (GS)	yes
Navisence	Zinal, Valais, CH	82	2011+ (GS)	yes
Ötztaler Aache	Sölden, AT	444	2011+ (GS)	yes
Urslau	Maria Alm, Salzburg, AT	55	2011+ (GS)	yes
Suggadinbach	St. Gallenkirch, AT	75	2013+ (GS)	yes
Ashiaraidani	Hodako Observatory, JP	6.5	2013+ (GS)	yes
Solda River	Valle Venosta, I	130	2014+ (GS)	yes
Albula River	Tiefencastel, CH	529	2015+ (GS, AS)	yes
Avancon de Nant	Pont de Nant, Vaud, CH	13.5	2015+ (GS)	yes

GS = geophone sensor, AS = Acceleration Sensor, PBIS = piezoelectric bedload impact sensor

(Rickenmann 2017, JHE)

Swiss plate geophone: Example of signal, summary values



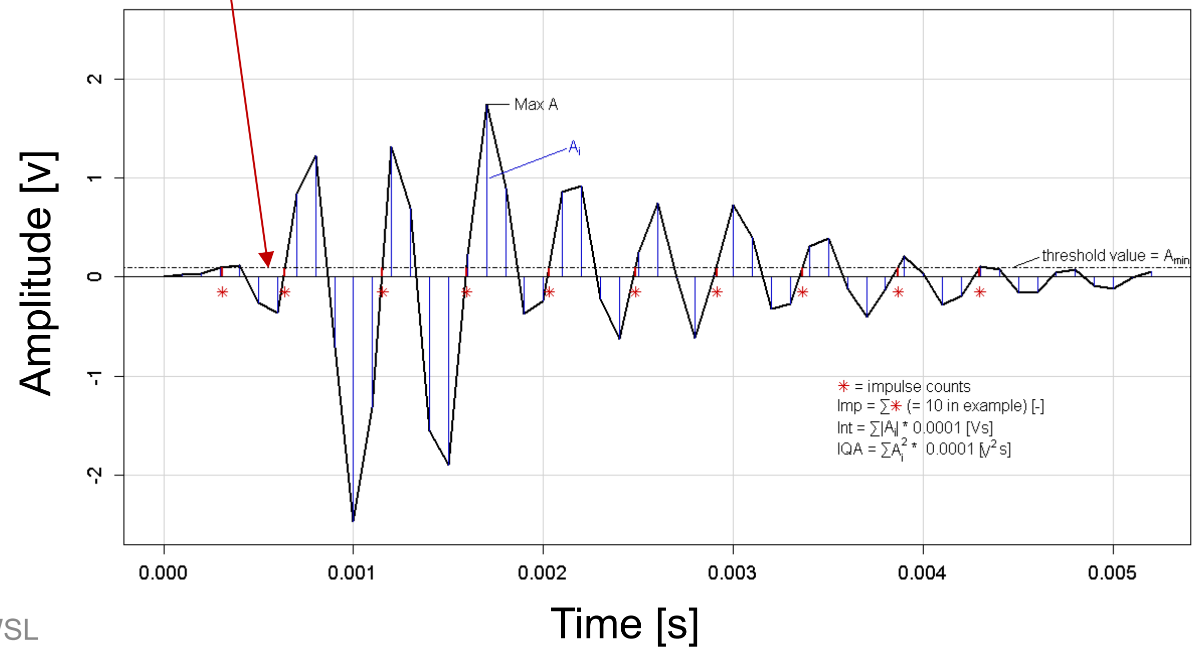
Impulses are recorded whenever the signal exceeds a predefined threshold value (on positive amplitude range), typically A_{min} = 0.1 V

Triggering and number of impulses depends on:

- grain size, grain shape, type of movement, number of grains, grain velocity
- limiting grain size is about 10 - 20 mm

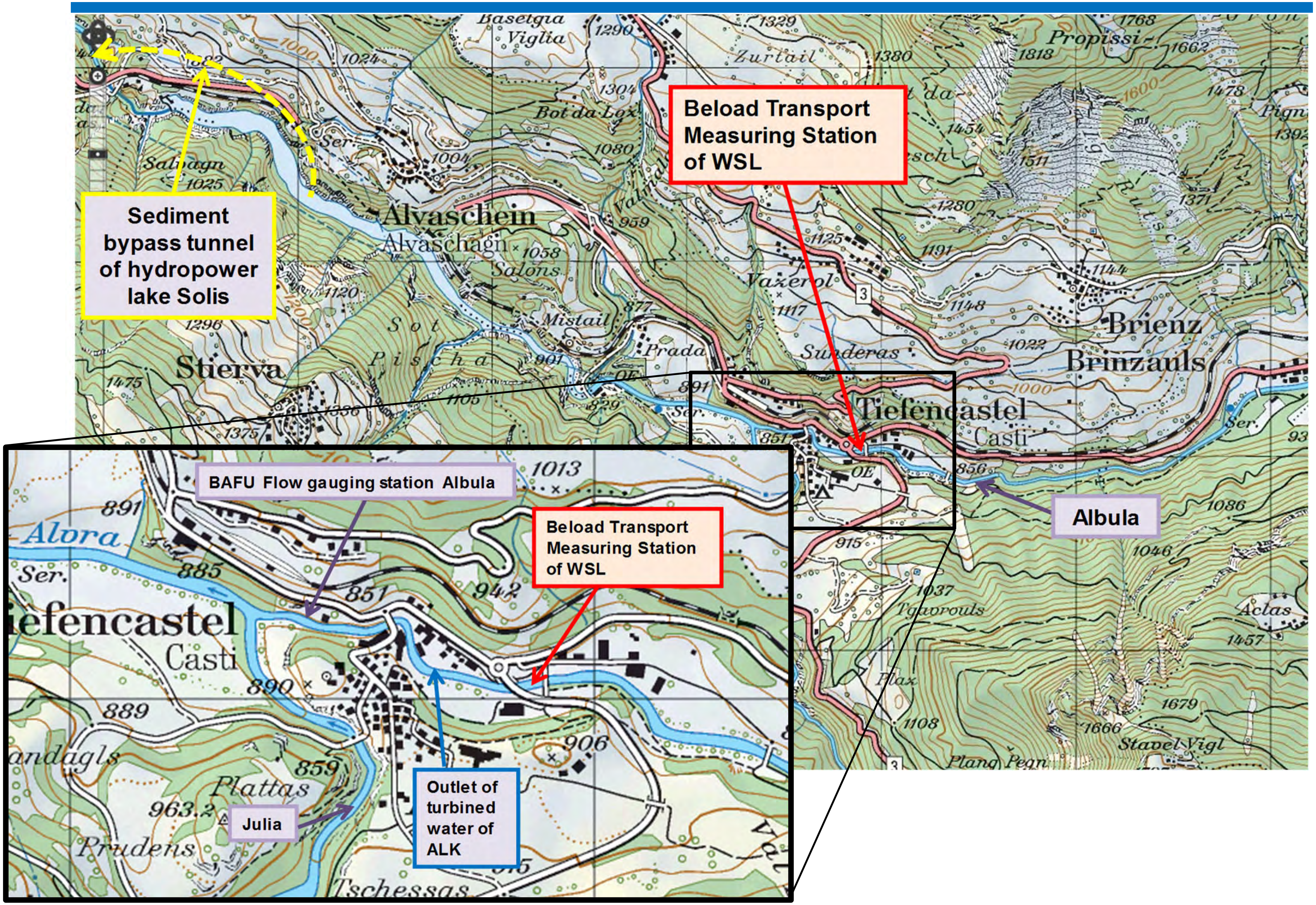
Raw signal is recorded only at a few sites during the calibration measurements.

(Rickenmann et al. 2014, ESPL)

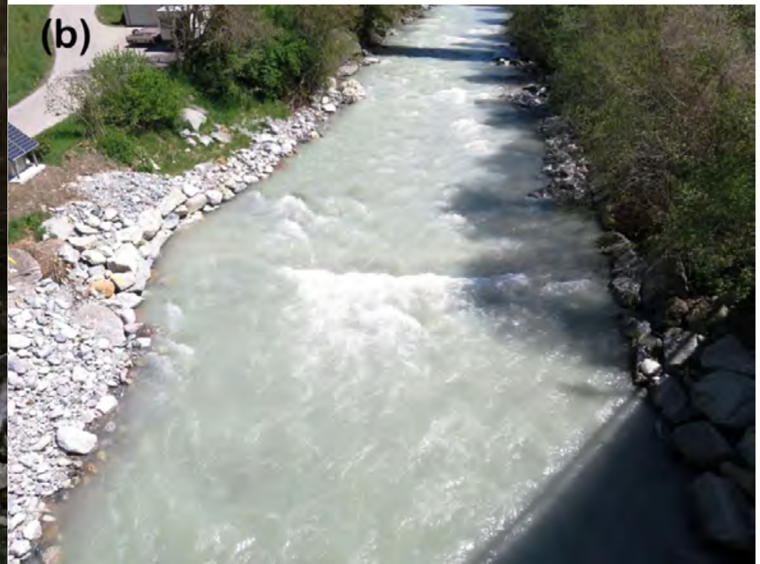


Content

Bedload transport measuring system at the Albula River



Bedload transport measuring system at the Albula River



	Albula at Tiefencastel
Catchment size	529 km^2
Channel slope	0.007
Channel width	15 m
Grain size D_{84}	0.16 m
Grain size D_{50}	0.065 m
10-year peak discharge	107 m^3/s
100-year peak discharge	128 m^3/s

The view on the photos is upstream. (a) Both geophone (orange) and accelerometer (violet) sensors are installed. (b) medium flow conditions on 7 May 2015 with a discharge of about 8 m^3/s.

(Rickenmann et al. 2017, PIAHS)

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1) Swiss plate geophone (SPG) system

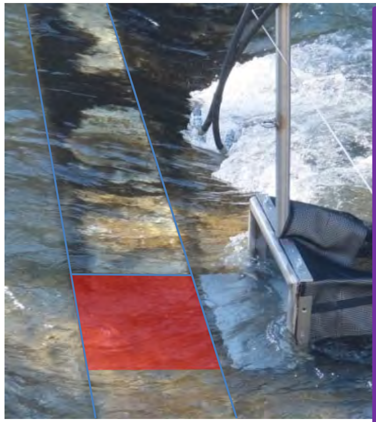
2) The measuring system at the Albula River

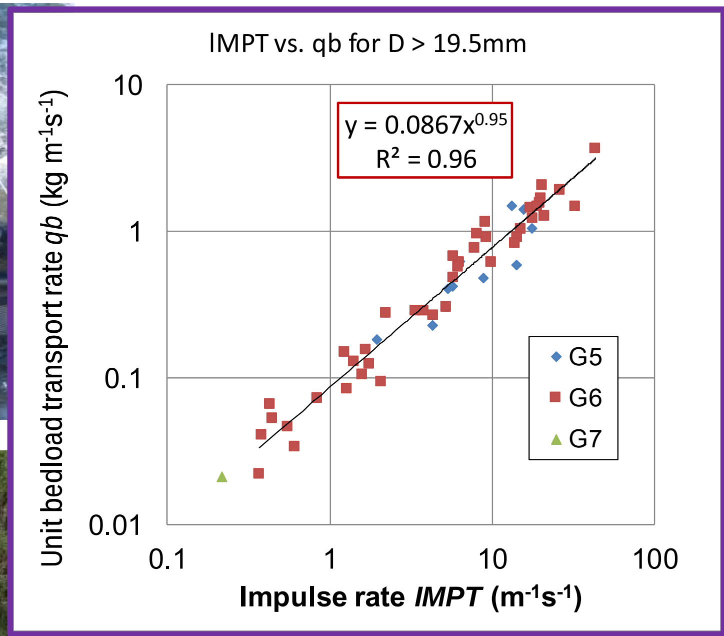
3) Direct bedload sampling for calibration

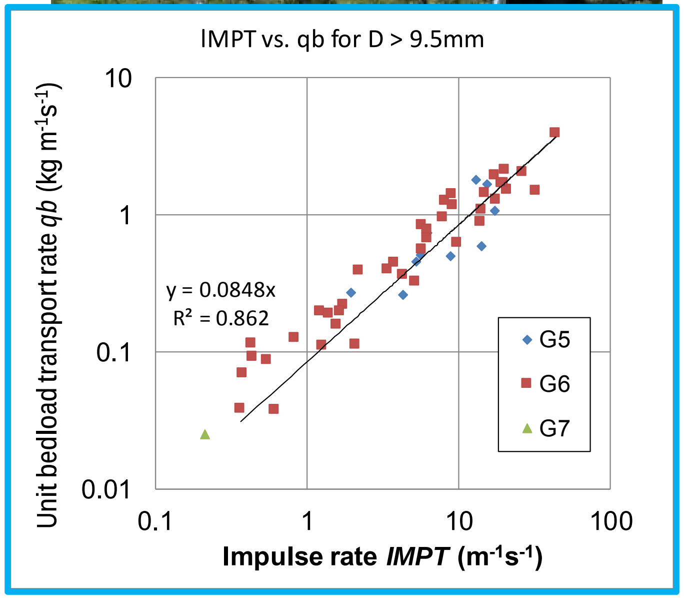
4) Bedload transport in the Albula River

5) Concluding remarks

Bedload transport measuring system at the Albula River







SNFS-DFG Research Project with TU Munich; calibration measurements in the Albula River

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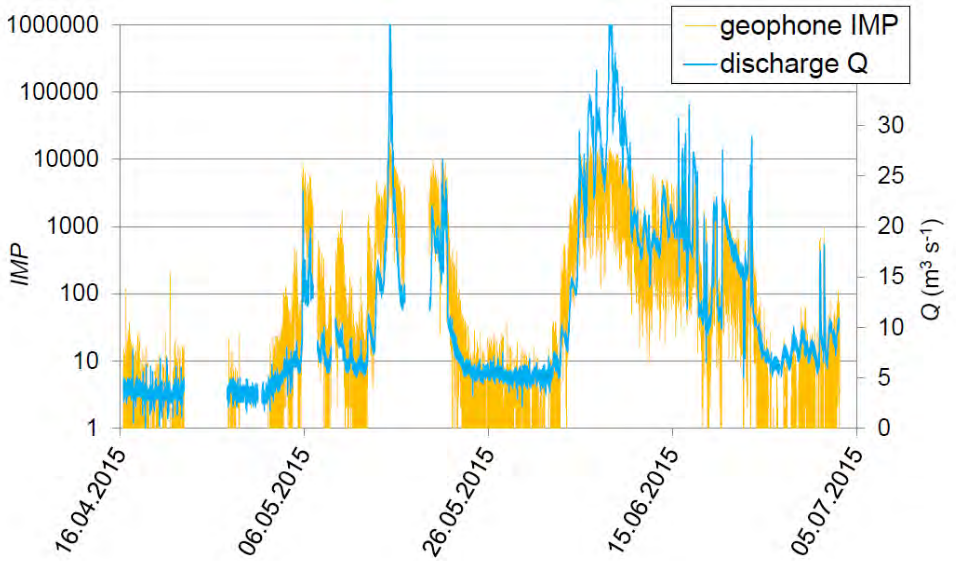
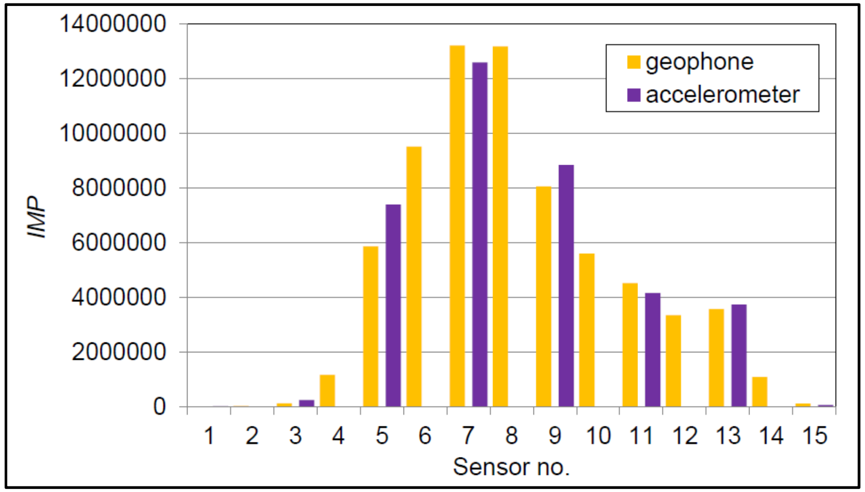
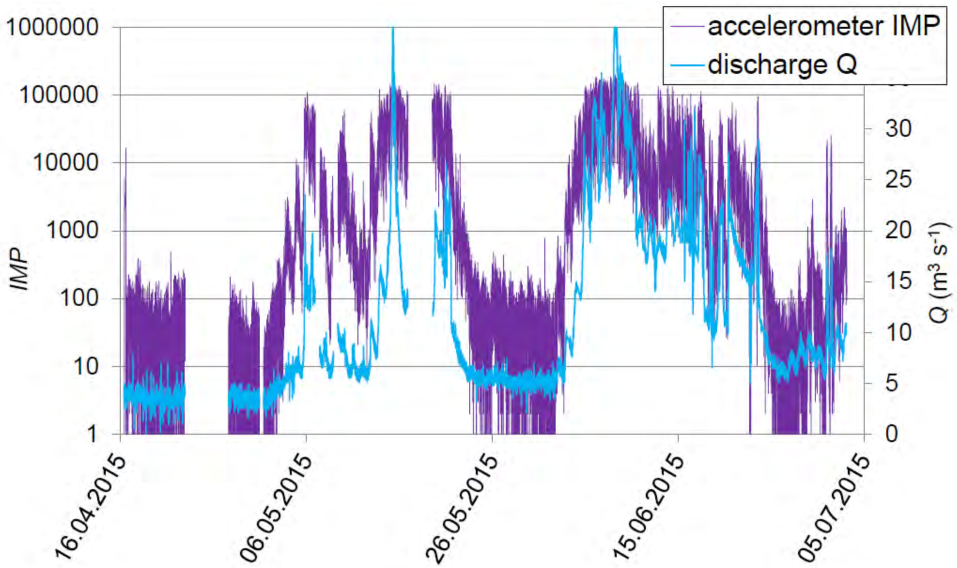
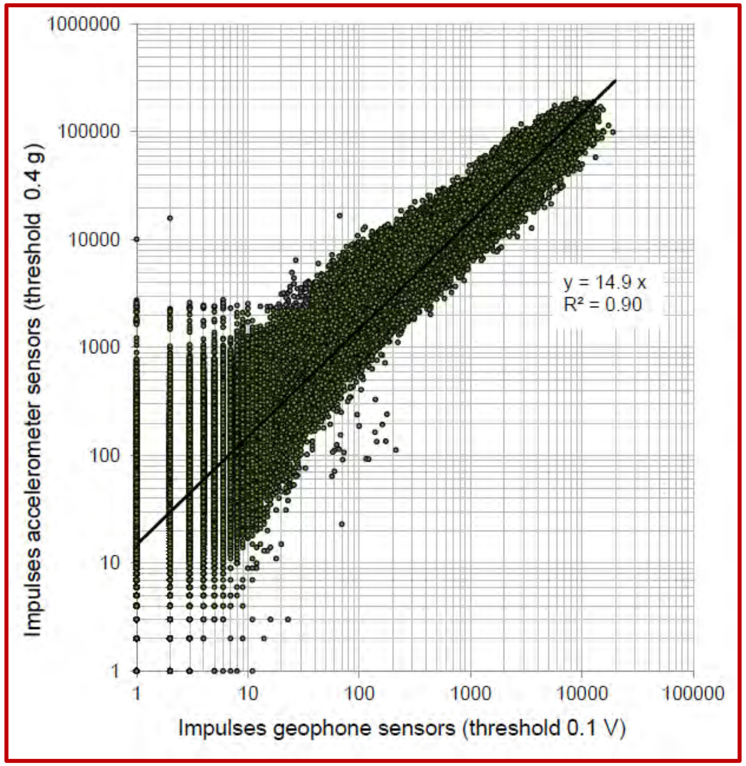






(Rickenmann et al. 2017, PIAHS)



(Rickenmann 2017, JHE)

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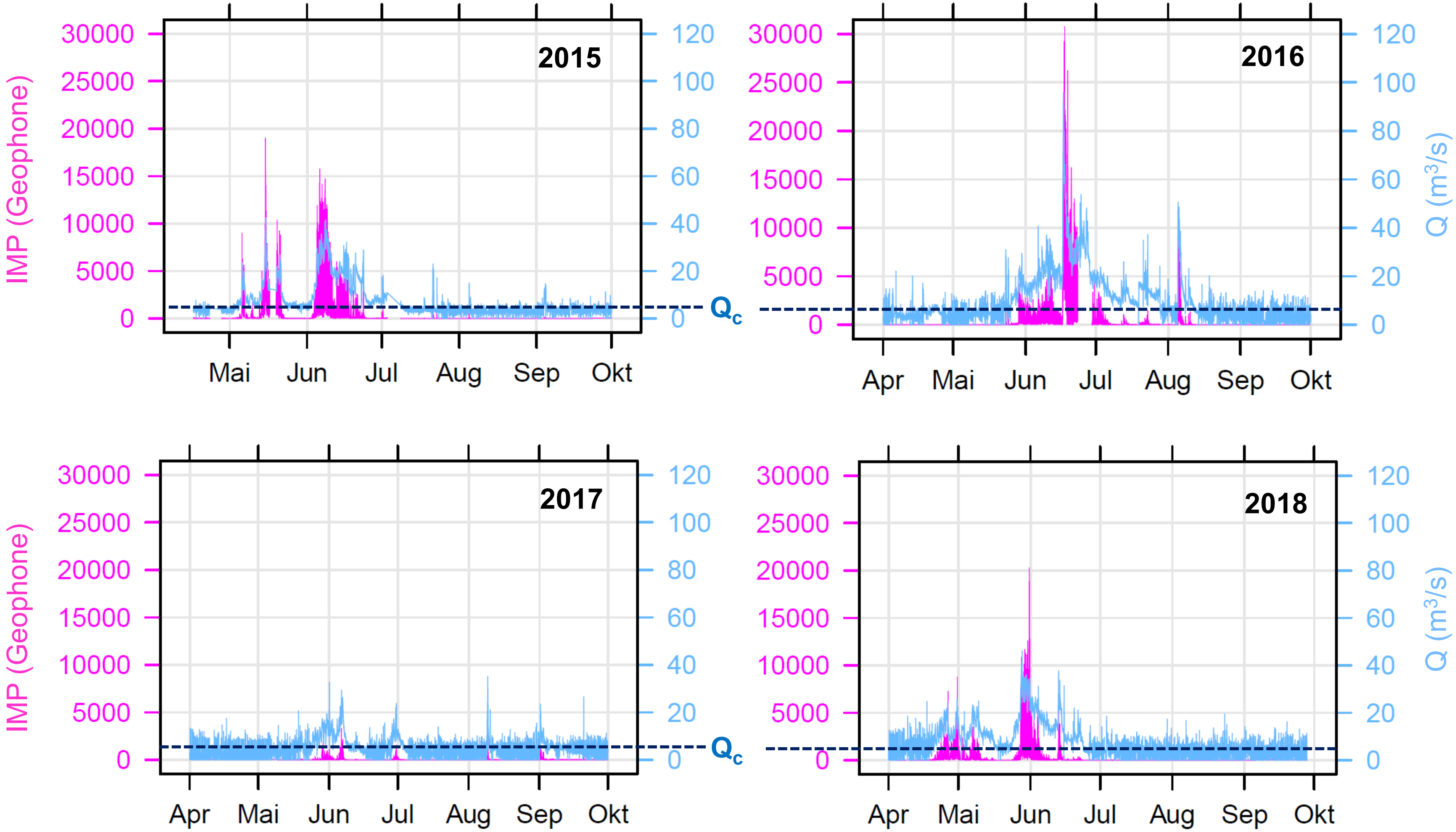
Bedload transport at the Albula River 2015 - 2018



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Q_c = critical discharge at initiation of bedload transport

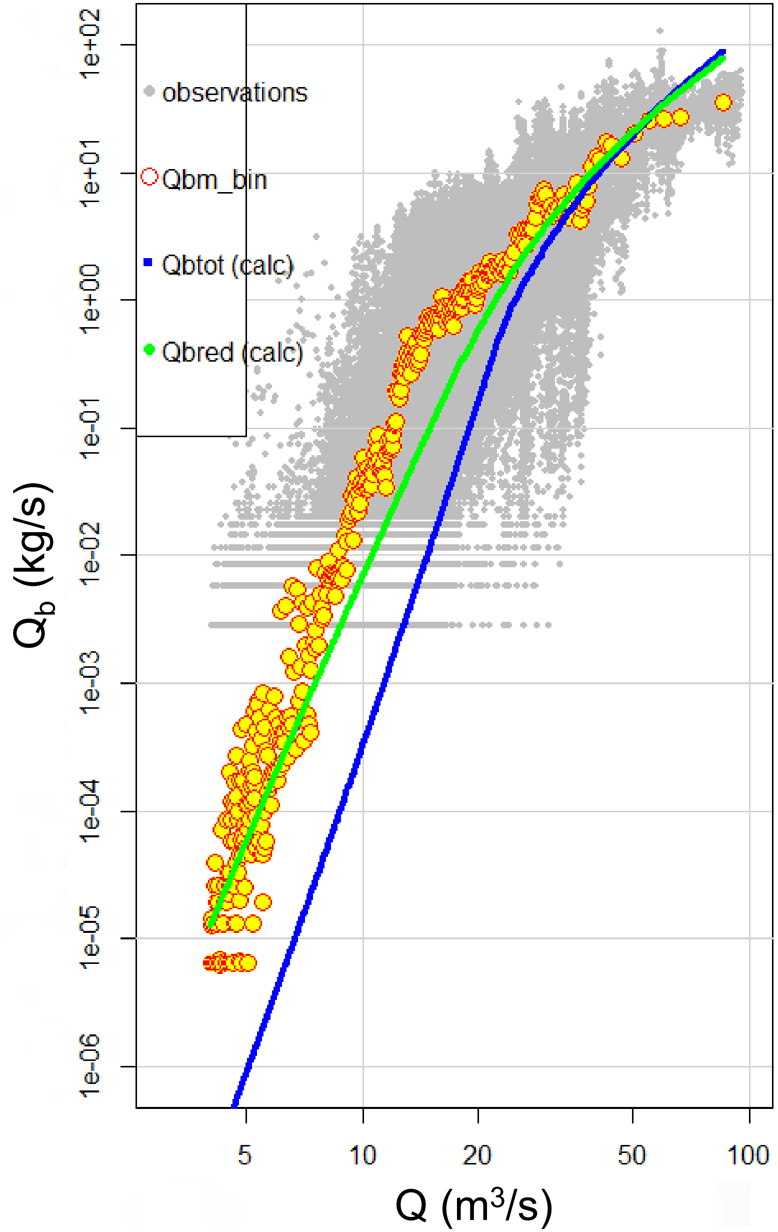
Bedload transport Q_b: observations and calculation

Observations with SPG

- Bedload transport rate Q_b: Albula Summer 2016
- linear calibration with kb = 11.7 for D>9.5mm
- Qbm_bin: binned data

Calculations

- Use two methods described in Schneider et al. (2015, WRR, eq. 13, eq. 14), modified equation of Wilcock & Crowe (2003)
- Qbtot: using total shear stress, combined with reference shear stress of 0.051 (slope dependent)
- Qbred: using reduced shear stress with method of Rickenmann & Recking (2011), combined with reference shear stress of 0.03 (slope independent)



Comparison: deposits in Solis lake; other mountain rivers

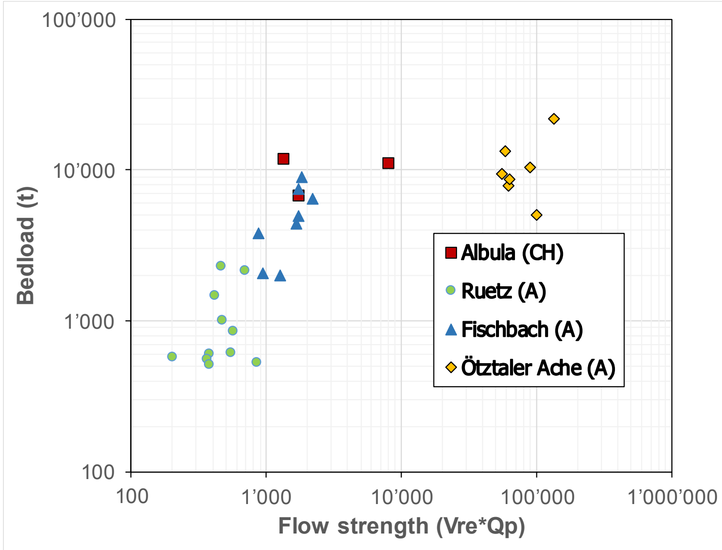
From surveys of the sediment deposits in the hydropower lake, on average the total annual volume of sediment transported into lake Solis is about 80 000 m^3 (Oertli and Auel, 2015), which is largely input from the Albula River.

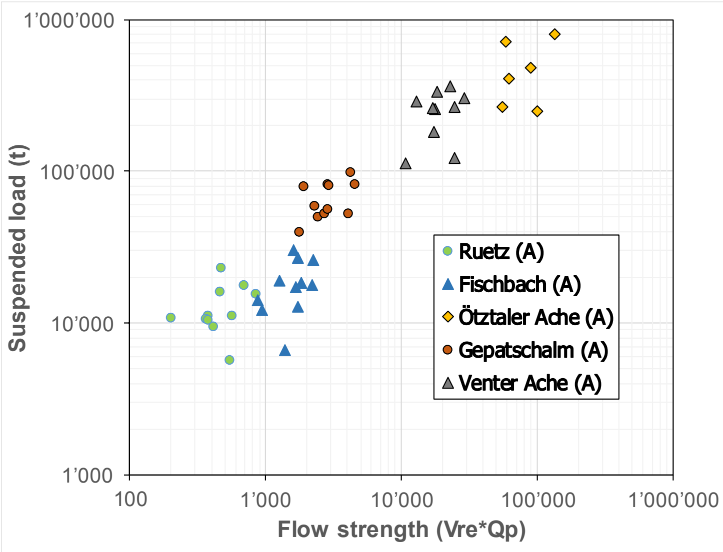
A comparison is made here with the mean value of coarse bedload transport (over three years 2015, 2016, 2018) for particles with D > 9.5 mm:

Albula river	
mean Bedload mass	9937 t
Bulk deposit density	1800 kg/m^3
Bedload deposit volume	5521 m^3
Annual deposit lake Solis	80’000 m^3
Bedload/Total load	0.07

Flood 2014: about 80 000 m^3 transported through bypass tunnel (SPG measurements) (Hagmann et al., 2015)

Mountain rivers in Austria (A):
- Bedload measurements with SPG system (of WSL);
- All data courtesy of TIWAG hydropower company, Innsbruck





V_{re} = ∫(Q-Q_c)dt = effective runoff volume
Q_p = annual peak discharge

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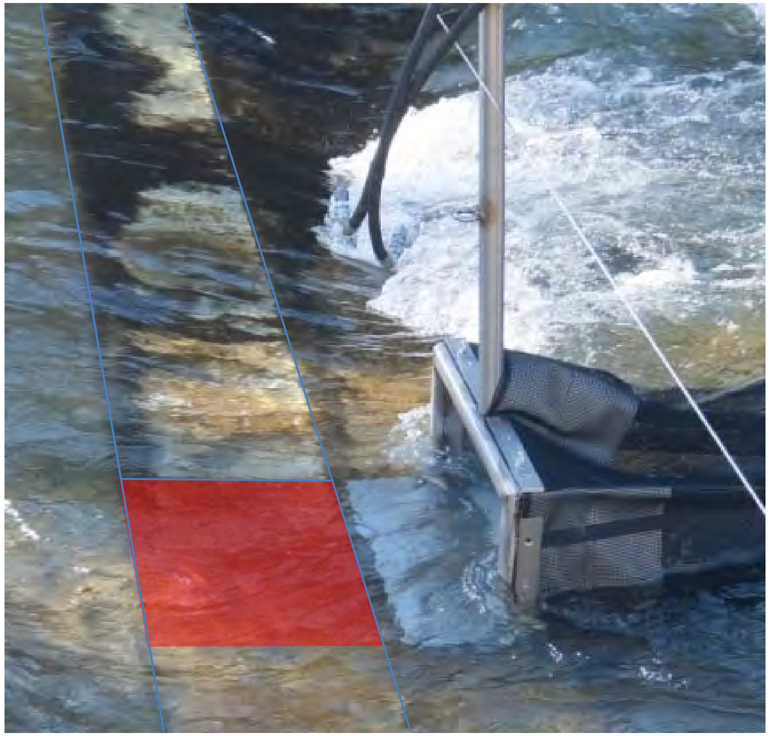
Concluding remarks

- The Swiss plate geophone (SPG) system has been successfully calibrated to determine bedload flux in the Albula River
- Annual bedload (and suspended load) can be estimated roughly as a function of the effective runoff volume and the (annual) peak discharge
- Along with a similar measuring system installed at the outlet of the sediment bypass tunnel, a sediment budget for the Solis lake can be established
- The SPG measurements are used by the EWZ hydropower company to optimize the duration of flushing operations through the bypass tunnel
- SPG or similar acoustic bedload transport measurements are helpful to improve the process understanding of bedload transport

Thank you for your attention



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Bedload transport at the Albula River 2015 - 2018