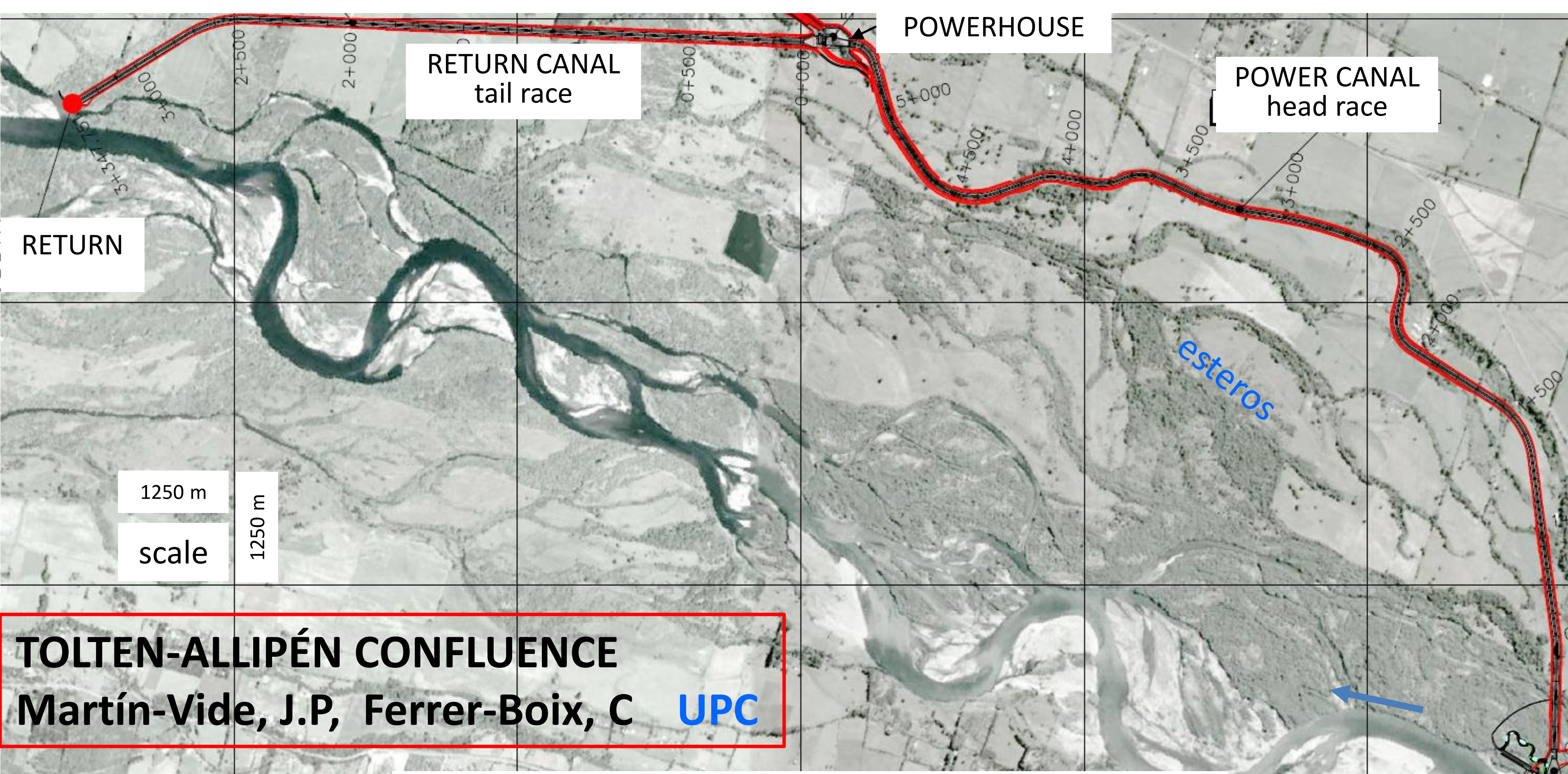


TOLTEN-ALLIPÉN CONFLUENCE

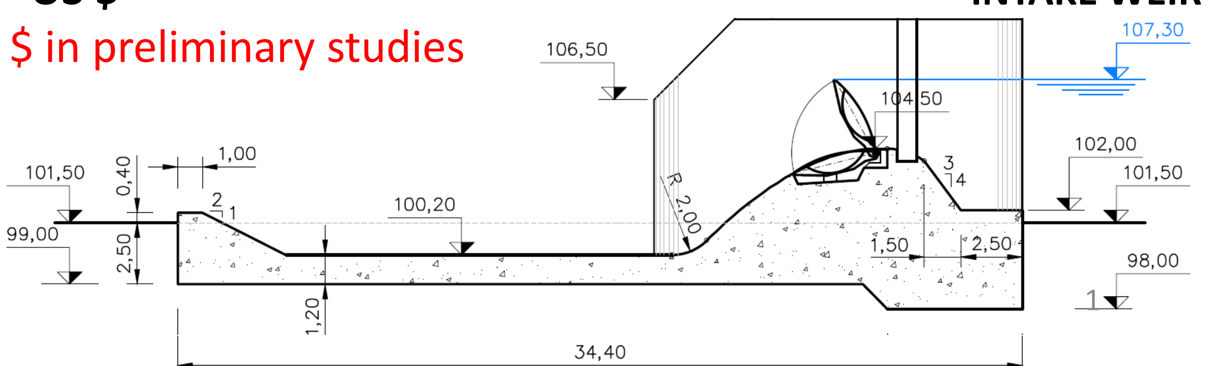
Martín-Vide, J.P, Ferrer-Boix, C UPC

Toltén river, Hydropower scheme

≈ 100 · 10^6 US $

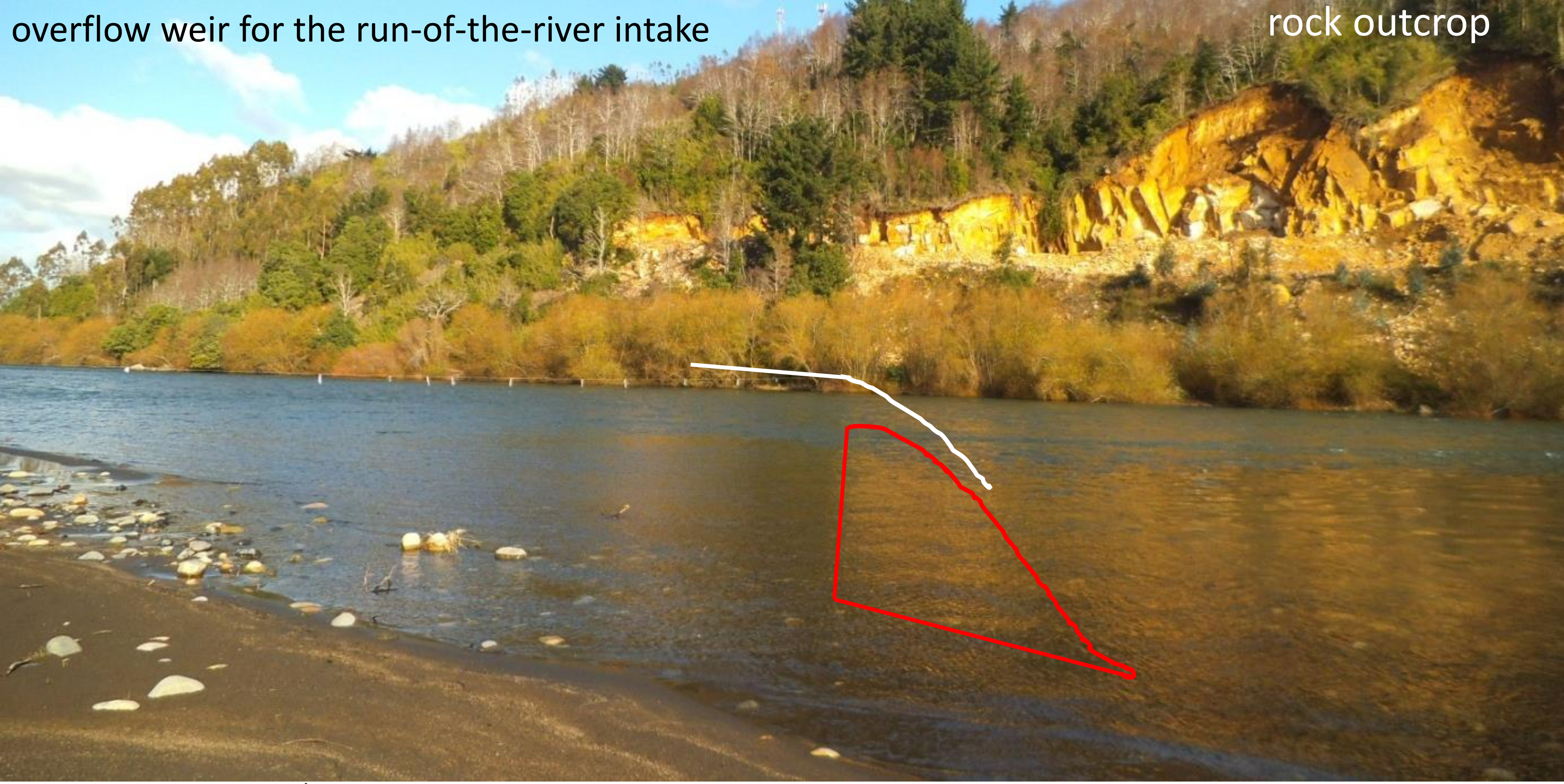
2 · 10^6 US $ in preliminary studies

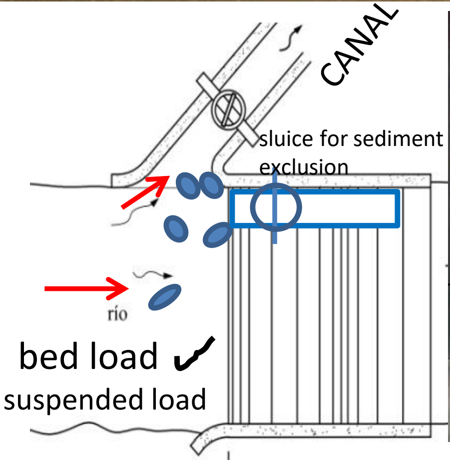
INTAKE WEIR

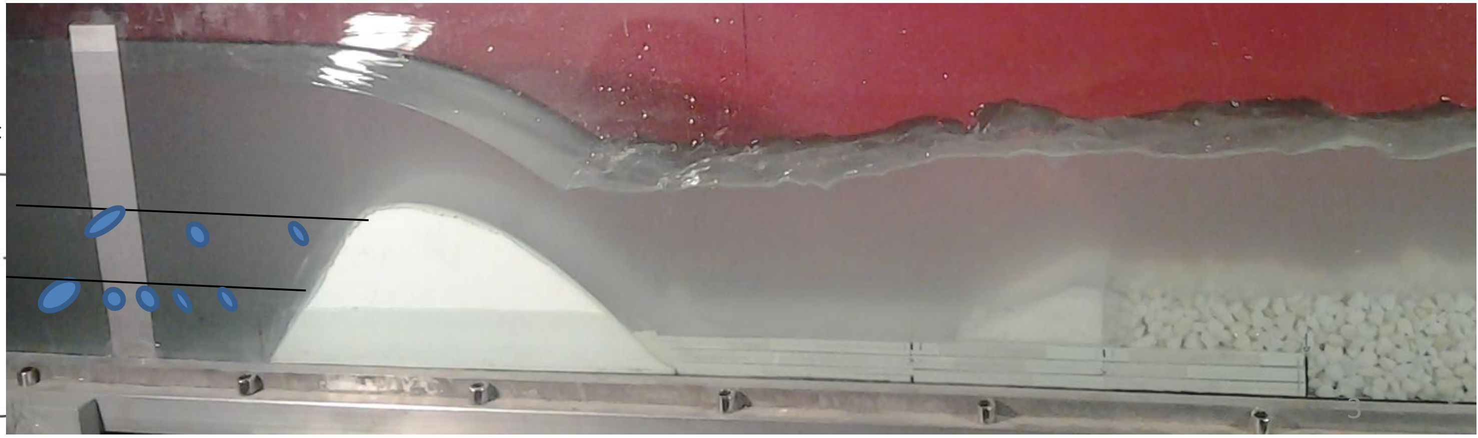


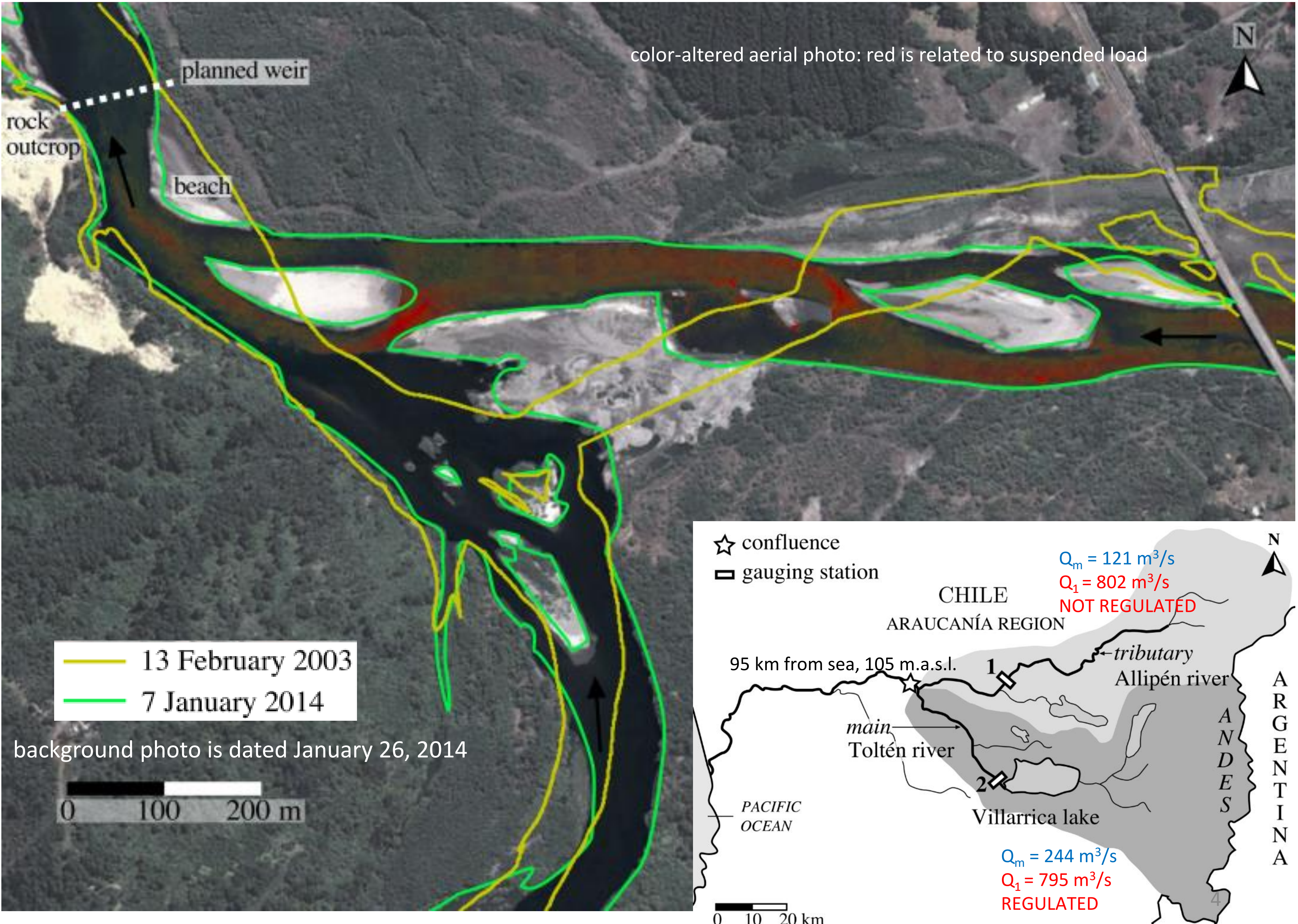
two gravel bed rivers

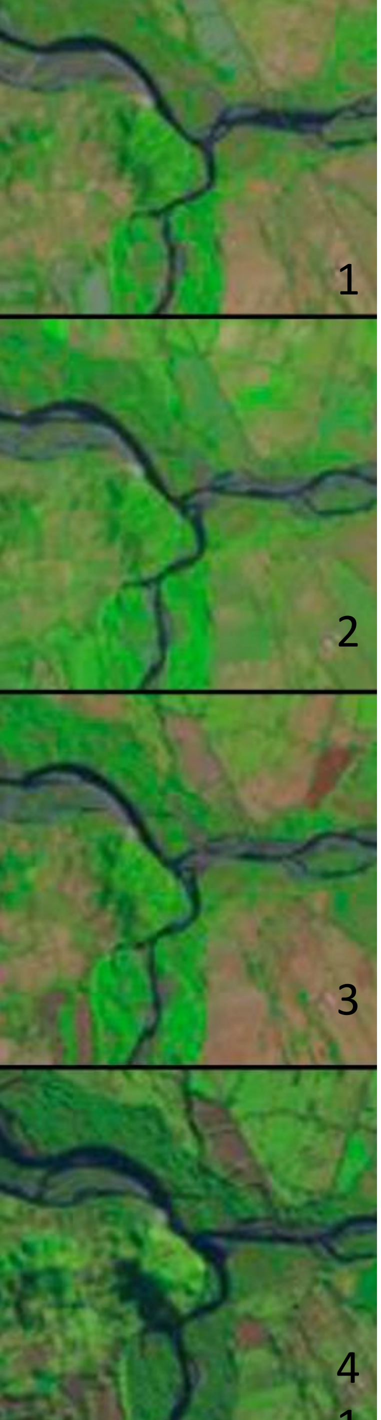
overflow weir for the run-of-the-river intake








color-altered aerial photo: red is related to suspended load
N
planned weir
rock outcrop
beach
13 February 2003
7 January 2014
background photo is dated January 26, 2014
0 100 200 m
confluence
gauging station
CHILE
ARAUCANÍA REGION
N
Qm = 121 m3/s
Q1 = 802 m3/s
NOT REGULATED
tributary
Allipén river
95 km from sea, 105 m.a.s.l.
1
main
Toltén river
2
Villarrica lake
ANDES
ARGENTINA
PACIFIC OCEAN
Qm = 244 m3/s
Q1 = 795 m3/s
REGULATED
0 10 20 km

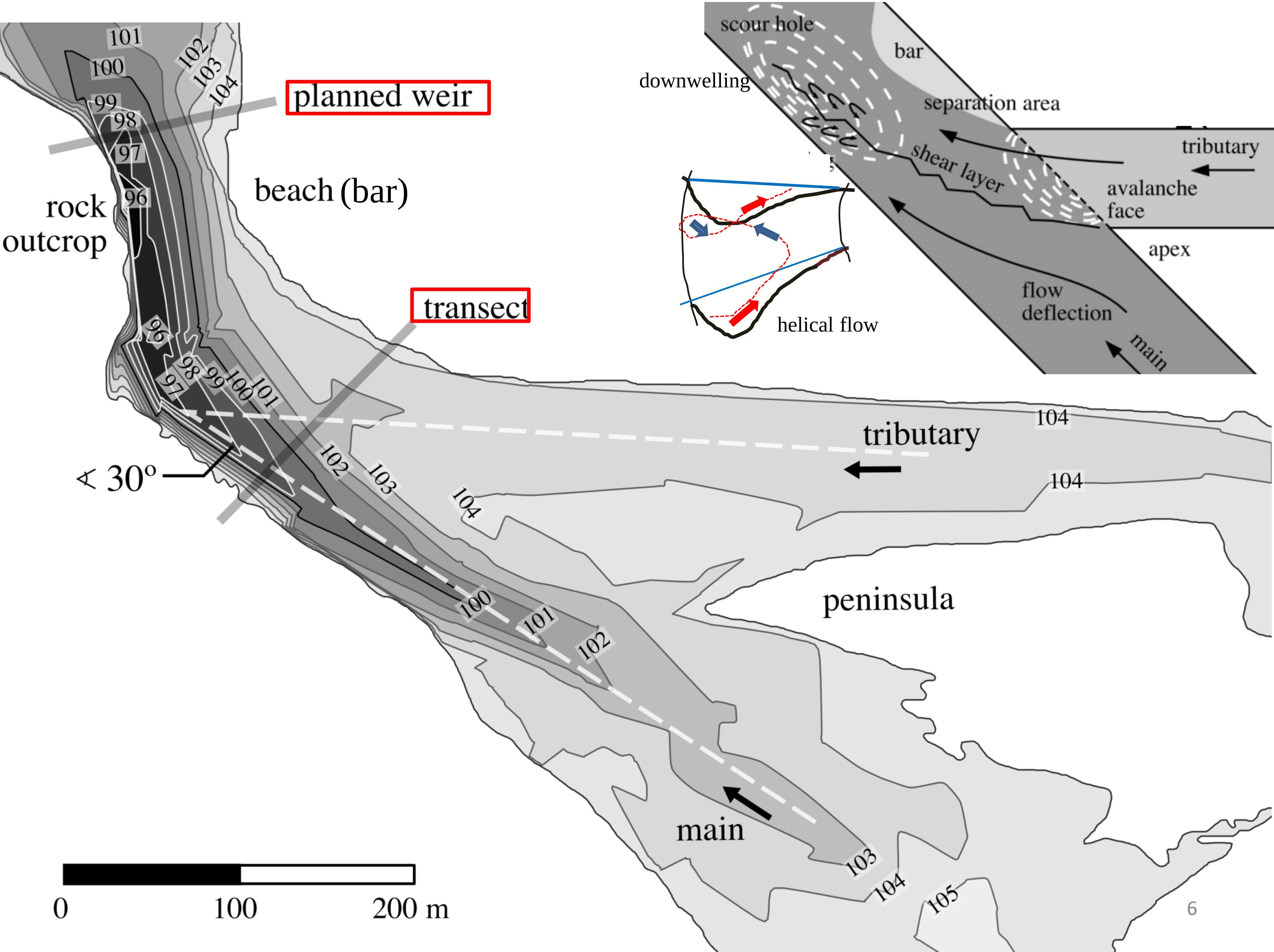


satellite images

1: january 2008 2: december 2008

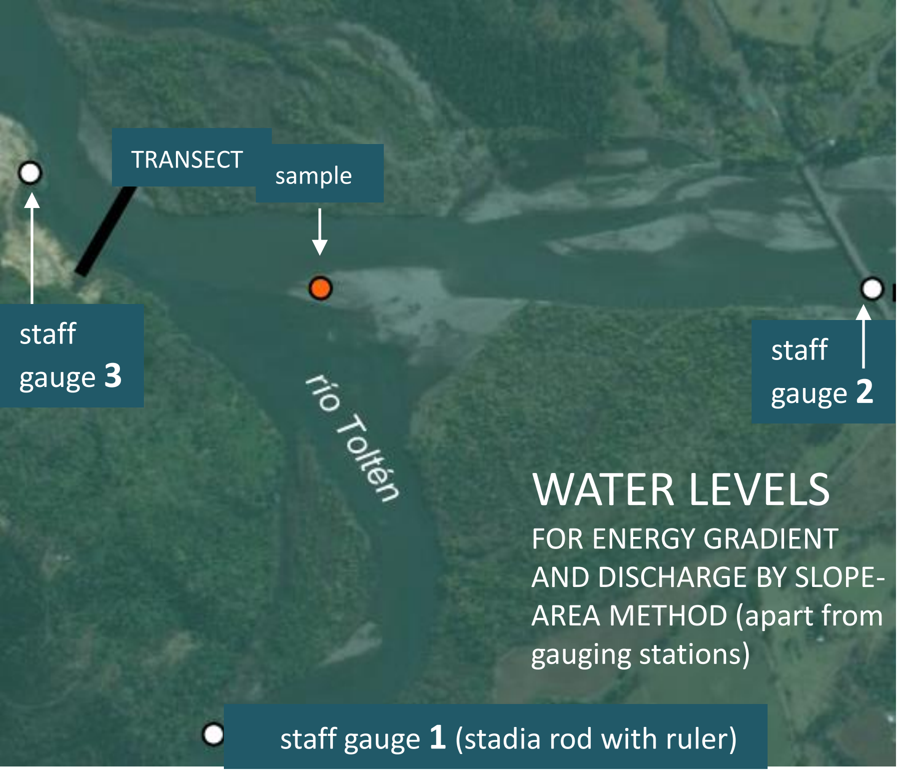
3: february 2009 4: july 2009

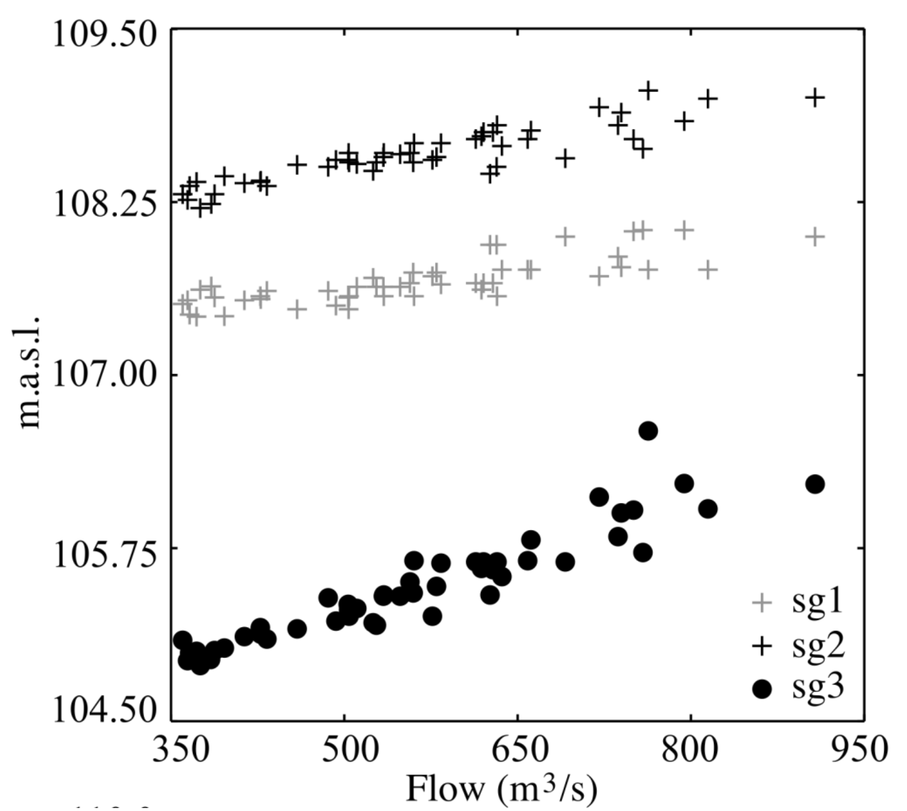
google earth, dic-2022

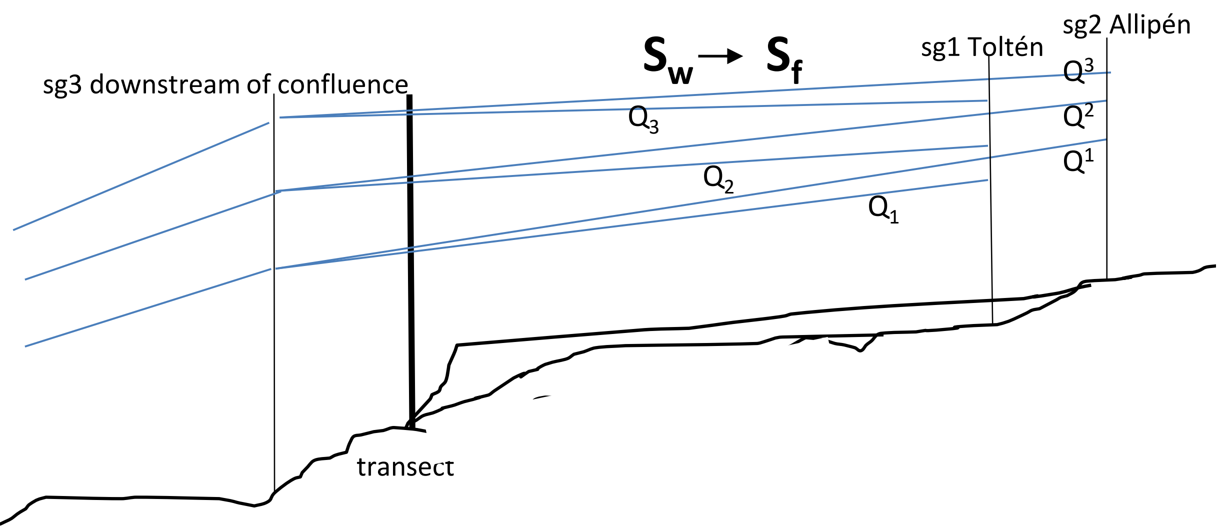

planned weir
transect
beach (bar)
rock outcrop
∢ 30°
tributary
peninsula
main
0
100
200 m
scour hole
bar
downwelling
separation area
tributary
shear layer
avalanche face
apex
flow deflection
main
helical flow

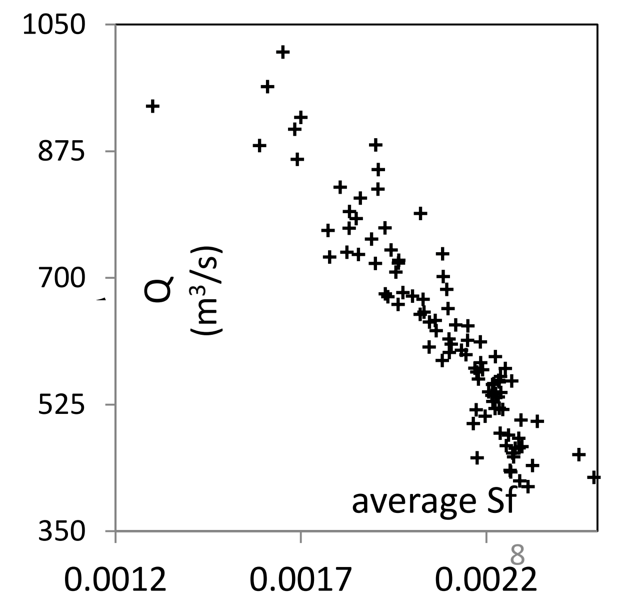
1

Sample SUBSURFACE	Sand (<2 mm)	Gravel (2–64 mm)	>64 mm	D_m (mm)	D_{50} (mm)	σ
Main river	12%	62%	26%	23.6	40.7	3.4
Tributary	20%	68%	12%	13.0	21.9	6.2
Confluence	23%	67%	10%	11.1	19.0	7.1


TRANSECT
sample
staff gauge 3
staff gauge 2
río Toltén
WATER LEVELS
FOR ENERGY GRADIENT AND DISCHARGE BY SLOPE-AREA METHOD (apart from gauging stations)
staff gauge 1 (stadia rod with ruler)


109.50
108.25
107.00
105.75
104.50
m.a.s.l.
350
500
650
800
950
Flow (m³/s)
sg1
sg2
sg3


S_w → S_f
sg1 Toltén
sg2 Allipén
sg3 downstream of confluence
Q3
Q2
Q1
Q³
Q²
Q¹
transect

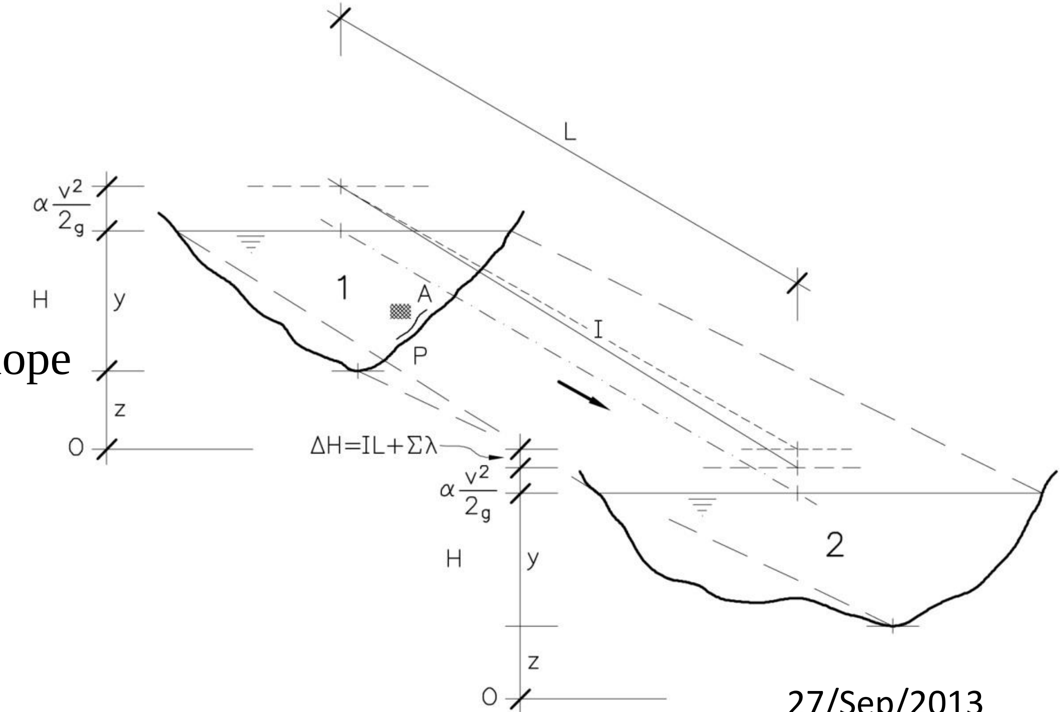

1050
875
700
525
350
Q (m³/s)
average Sf
0.0012
0.0017
0.0022

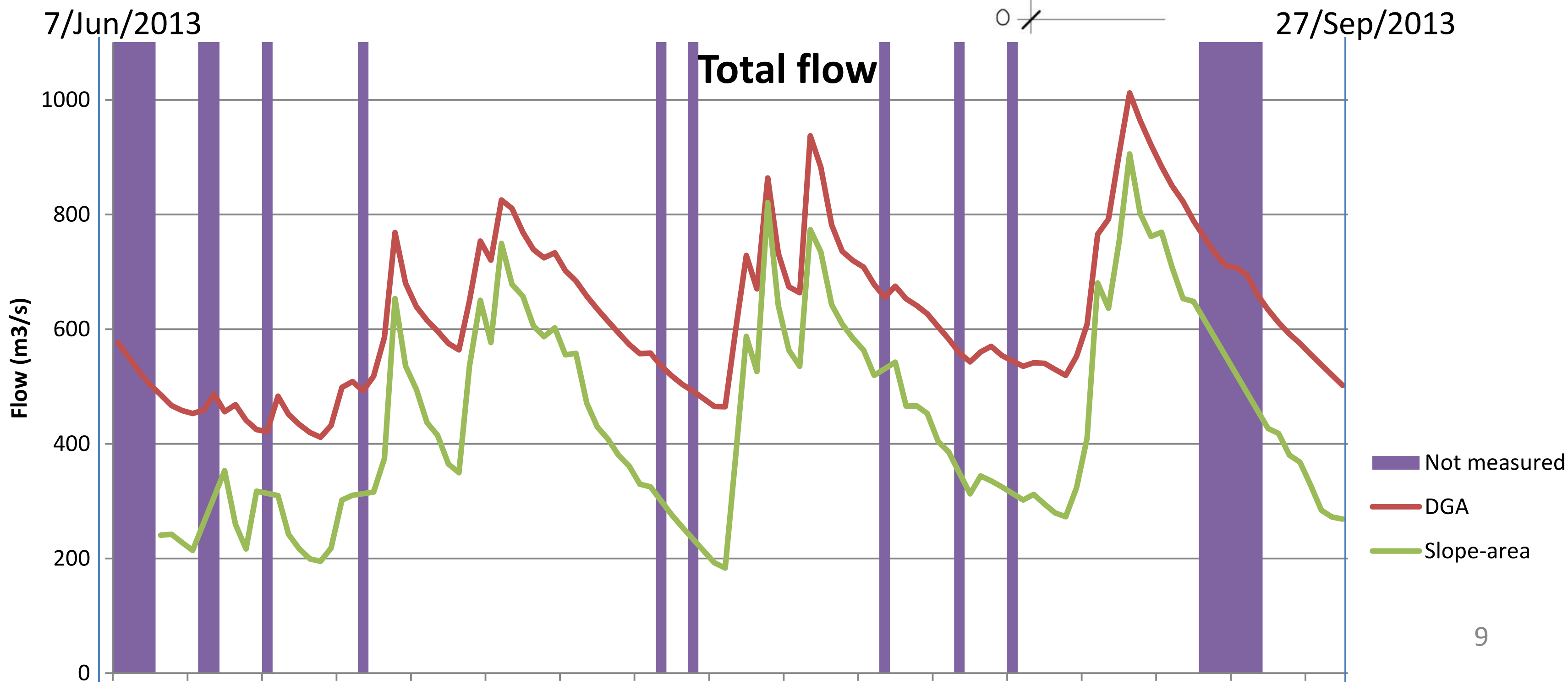
SLOPE-AREA METHOD

$$H_1 + \alpha_1 \frac{v_1^2}{2g} = H_2 + \alpha_2 \frac{v_2^2}{2g} + IL + \sum \lambda \frac{v^2}{2g}$$

0

v = Q / A + Manning eq. for energy slope





BED LOAD SAMPLING

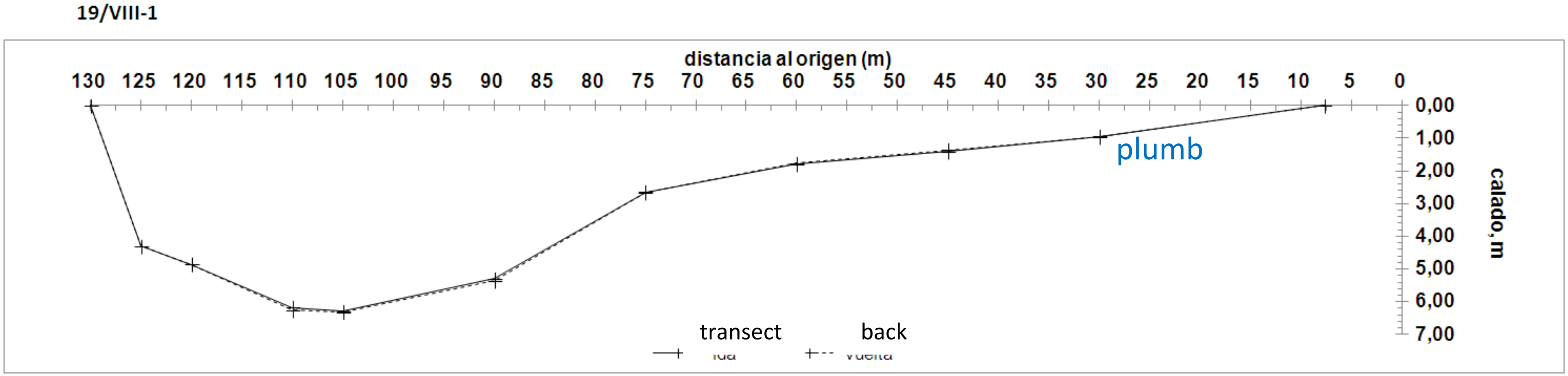
steel cable tied to a big tree and a concrete block

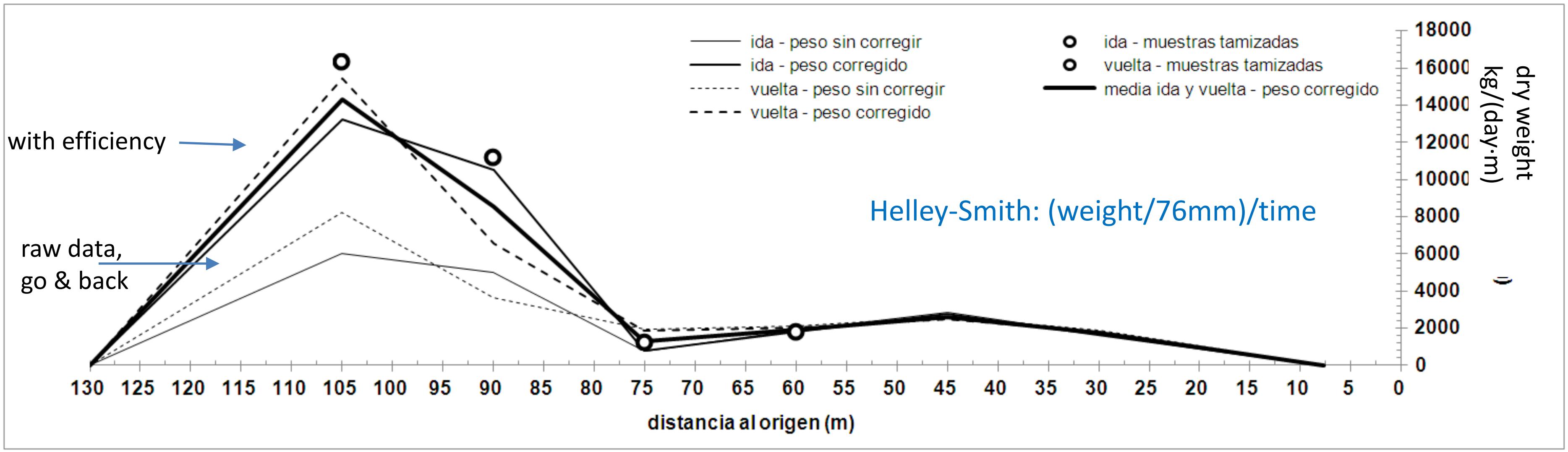
for boat operations + marked every 5 m

76 mm Helley-Smith bed load sampler

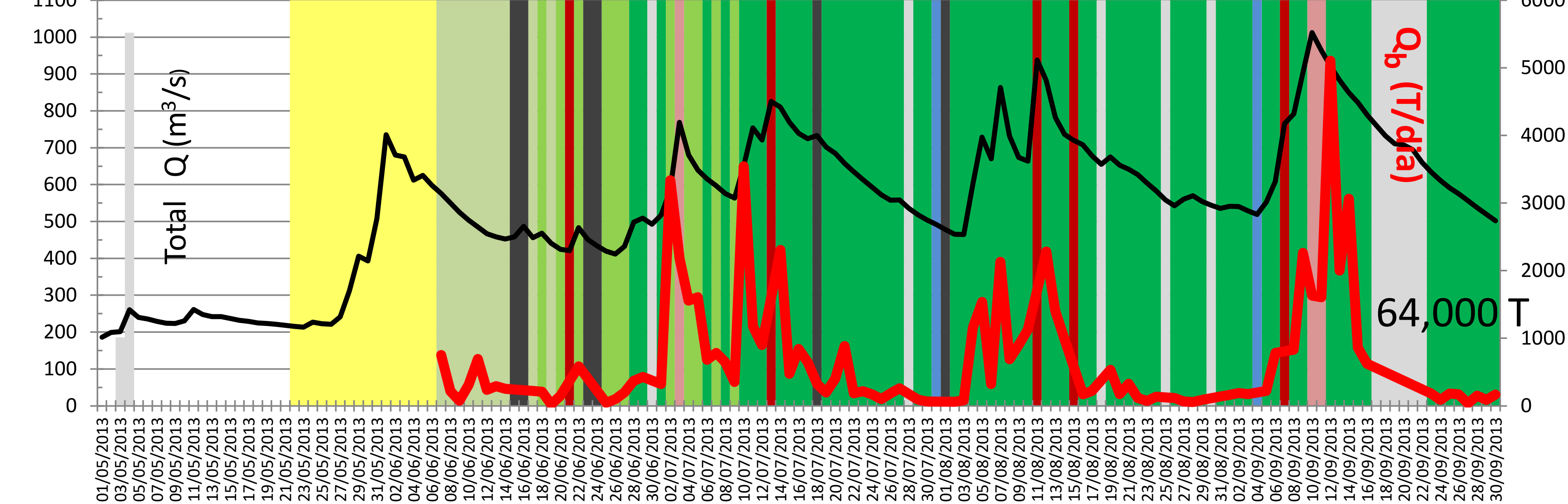
0.25 mm mesh basket

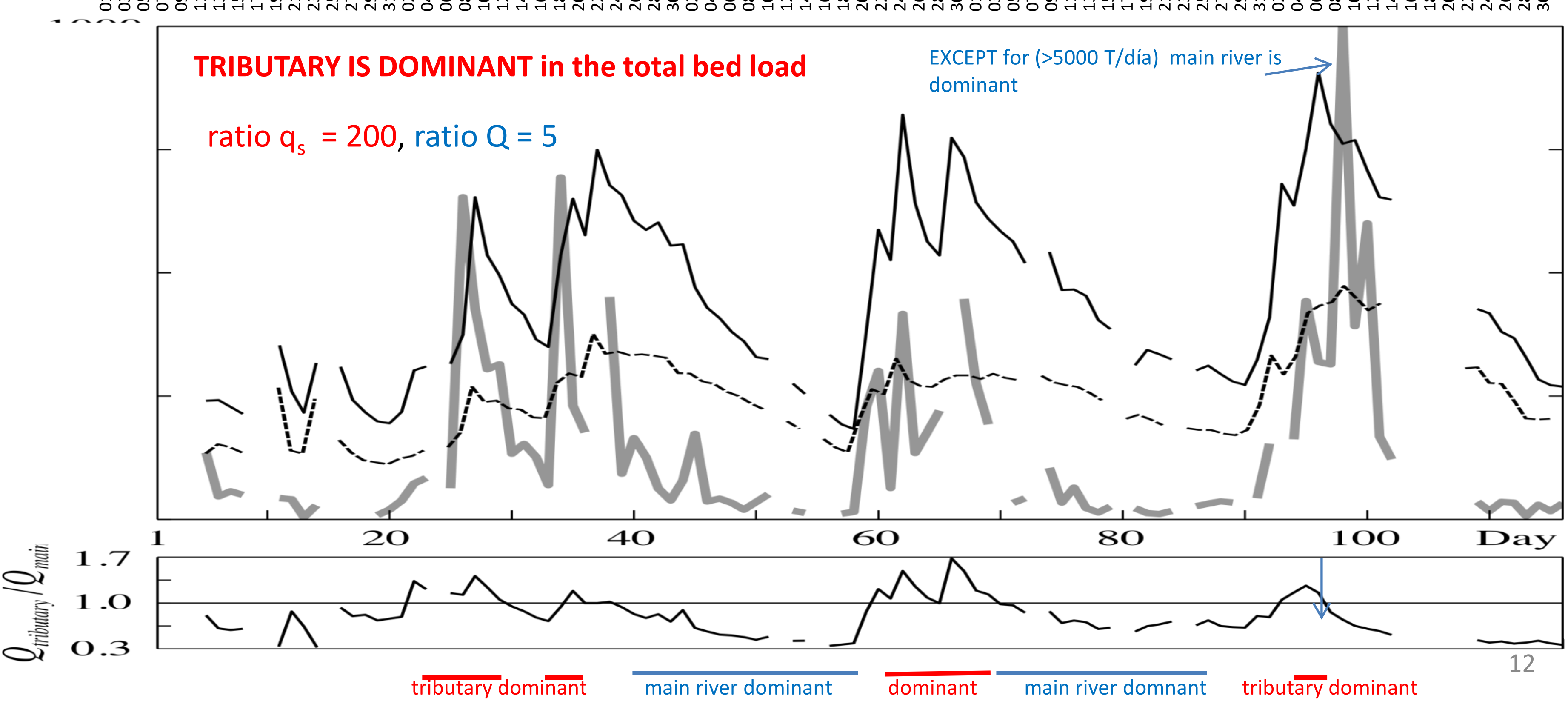
Example, 117 days of sampling starting 7-June-2013, HIGH-FLOW SEASON
1193 samples, 253 of them sieved



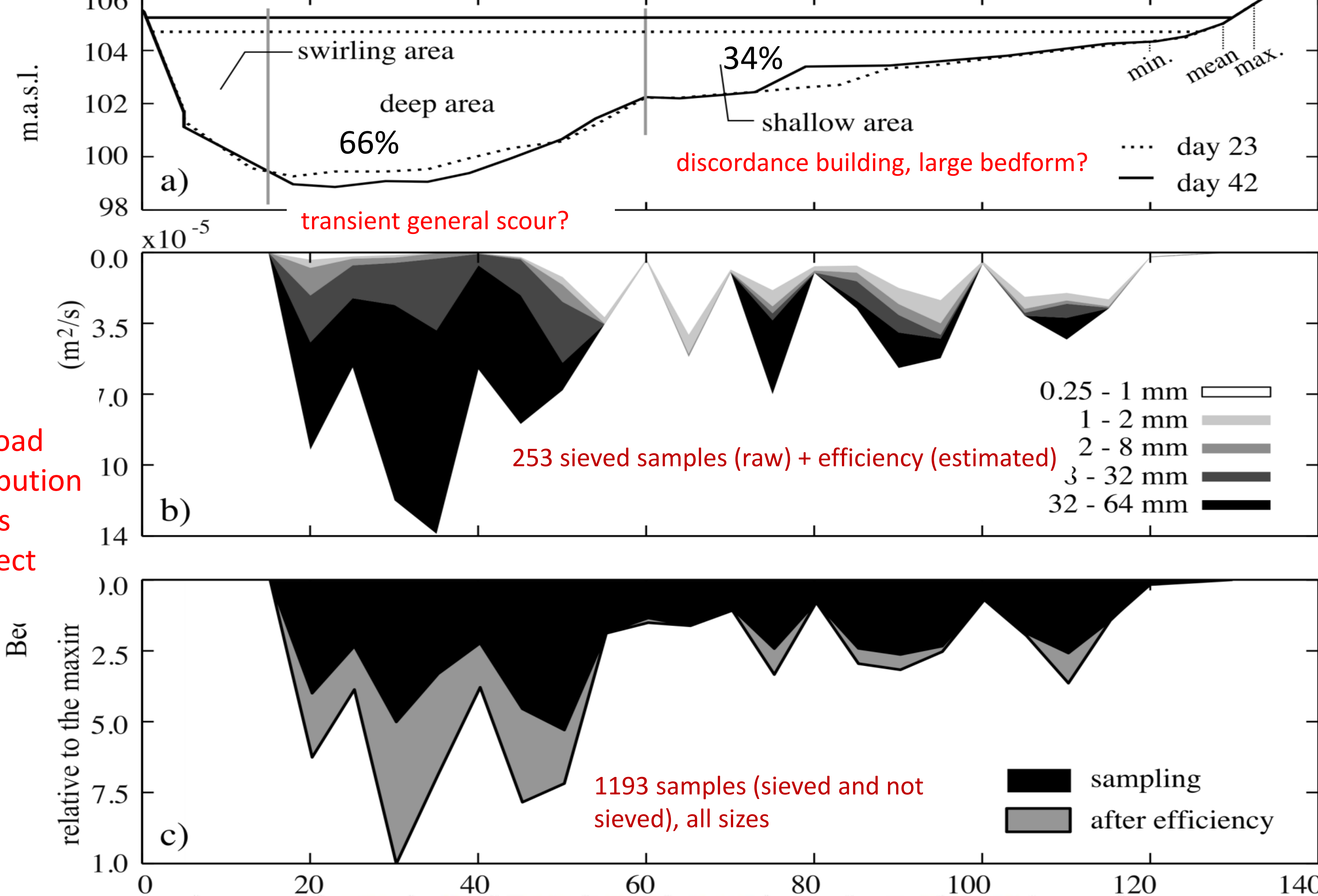


Size (mm)	efficiency
< 0.25	-
0.25 – 16	1.00
16 – 32	0.70
32 – 76	0.37
76 – 96	*0.05*
> 96	-


Total Q (m3/s)
Qb (T/día)
64,000 T

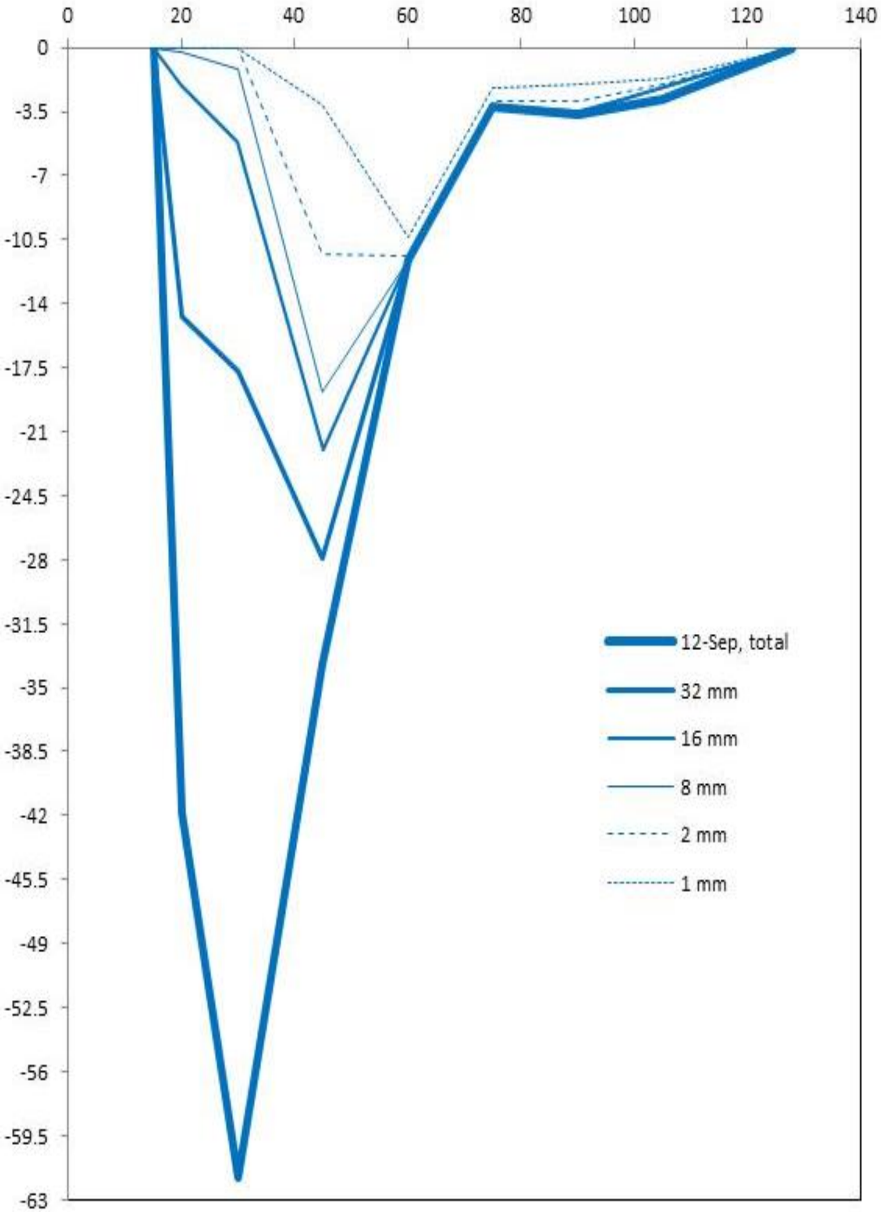

TRIBUTARY IS DOMINANT in the total bed load
ratio qs = 200, ratio Q = 5
EXCEPT for (>5000 T/día) main river is dominant
Day
Qtributary/Qmain
tributary dominant
main river dominant
dominant
main river domnant
tributary dominant

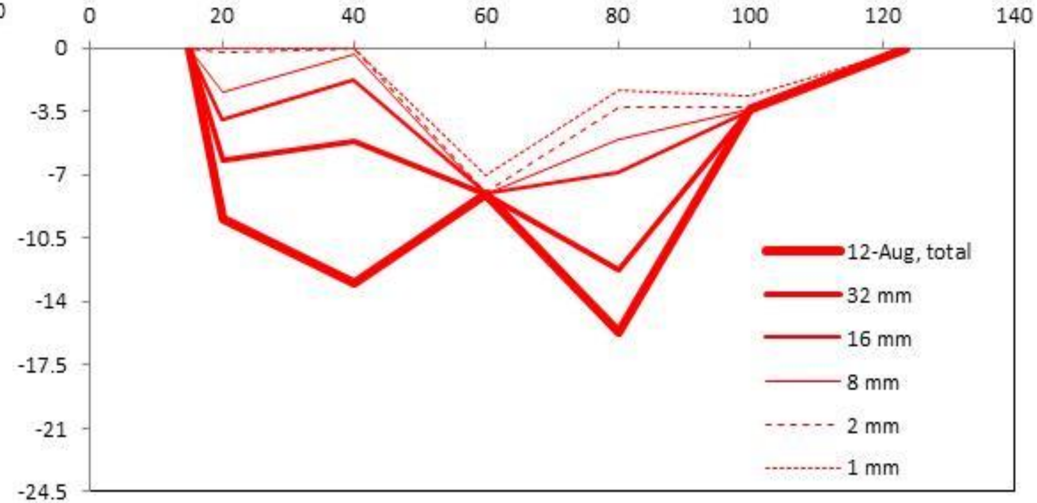
Bed load distribution across transect



Area	2-4 mm	4-8 mm	8-32 mm	32-64 mm	**total gravel**	parent sand	rest of sand	**total sand**	**Total**
shallow	3.7%	1.5%	2.1%	2.0%	9.3%	5.0%	20.0%	25.0%	**34.3%**
deep	7.8%	2.7%	13.4%	28.0%	51.9%	2.8%	11.0%	13.8%	**65.7%**
Total	11.5%	4.2%	15.5%	30.0%	**61.2%**	7.8%	31.0%	**38.8%**	**100%**

IMBALANCED BEDLOAD TRANSPORT





event date(nr)	tot.Q (m^3/s)	(1)Q_{main} (m^3/s)	(2)$Q_{tributary}$ (m^3/s)	ratio (2)/(1)	nr. verticals
12-Aug(68)	735	292	443	1.52	5
12-Sep(99)	762	441	321	0.73	7

(figures at the same scales)

Bedload distribution across the transect in m^2/s divided into 5 grain fractions. Ordinates: bedload (m^2/s); abscissas: distance (m) . **Blue**: the 12-Sept event with detailed measurements at seven locations (abscissas): 20, 30, 45, 60, 75, 90 and 105 m. **Red**: the 12-Aug event with detailed measurements at five locations: 20, 40, 60, 80 and 100 m. Amounts by fractions 1, 2, 8, 16, 32 and 64 mm (total) included. Abscissa 60 m separates the shallow from the deep area in both events.

	Sample SUBSURFACE	Sand (<2 mm)	Gravel (2–64 mm)	>64 mm	D_m (mm)	D_{50} (mm)	σ
	Main river	12%	62%	26%	23.6	40.7	3.4
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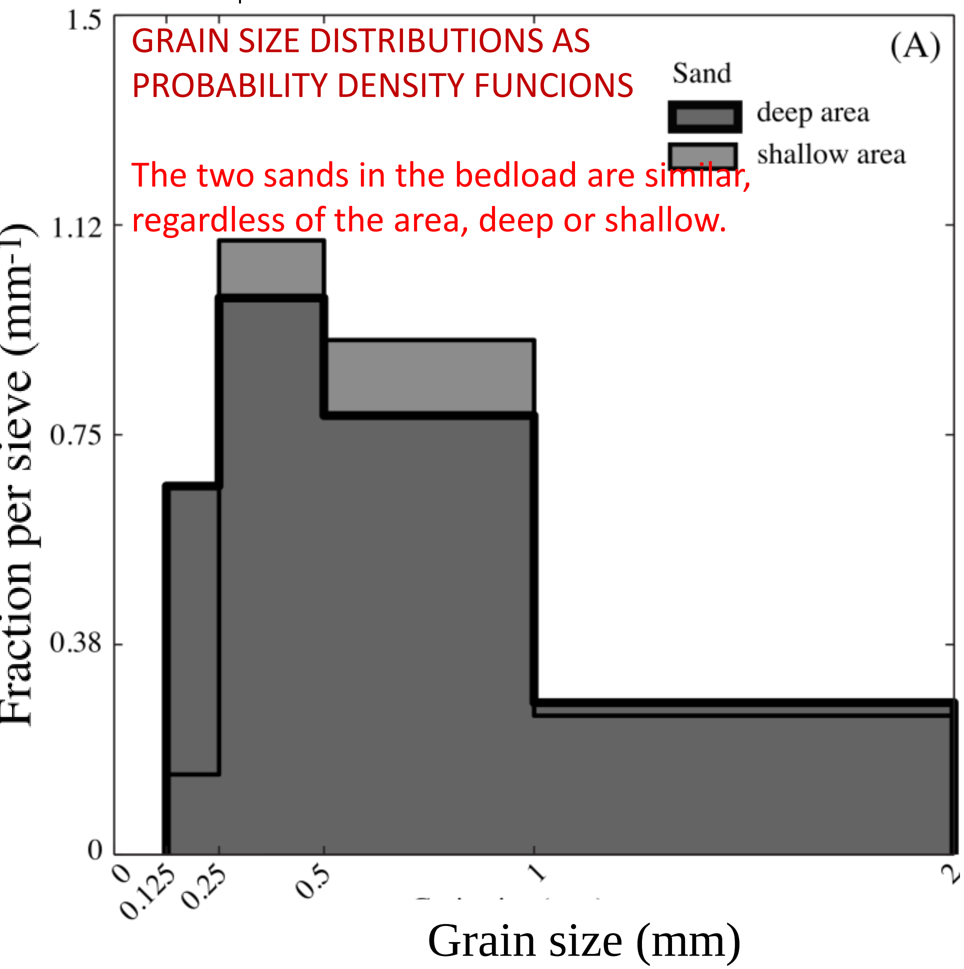
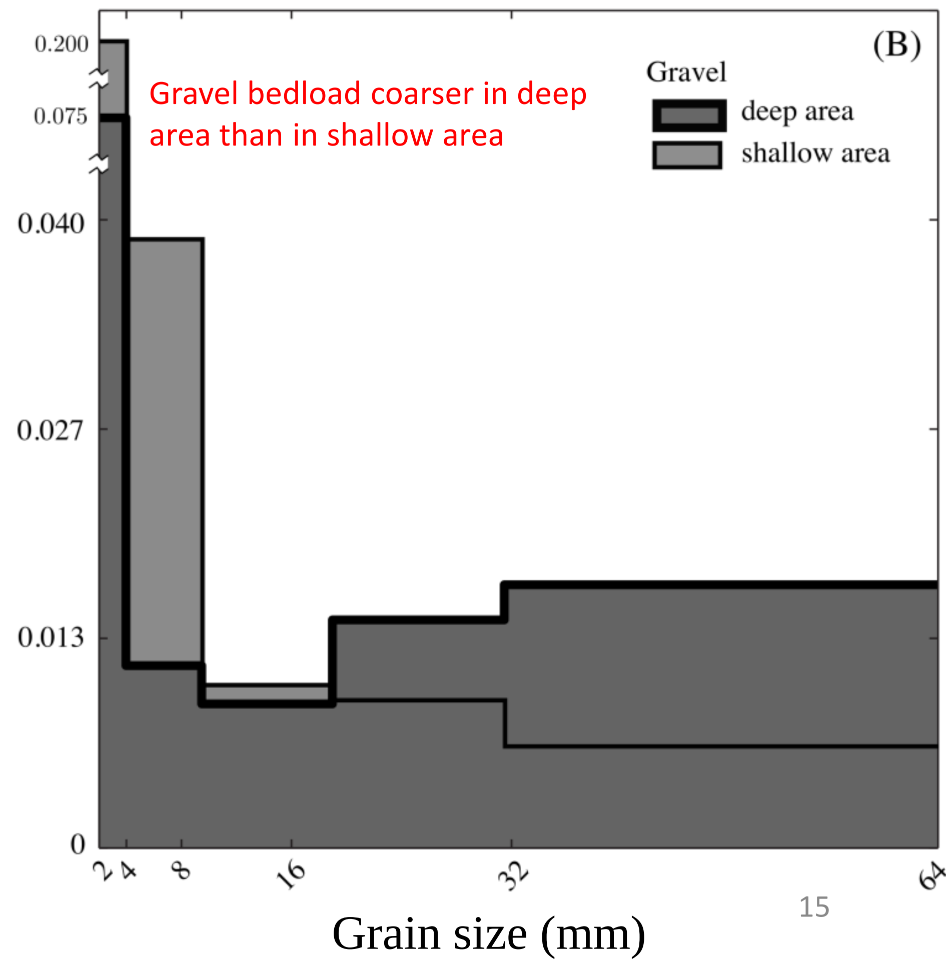
	Confluence	23%	67%	10%	11.1	19.0	7.1
Bedload							
66 %	Deep area	21%	79%	*	14.0	31.9	7.3
34 %	Shallow area	73%	27%	*	1.6	0.9	7.3





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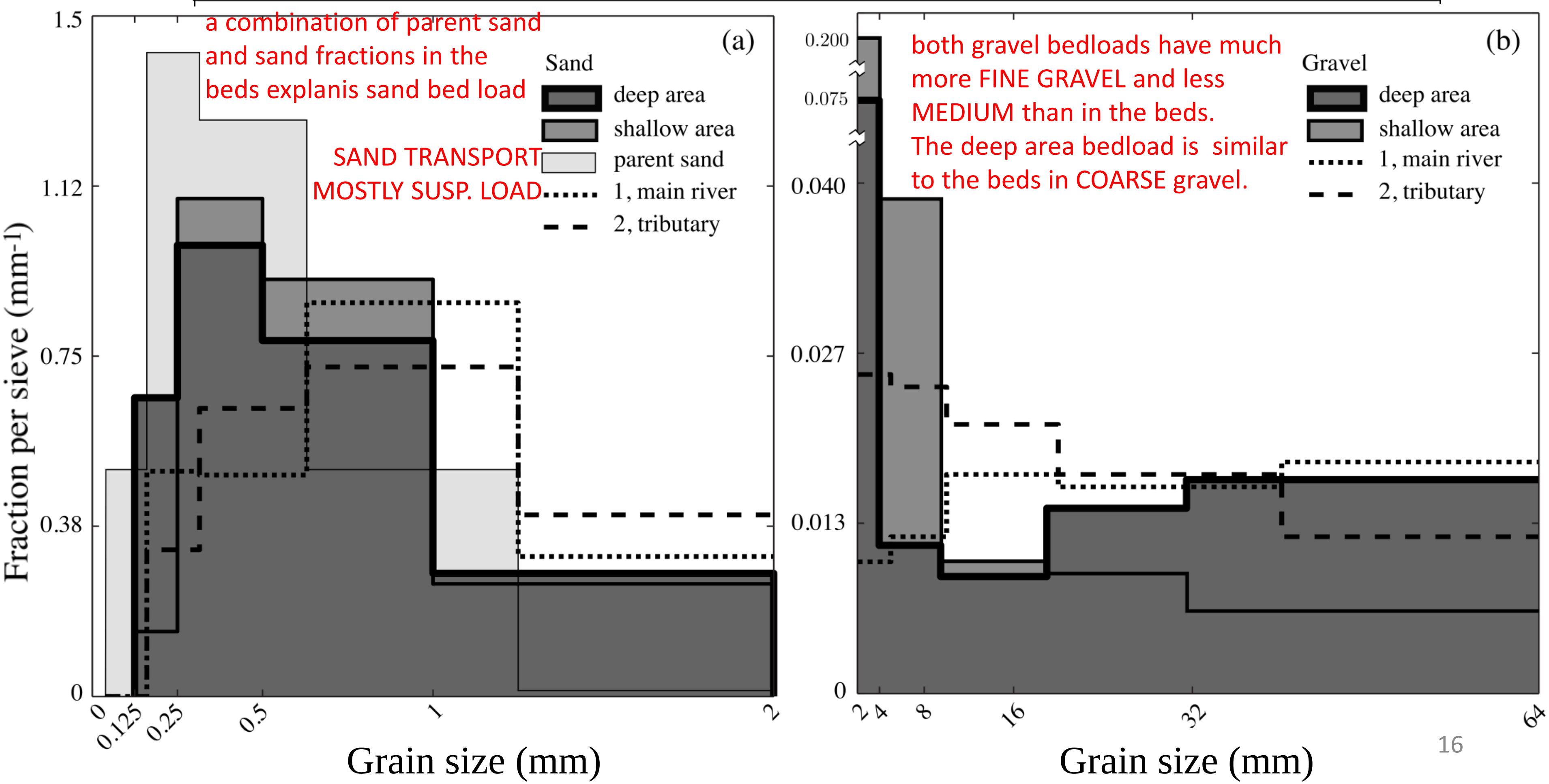
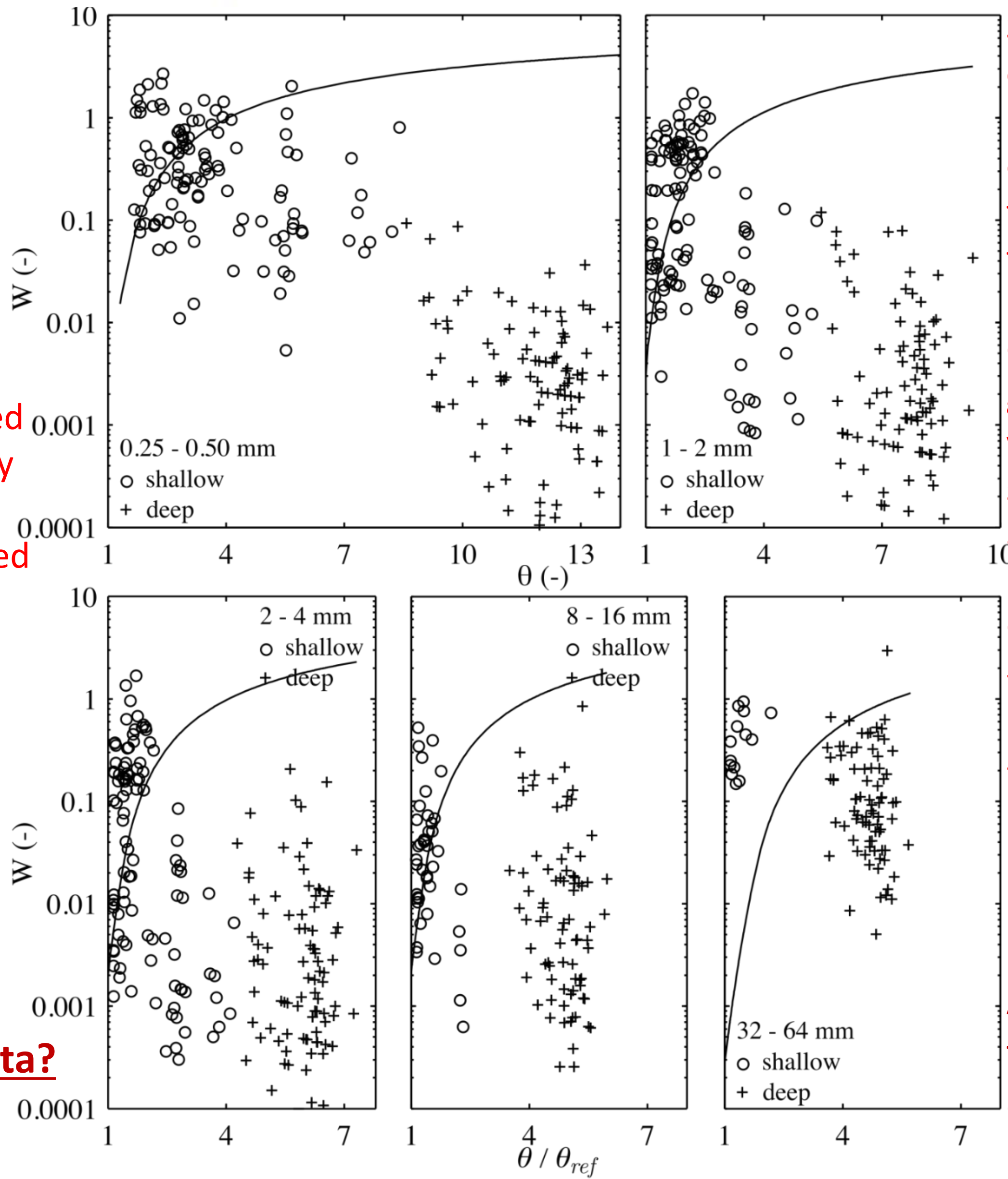


Field data is worked out, as it is customarily done, to get the Shields parameter $\theta = y \cdot S / R \cdot D$, where $R = (\rho_s / \rho) - 1$ is the submerged specific gravity of sediment, $\rho_s = 2600$ kg/m^3 is sediment density and D is a grain size (m); the Einstein mobility parameter $\Phi = \sqrt{(q_s / (g \cdot R \cdot D^3))}$ and the quotient $W = \Phi / \theta^{3/2}$.

Wilcock
Bed load predictor



Deep area controlled by SUPPLY (below-capacity conditions) for any size: much less bedload than expected, even 2-3 orders of magnitude for sand, 1 order of magnitude for coarse gravel;

OR inception of sands and fine gravel into SUSPENSION, since v* > ω (fall velocity) and shear stress much higher in deep area.

OR both:
- SUPPLY control in coarse gravel
- SUSPENSION in sand and fine gravel

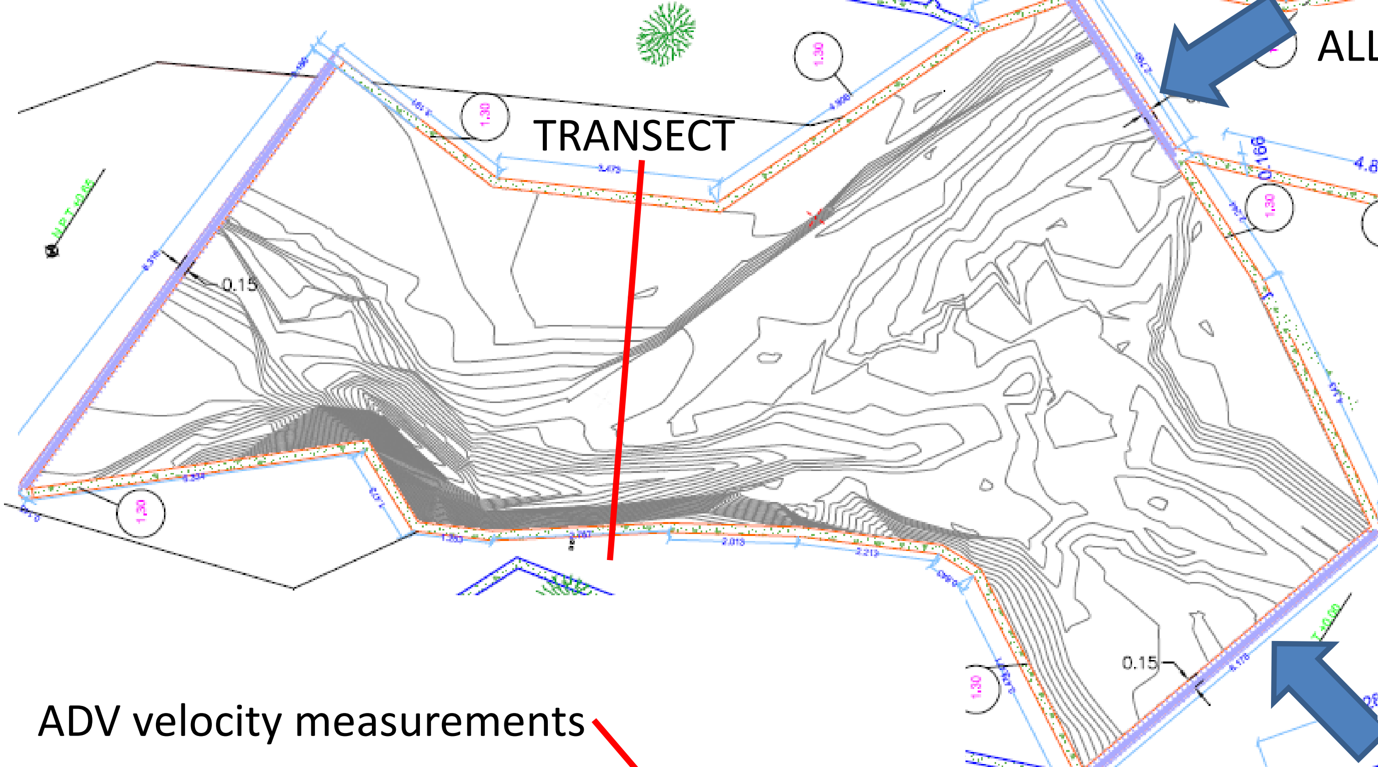
AND of course highly 3D flow behavior at the confluence (flow deflexion, helical flow...)

Shallow area controlled by capacity (at capacity conditions) for sands: but underestimated bed load for gravel.

WARNING: Estimating bedload without any real data?

3D behavior investigated through a scale model 1:59.2

UDEP-UPC Piura (Perú)



ADV velocity measurements

TOLTEN-ALLIPÉN CONFLUENCE. Martín-Vide, J.P, Ferrer-Boix, C UPC

Villarrica, December-12, 2023