Swiss experience in monitoring sediment and wood fluxes

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Content

1) Flood event in August 2005 in CH

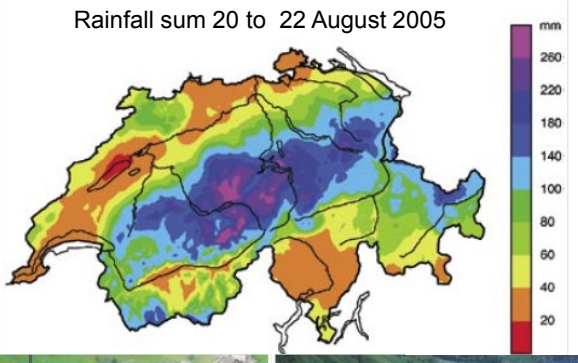
2) Bedload monitoring with geophones

3) Large wood during the 2005 flood

4) Conclusions

Floods of August 2005 in Switzerland:

Rainfall sum 20 to 22 August 2005



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Floods of August 2005 in Switzerland:

Debris flows, sediment transport and large woody debris

- high and long lasting flood flows in mountain rivers, many channel avulsions
- debris flows and intense sediment in torrent catchments
- insufficient discharge capacity and blockage of flow cross-sections
- large amounts of woody debris entrained
- considerable damage to infrastructure (e.g. traffic routes) and settlements

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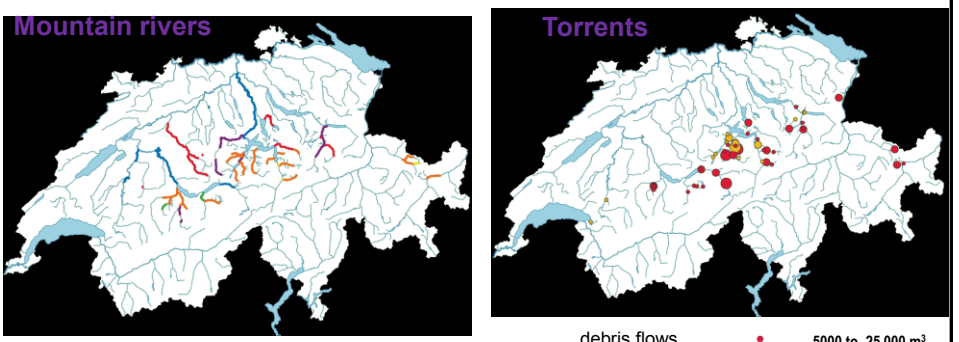
Floods of August 2005: documentation of channel processes



2005 Events: Observations on transported sediment volumes for
- **34 debris flow events**
- **39 flood events with fluvial bedload transport**

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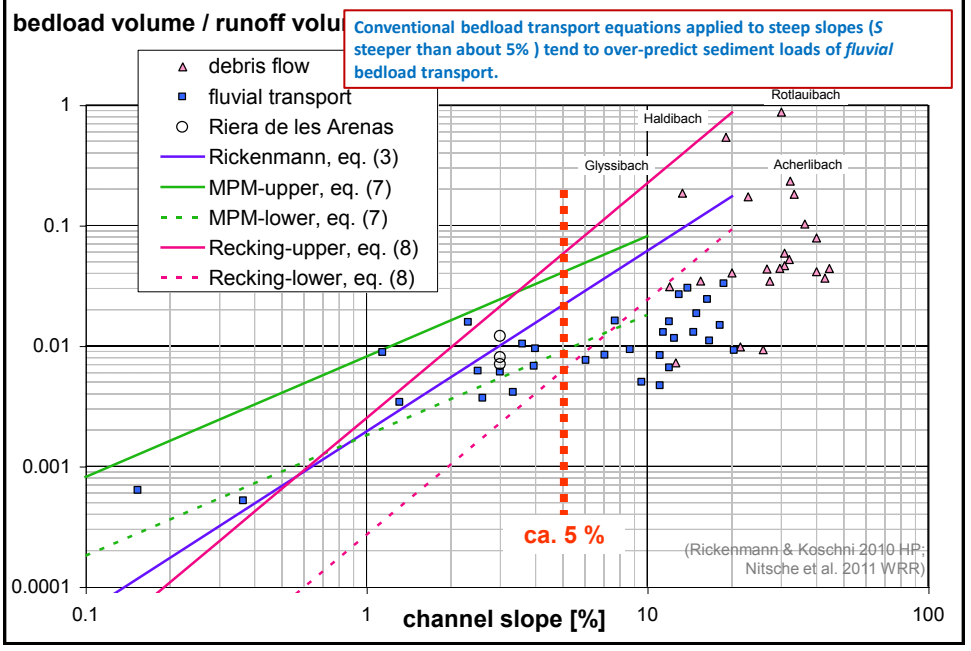
(Rickenmann & Koschni 2010 HP)

Floods 2005 and bedload transport formulae



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1) Flood event in August 2005 in CH

2) Bedload monitoring with geophones

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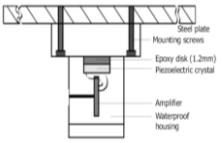
The standard design of the WSL system

- Steel plate 36 cm x 50 cm
  - acoustically isolated
- Geophone sensor fixed in the center
  - records vibrations

Old piezoelectric bedload impact sensor

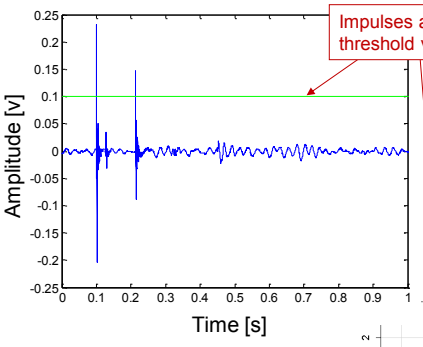


New geophone sensor

Old version of the aluminum housing for the geophone sensors

New version of the aluminum housing which is water-tight

Signal and recorded geophone summary values

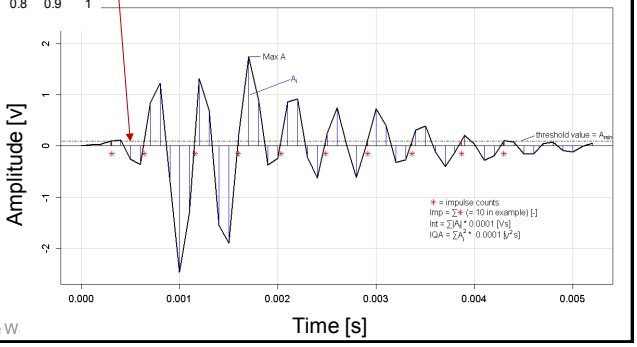


Impulses are recorded whenever the signal exceeds a predefined threshold value (on positive amplitude range), typically A_{min} = 0.1 V

At most measuring sites, we record the following geophone summary values:

- Impulses
- Integrals / Squared integrals
- Max. Amplitude

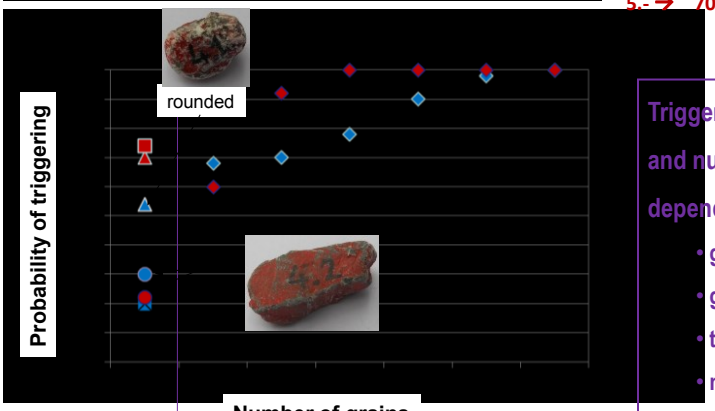
Raw signal is recorded only at a few sites during the calibration measurements.



(Rickenmann et al. 2014 ESPL)

Triggering of impulses

Code	mass	b-axis
4.- →	50g pebbles	28 - 34 mm
5.- →	70g pebbles	28 - 47 mm



Triggering of impulses and number of impulses depend on:

- grain size
- grain shape
- type of movement
- number of grains
- grain velocity

→ limiting grain size is about 20 mm (b-axis)

(Böckli 2011; Rickenmann et al. 2012, 2014)

The Erlenbach bedload observatory

- small catchment (0.7 km^2)
- long-term sediment transport observations (>25 years)
  - Bedload transport rates are measured in various ways
- step-pool morphology

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Swiss plate geophone measurements at various sites

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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)	
Drau	Dellach, Carynthia, AT	2300	2006+ (GS)	yes
Isel	Lienz, Tyrol, AT	1199	2006+ (GS)	
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
Navisence	Zinal, Valais, CH	82	2011+ (GS)	yes
Ötztaler Aache	Sölden, AT	197	2011+ (GS)	yes
Urslau	Maria Alm, Salzburg, AT	55	2011+ (GS)	yes
Elwha River	Washington, USA	833	2009+ (GS)	yes
Suggadinbach	St. Gallenkirch, AT	75	2013	(yes)
Solda River	Valle Venosta, I	130 (?)	2014 (?)	(yes)
Albula River	Tiefencastel, CH	529	2015	(yes)

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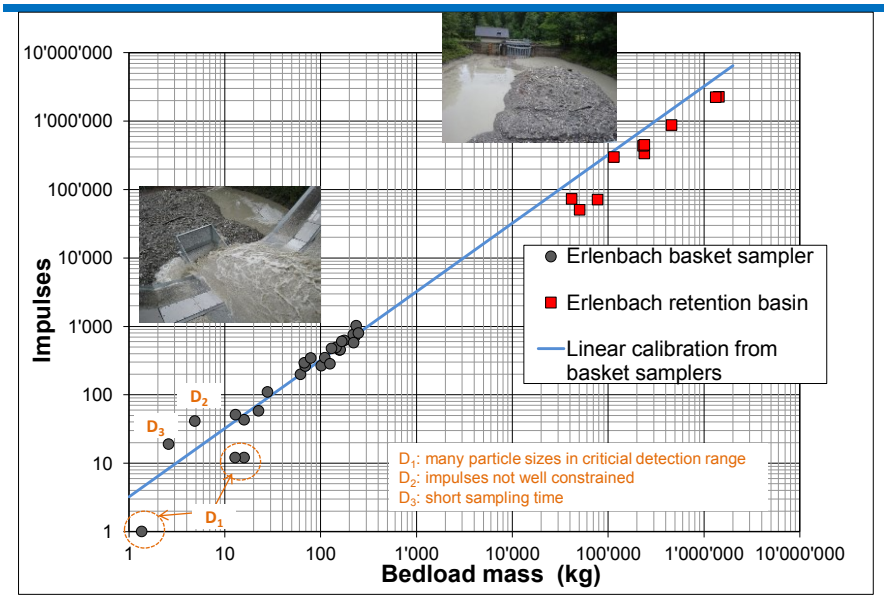
GS = geophone sensor,
PBIS = piezoelectric bedload impact sensor

(Rickenmann et al. 2014)

Calibration of the geophon system at the Erlenbach



→ **Linear calibration between impulses and bedload mass works well at Erlenbach**

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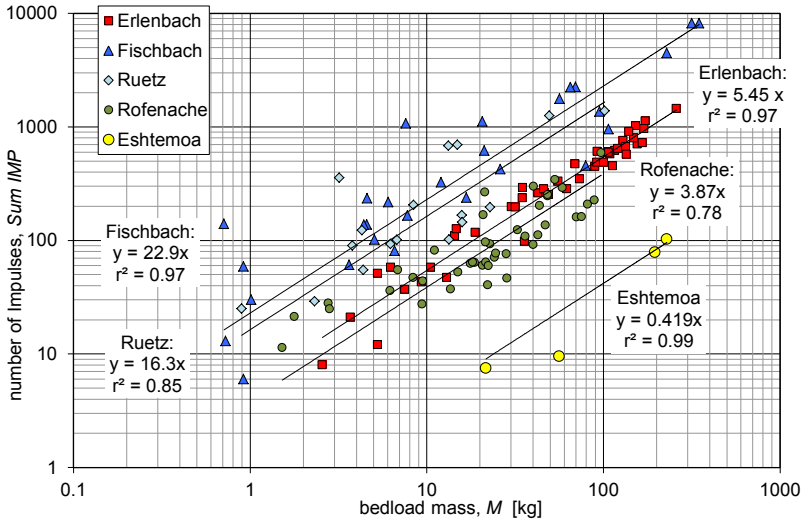
(Rickenmann et al. 2012 ESPL)

Comparison of geophone calibrations at different sites



→ Calibration relations differ for various streams; → Larger scatter at some sites
→ Local hydraulics and particle (transport) characteristics are probably important

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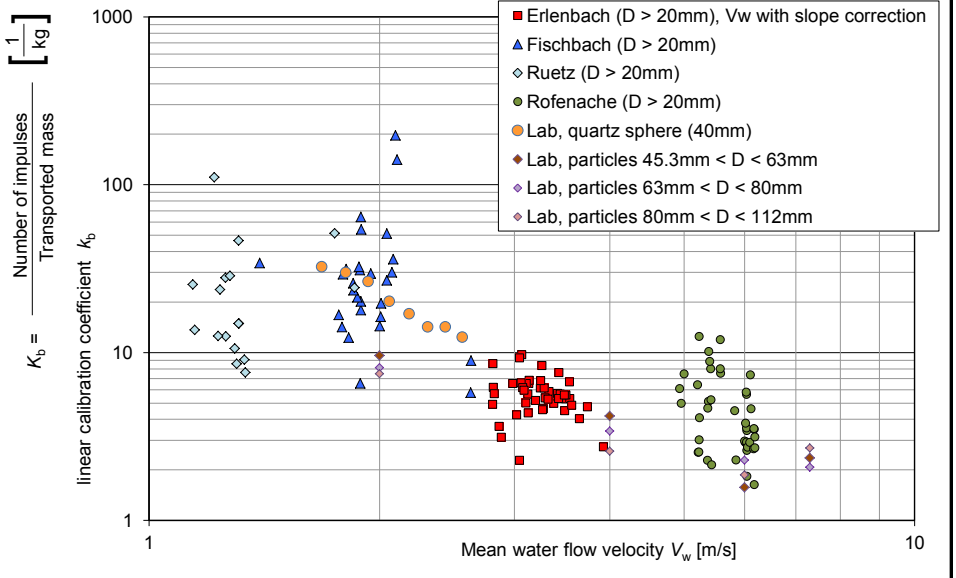
Comparison of geophone calibrations at different sites



→ Flow or particle velocity likely explains part of differences in mean calibration coefficient

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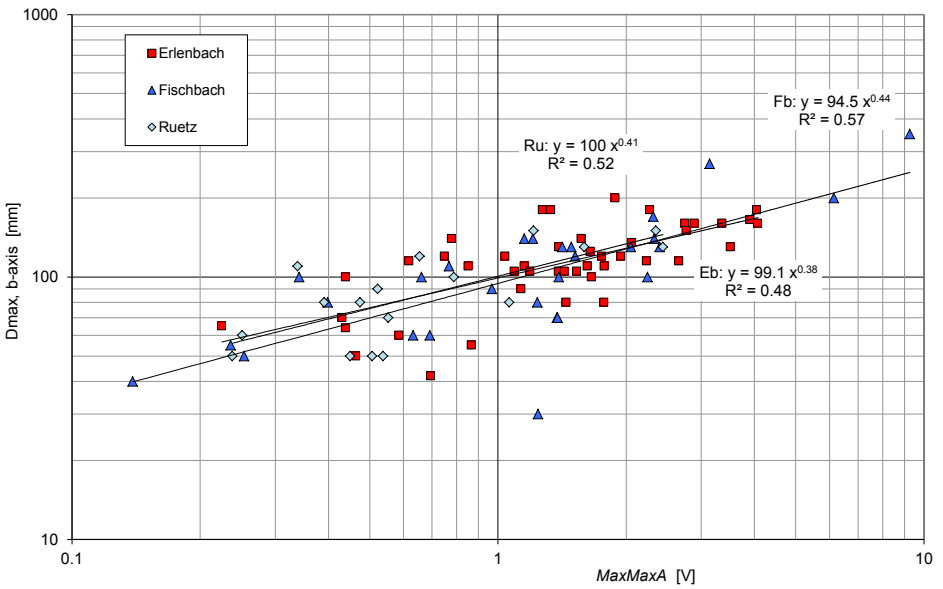
Comparison of geophone calibrations at different sites



→ **Maximum grain size correlates with signal strength, almost independent of site**

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Grain size estimation ?

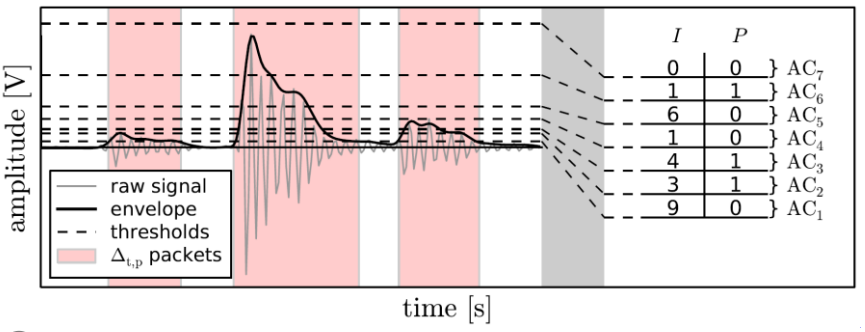
Hypothesis:

→ **Amplitude Histogram method**

→ displacement of the plate proportional to the size of the transported particle

→ every particles collides only once against the steel plate

→ amplitude thresholds can discriminate between grain-size classes



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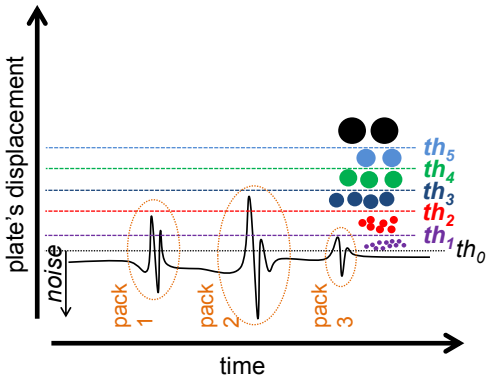
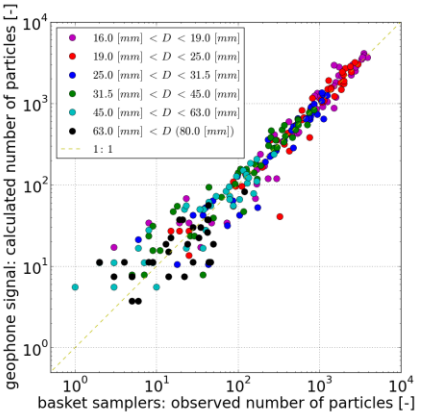
Grain size estimation: Amplitude Histogram method





Analysis of moving basket bedload samples at Erlenbach

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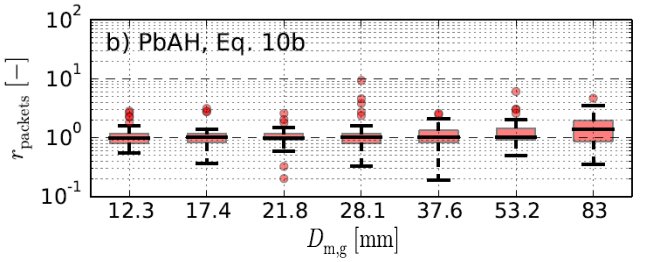
Grain size estimation at the Erlenbach

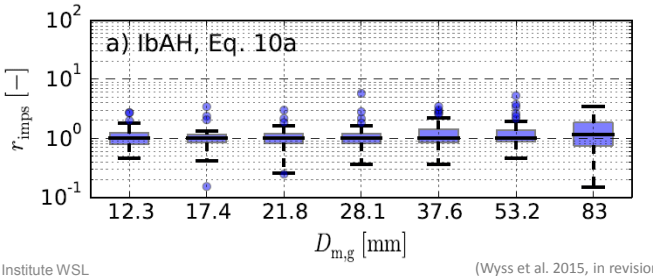
r = ratio of calculated to observed bedload mass

$D_{m,g}$ = mean diameter of grain-size class

PbAH = Pack based Amplitude Histogram method



IbAH = Impulse based Amplitude Histogram method



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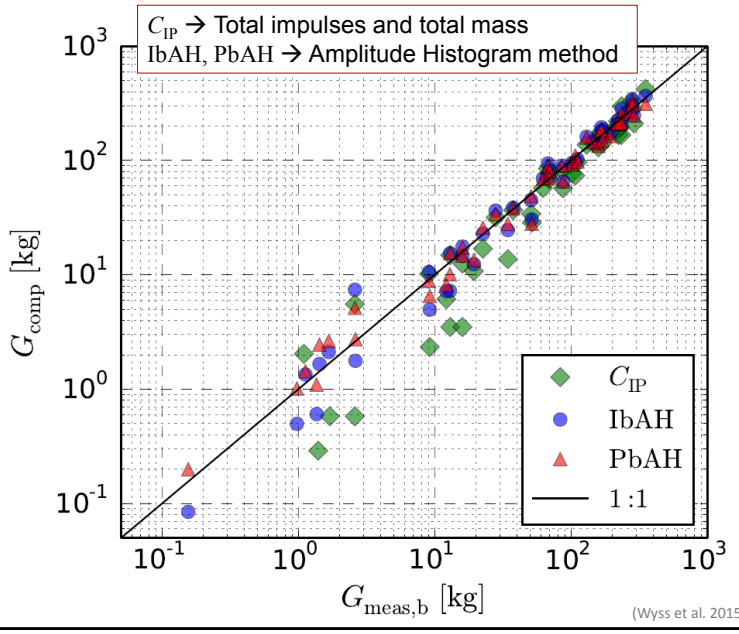
Erlenbach: Comparison of calibration approaches



(Wyss et al. 2015, in revision)

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Clogging by large wood at many locations

Grosse Melchaa (Obwalden, CH)

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Clogging by large wood at many locations

Reuss (weir at Perlen, canton Luzern, CH)

Lake of Thun (canton Berne, CH)

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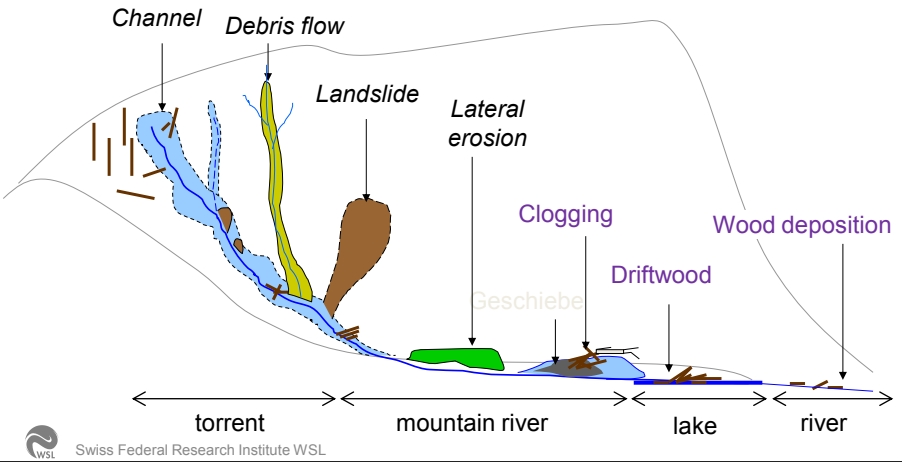
Analysis of large wood (LW) of 2005 flood events

→ Sources of woody debris
→ Case studies to construct LW budgets
→ Composition of transported woody debris
→ Recommendations for future stream management



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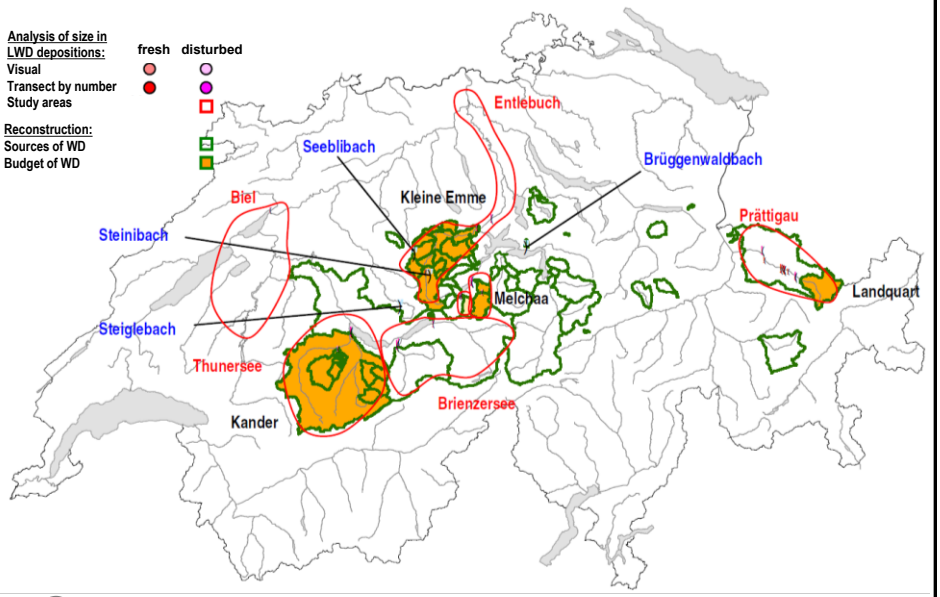
Study catchments for LW analysis



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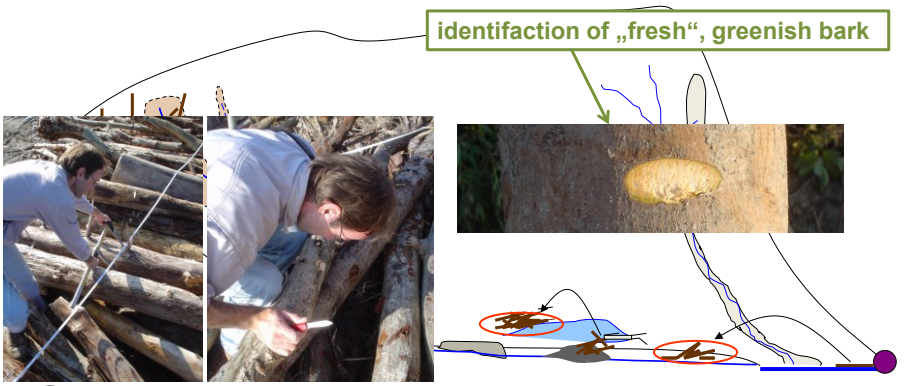
Large wood characteristics

Determination of characteristics of "deposited" woody debris:

- Size of peaces (diameter, length)
- tree type
- degree of weathering



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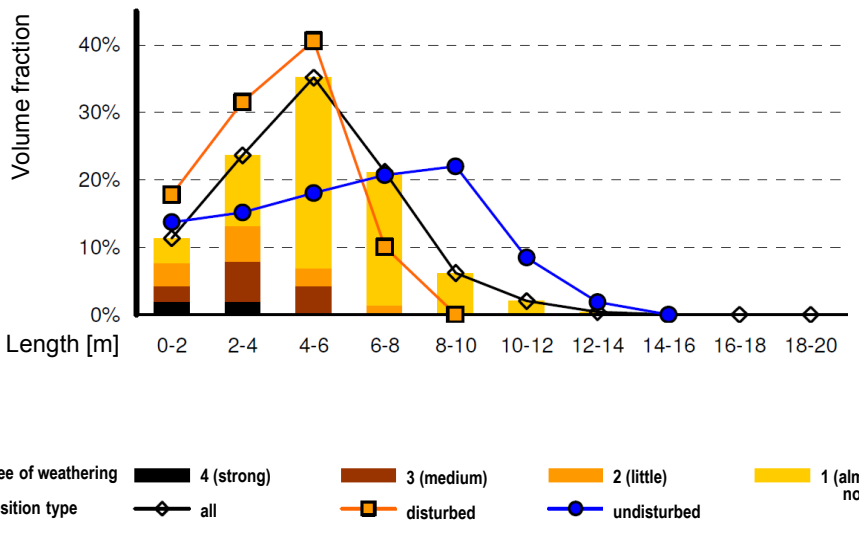
Characteristics of „deposited“ LW: length of pieces



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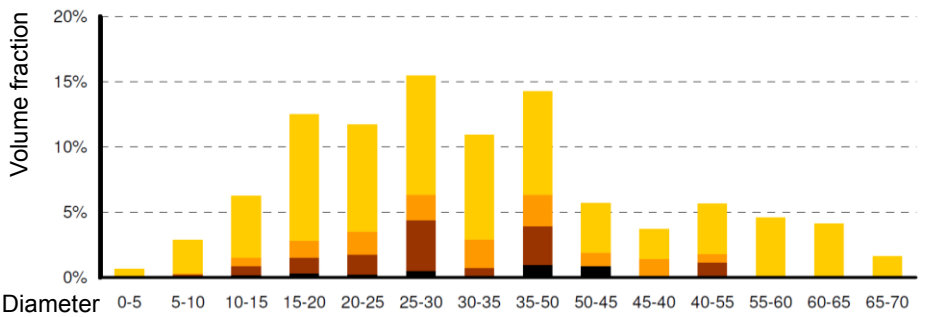
Characteristics of „deposited“ LW: diameter of pieces



Degree of weathering
- 4 (strong)
- 3 (medium)
- 2 (little)
- 1 (almost none)

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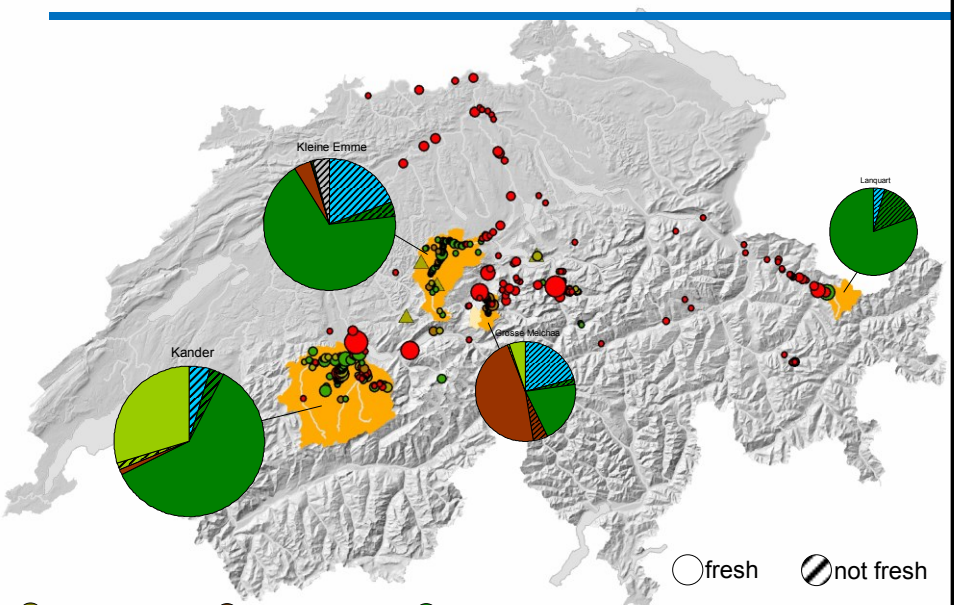
Processes of LW entrainment



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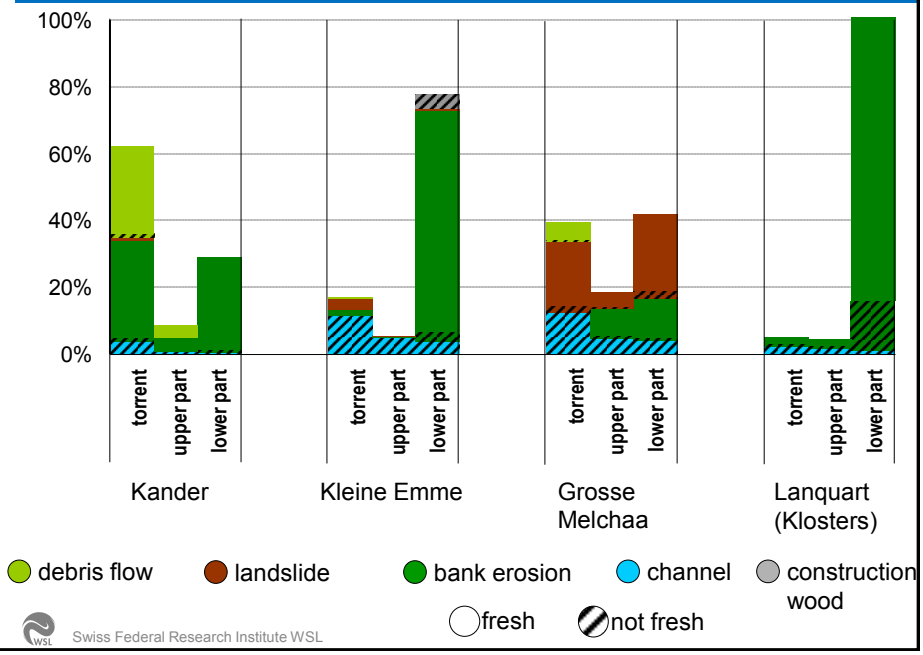
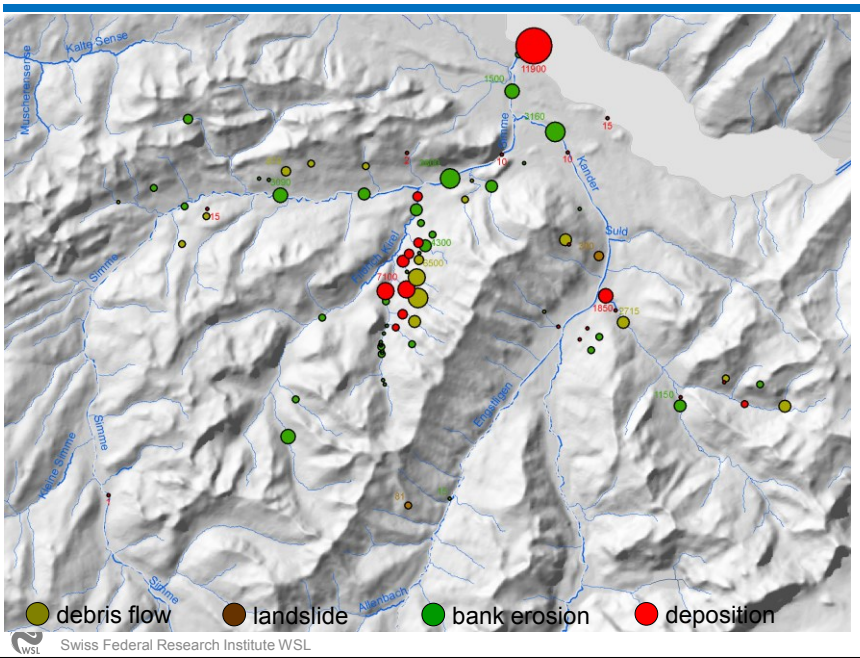
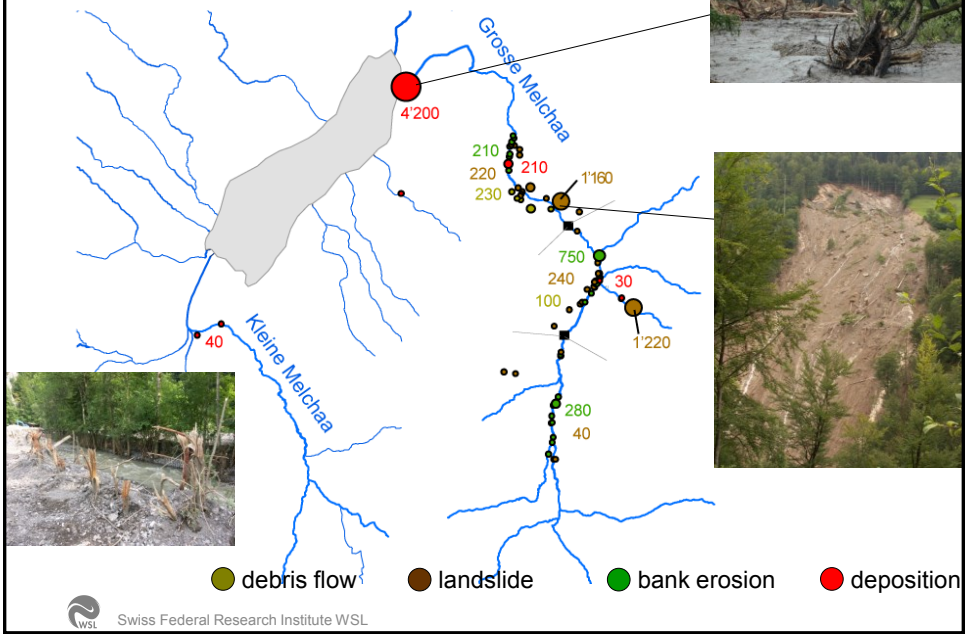
Processes of LW entrainment



Example of LW budget: Kander



Example of LW budget: Melchaa



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Summary of LW budgets

Summary of estimation of LW input or entrainment and LW deposition or extraction.

(*) The numbers indicate total volumes of large wood without pore spaces [m^3]

Catchment	Input [m^3] (*)		Deposition [m^3] (*)	
	best estimate	minimum/maximum	best estimate	minimum/maximum
Kander	30'700	23'900 / 58'200	23'500	10'900 / 26'300
Kleine Emme	5500	4300 / 7300	5300	4500 / 6600
Grosse Melchaa	5100	3600 / 8100	4400	3500 / 5400
Kleine Melchaa	40	20 / 100	40	20 / 100
Landquart, Klosters Dorf	4000	3900 / 4600	3700	3100 / 4400

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Conclusions: Large wood study

LW entrainment and deposition

- Floods 2005: long duration, high discharge and landslides enhanced problems with LW
- Main sources: debris-flow like processes, large landslides, lateral bank erosion
- Clogging at enginnering structures: main cause for large damage
- Transport and deposition of LW did not cause damage everywhere

Protection measures and emergency intervention

- Forest management can reduce (but not avoid) entrainment
- Rapid emergency intervention can reduce clogging risk (requires good communication and emergency management)
- To prevent clogging at engineering structures: free board, horizontal clearing, smooth upstream cover; LW dimensions relative to clearing
- Retention structures: if possible separate bedload and LW deposition

Conclusions: Swiss plate geophone system

Advantages of the system

- relatively cheap
- low maintenance
- continuous measurements at high temporal resolution
- robust, even for high-energy environments
- reasonable accuracy for total bedload mass estimates
- grain-size estimation of bedload for Erlenbach

Disadvantages of the system

- needs a fixed (stable) cross section (e.g. check dam)
- needs independent calibration
- lower limit of particle size (~2 cm)
- the effects of hydraulic conditions, particle shapes, g.s.d. and type of movement are all important

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Thank you for your attention

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