Comparing a newly developed DEM-based runout model for hillslope debris flows with full-scale experiments and historical events

Adel Albaba*

Niels Hollard

Dominik May

Christoph Schaller

Massimiliano Schwarz

Luuk Dorren

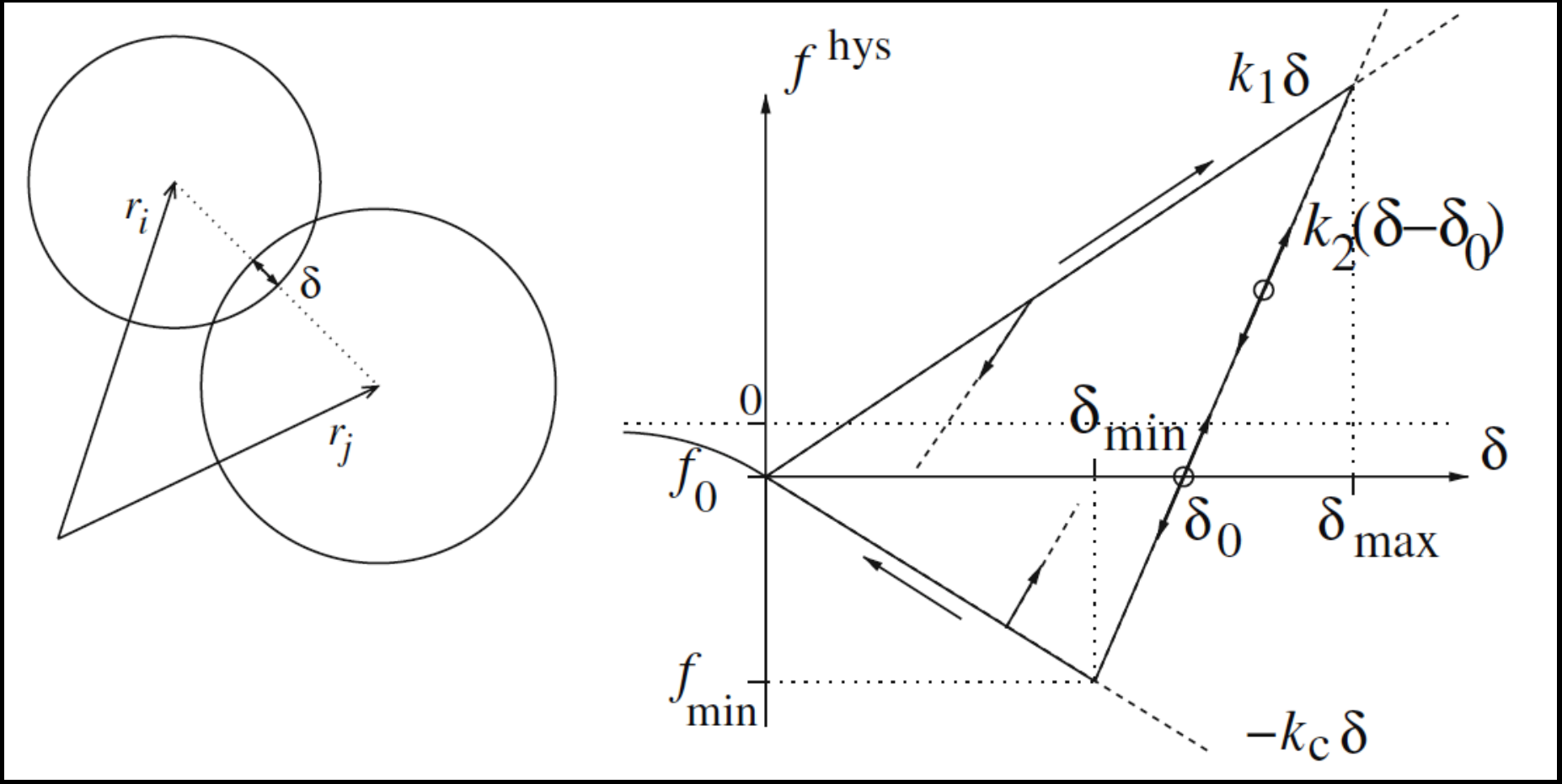
HAFL, Zollikofen, 05 May 2020

Bern University of Applied Sciences

*Department of Forest Science, Bern University of Applied Science, Zollikofen, Switzerland (adel.albaba@bfh.ch)

DEM Contact law: Elasto-plastic adhesive

(Luding, 2008)



Elasto-plastic adhesive contact law

$$f^{\text{hys}} = \begin{cases} k_1\delta & \text{if } k_2(\delta-\delta_0) \geq k_1\delta \\ k_2(\delta-\delta_0) & \text{if } k_1\delta > k_2(\delta-\delta_0) > -k_c\delta \\ -k_c\delta & \text{if } -k_c\delta \geq k_2(\delta-\delta_0) \end{cases}$$

$$\epsilon_n = k_1/k_2$$

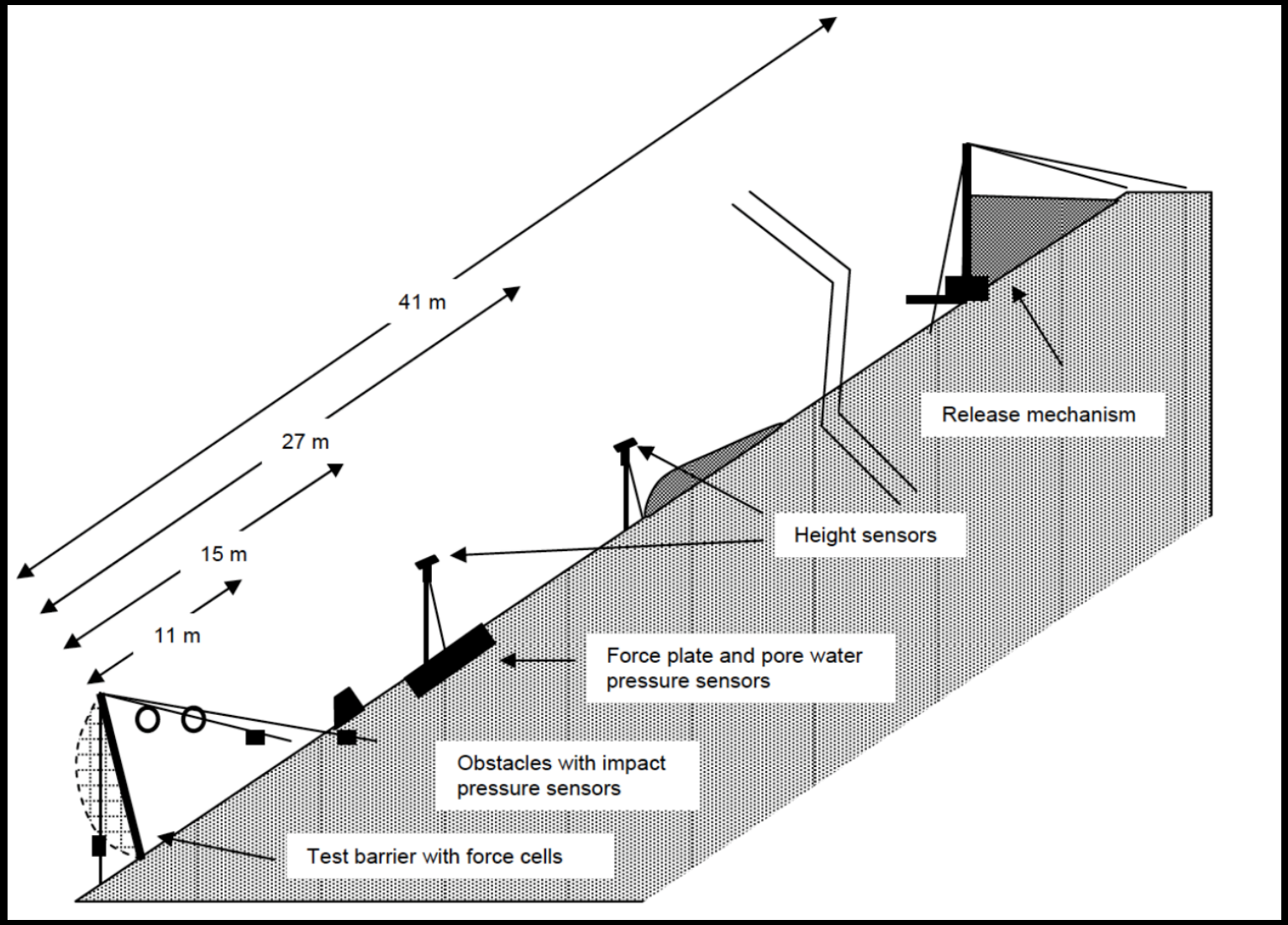
$$k_1 = \frac{2E_1r_1E_2r_2}{E_1r_1+E_2r_2}$$

$$\delta_0 = (1-k_1/k_2)\delta_{max}$$

$$\boldsymbol{F_n} = (F_{hys}+\gamma_n v_n)\boldsymbol{n}$$

$$\boldsymbol{F_t} = \begin{cases} \frac{k_t\boldsymbol{u_t}}{|k_t\boldsymbol{u_t}|}|\boldsymbol{F_n}|\tan\Phi_p & if|k_t\boldsymbol{u_t}| > |\boldsymbol{F_n}|\tan\Phi_p \\ k_t\boldsymbol{u_t} & otherwise \end{cases}$$

Field experiment of hillslope debris flow (Bugnion, 2012)



Field experiment of hillslope debris flow

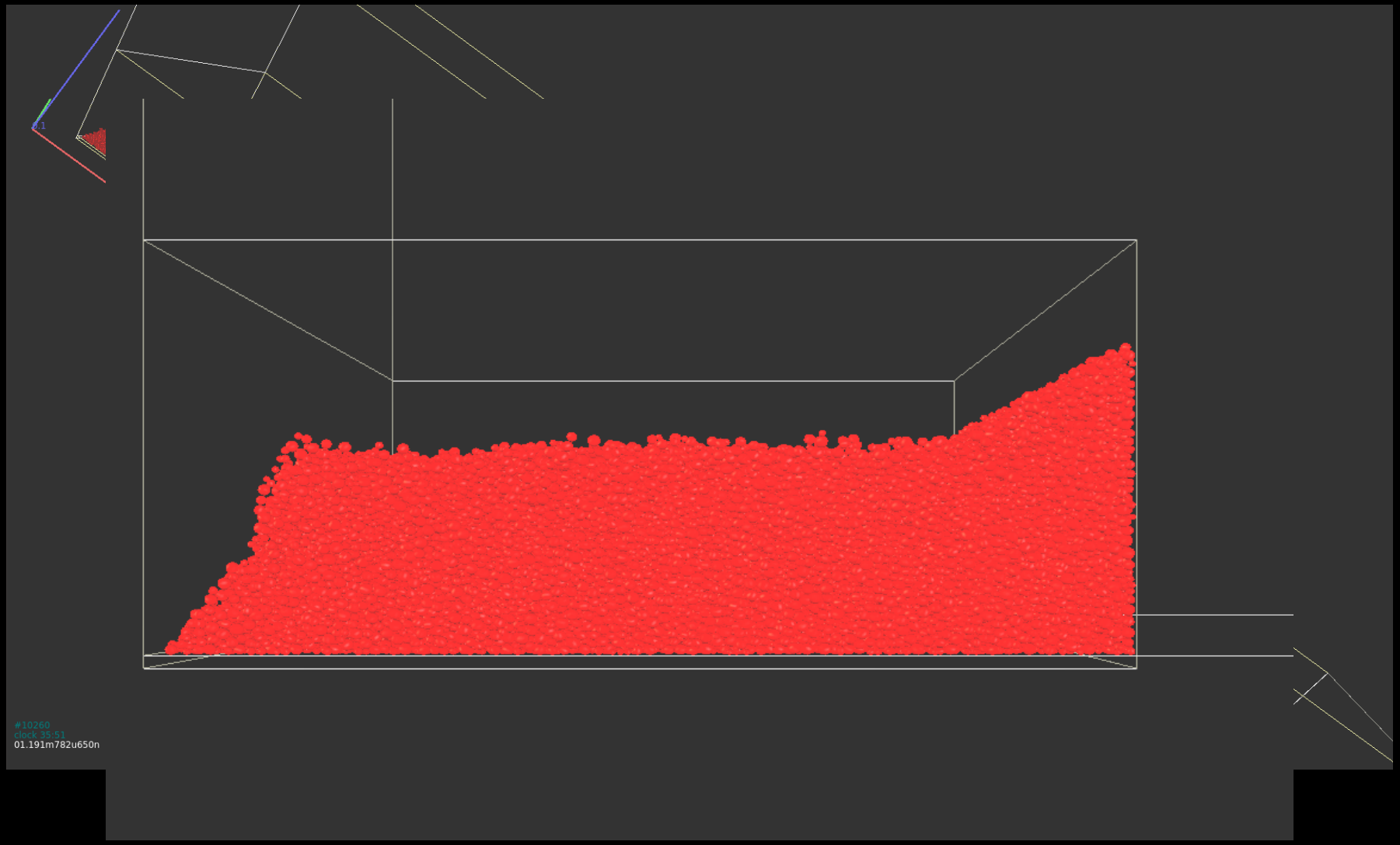
- A 41-m-long, 8-m-wide channel was constructed on the side of a rock quarry
- Excavated material in the site was used to prepare the granular flow (different PSD).
- Water content levels of 14-28% which created densities between 1760-2110 kg/m^3.
- Laser distance sensors at distances 14 and 26 meters.
- Two pressure plates (2-kHs) installed at a distance 30 meters away from the reservoir gate (small and large).

Field experiment: Screenshots of test no. 10

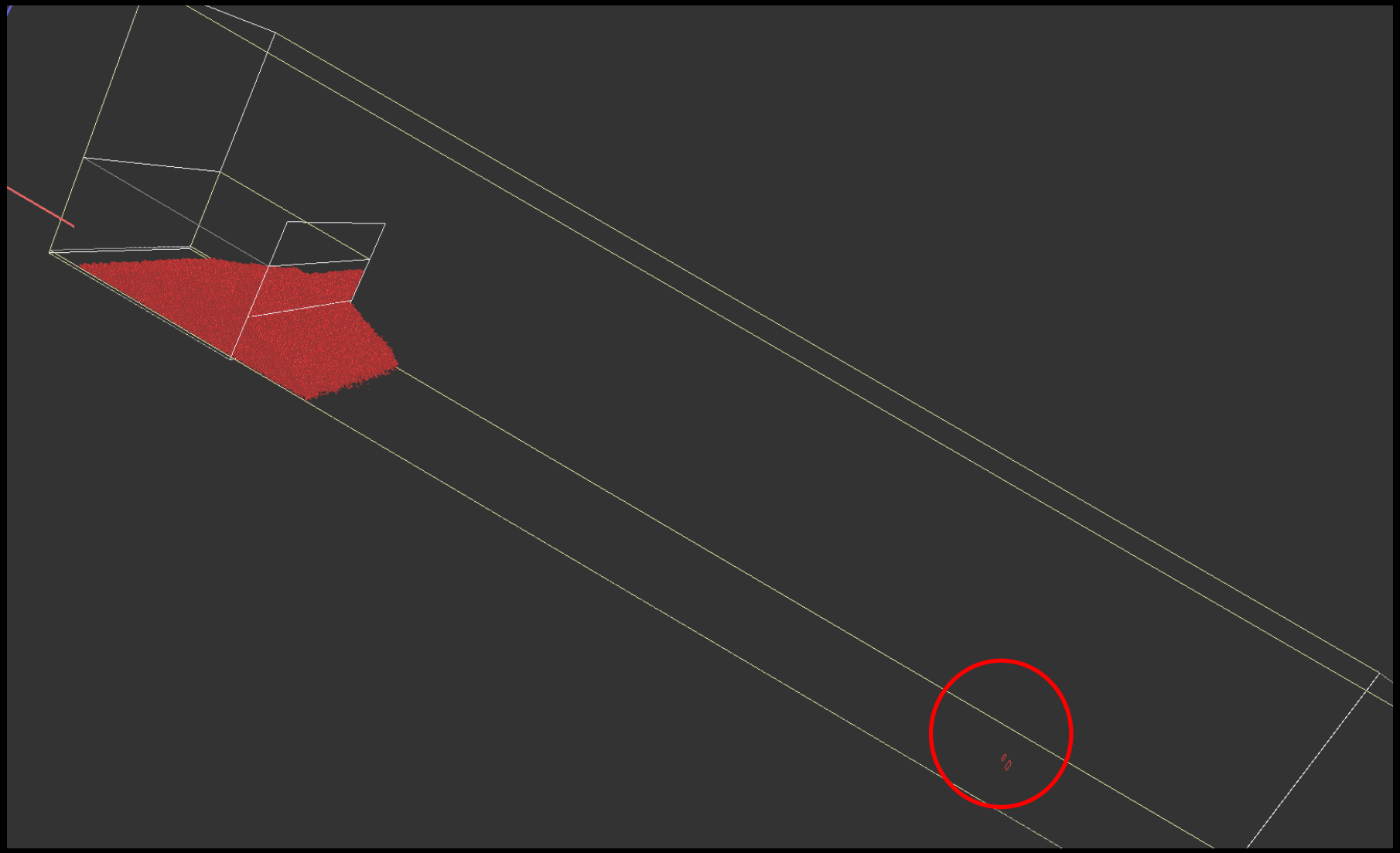
(a)

(b)

DEM simulations: Geometry and chosen parameters



DEM simulations: Geometry and chosen parameters



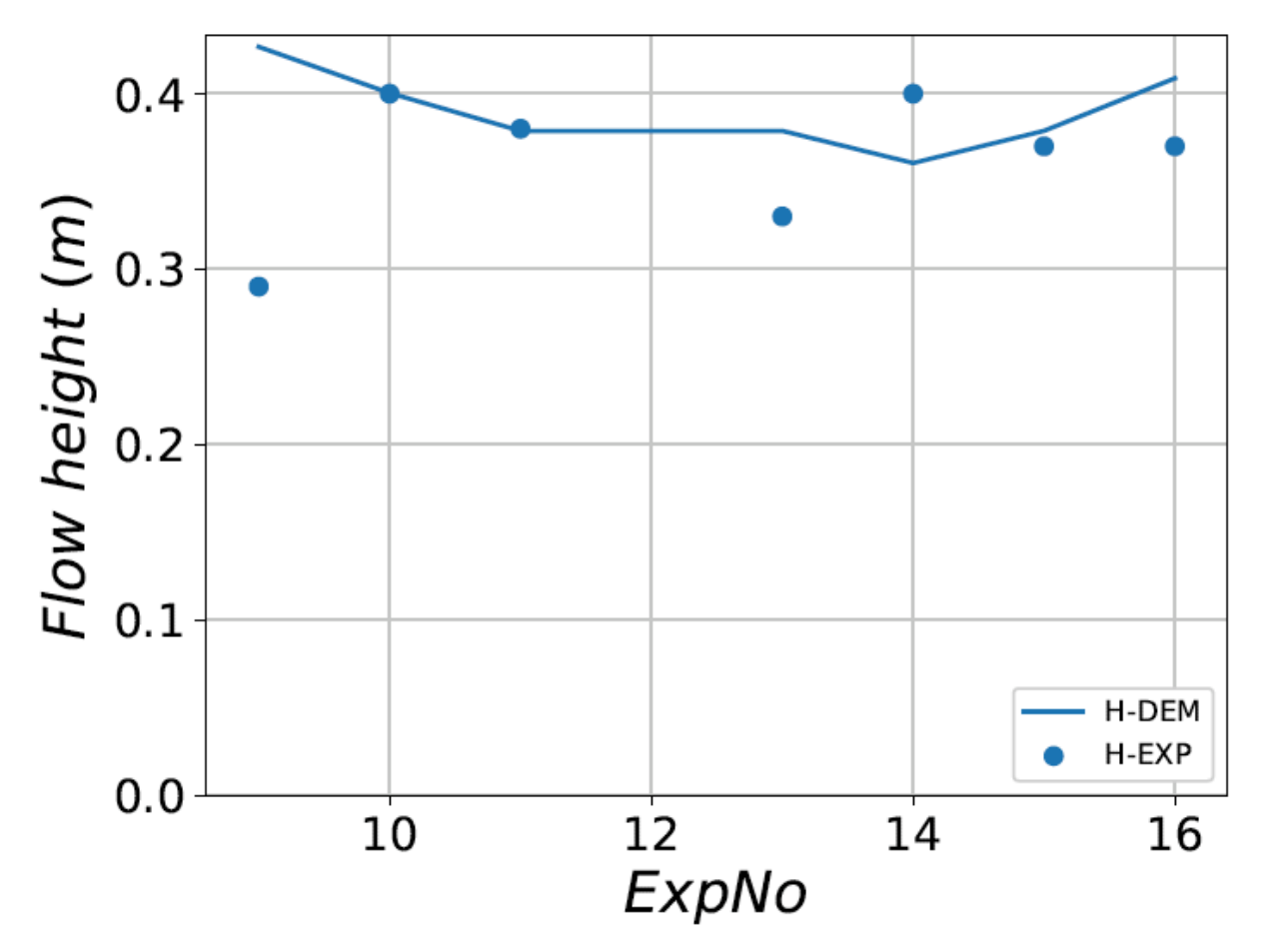
Cross comparison: Chosen field tests

Release No.	Wet density (kg/m^3)	Water mass fraction (%)	Fine mass fraction (%)	Mean front velocity (m/s)	Max. flow height at pos. 2 (m)	Max pressure on large sensor (kPa)
9	1,790	28	48	10.2	0.29	65.9
10	1,900	18	21	8.2	0.4	96
11	2,060	16	27	9	0.38	94.6
13	1,880	22	28	8.4	0.33	98.5
14	1,990	17	25	9.1	0.4	138
15	1,830	23	25	8.9	0.37	109.4
16	2,110	14	41	6.4	0.37	69.2

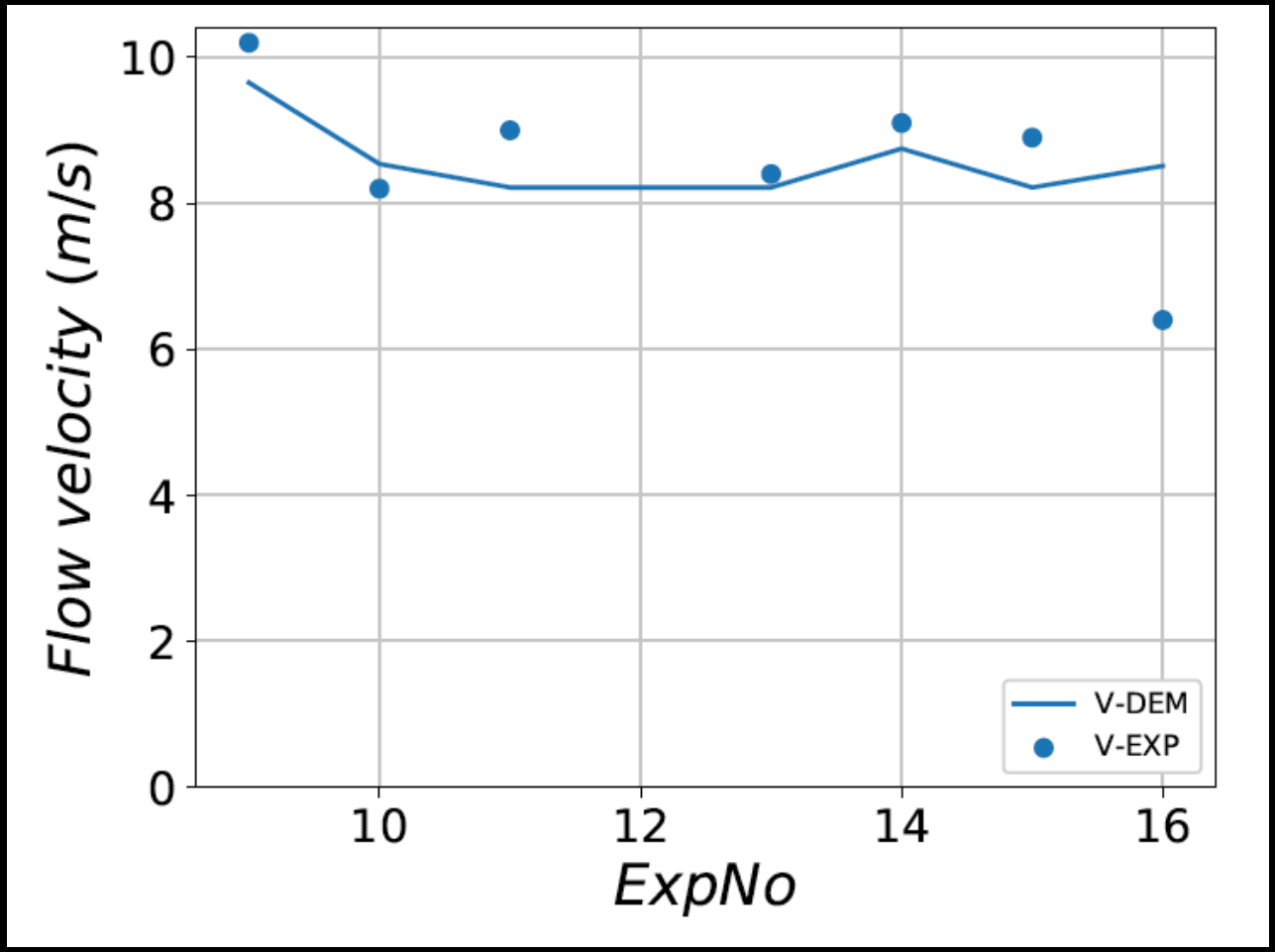
$$R_{min} = \min_{\forall i \in n_s} \left(\frac{\sqrt{(H_{DEM})_i - H_{EXP}}}{H_{EXP}} + \frac{\sqrt{(V_{DEM})_i - V_{EXP}}}{V_{EXP}} + \frac{\sqrt{(P_{DEM})_i - P_{EXP}}}{P_{EXP}} \right)$$

where n_s is the number of simulations

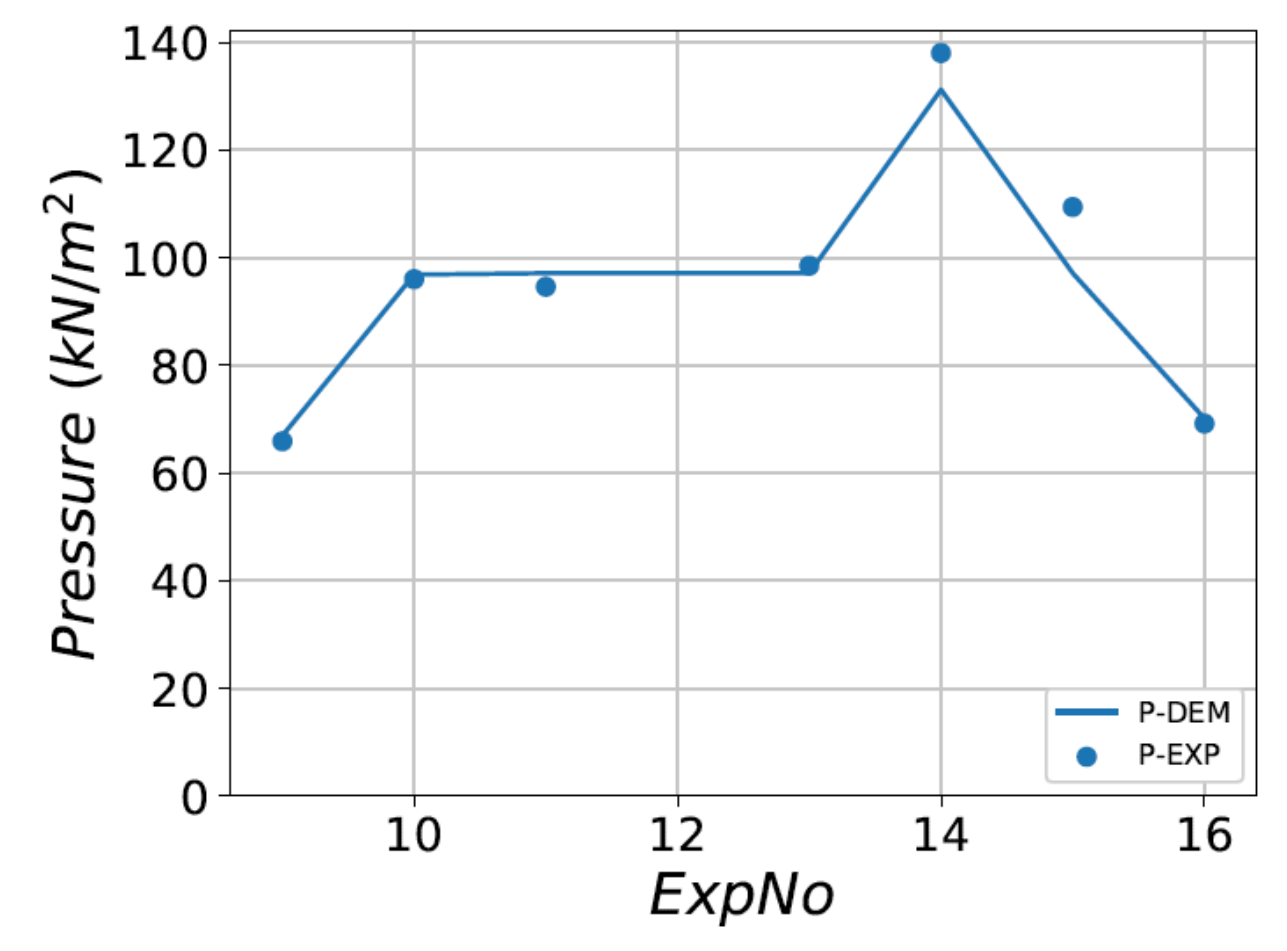
Cross comparison results



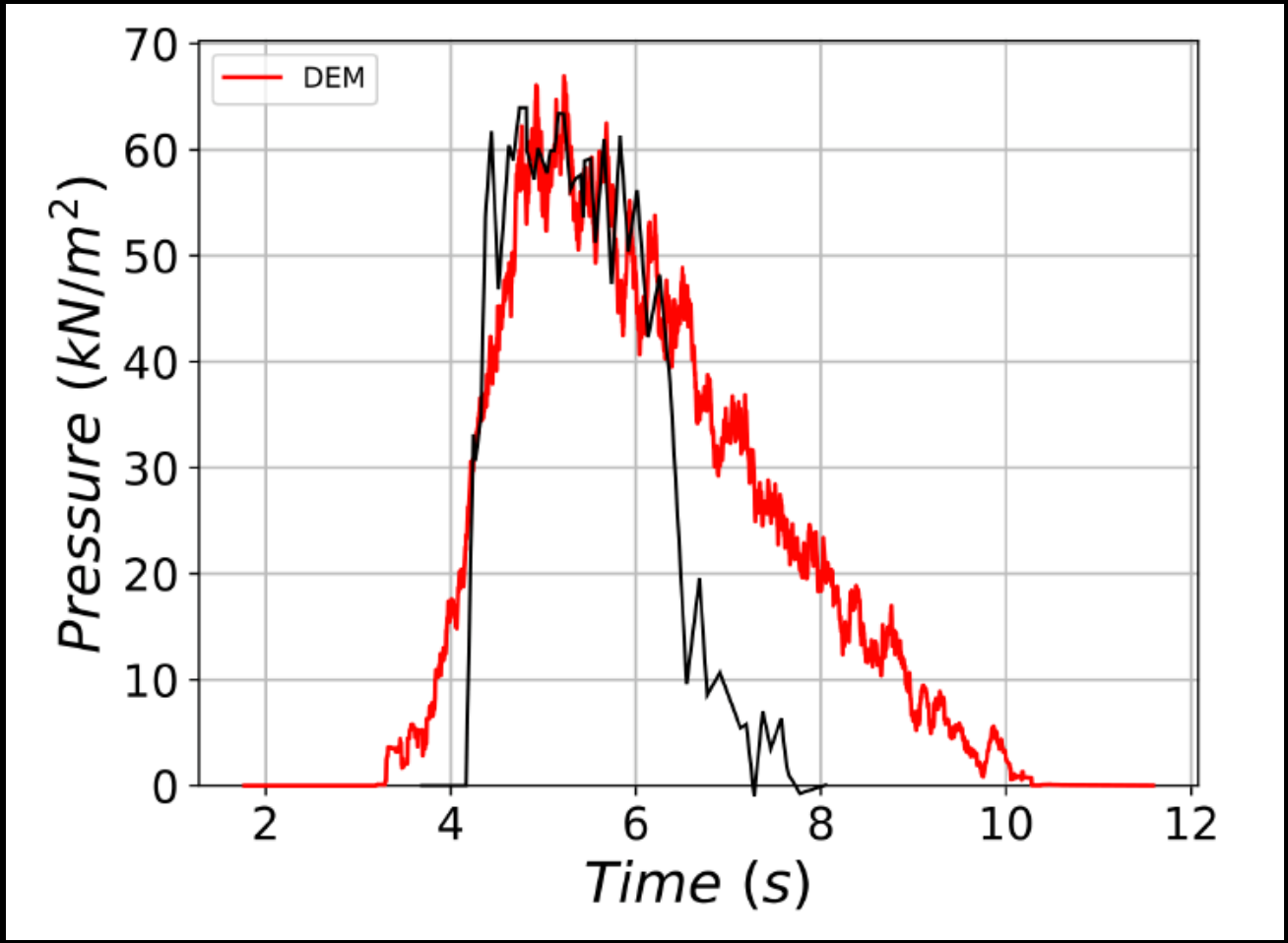
Cross comparison results



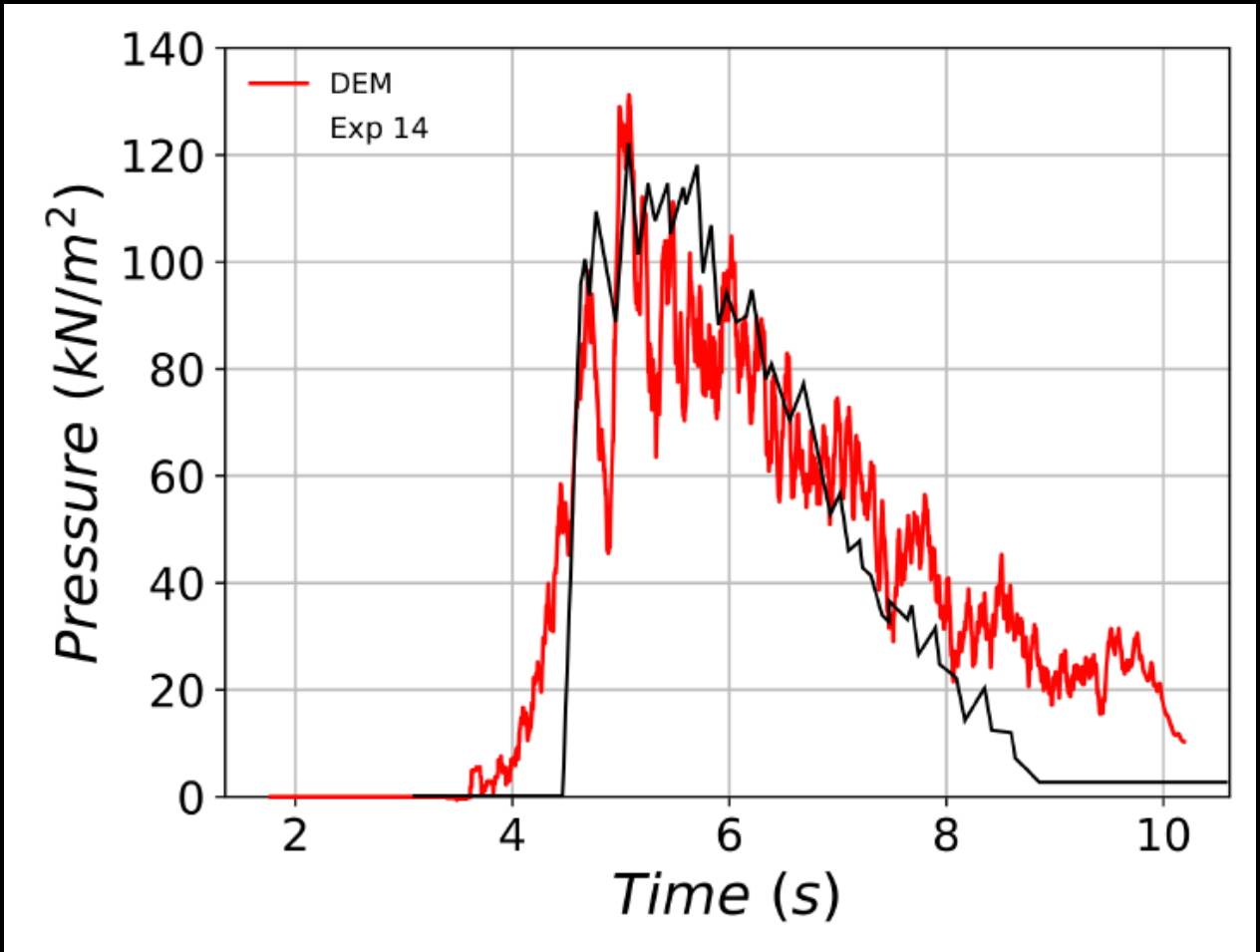
Cross comparison results



Cross comparison results: Pressure evolution test no. 9



Cross comparison results: Pressure evolution test no. 14



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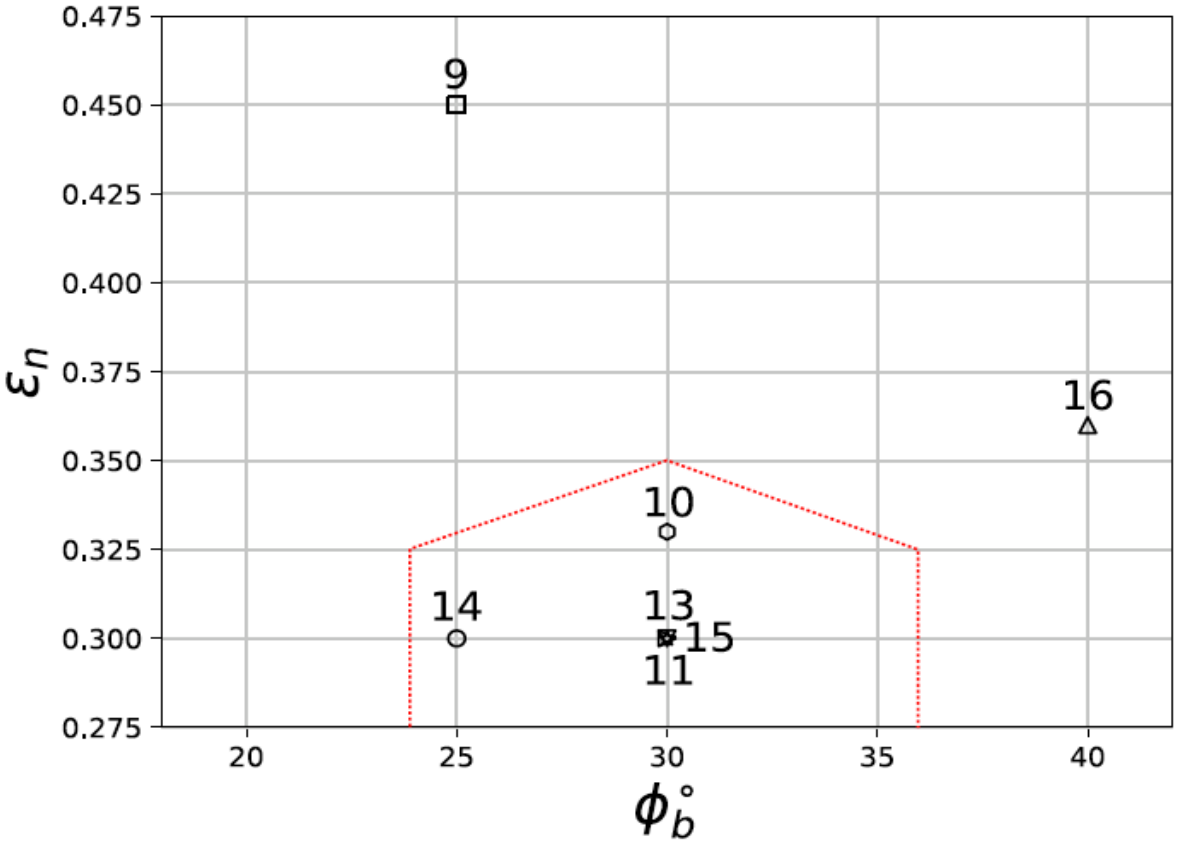
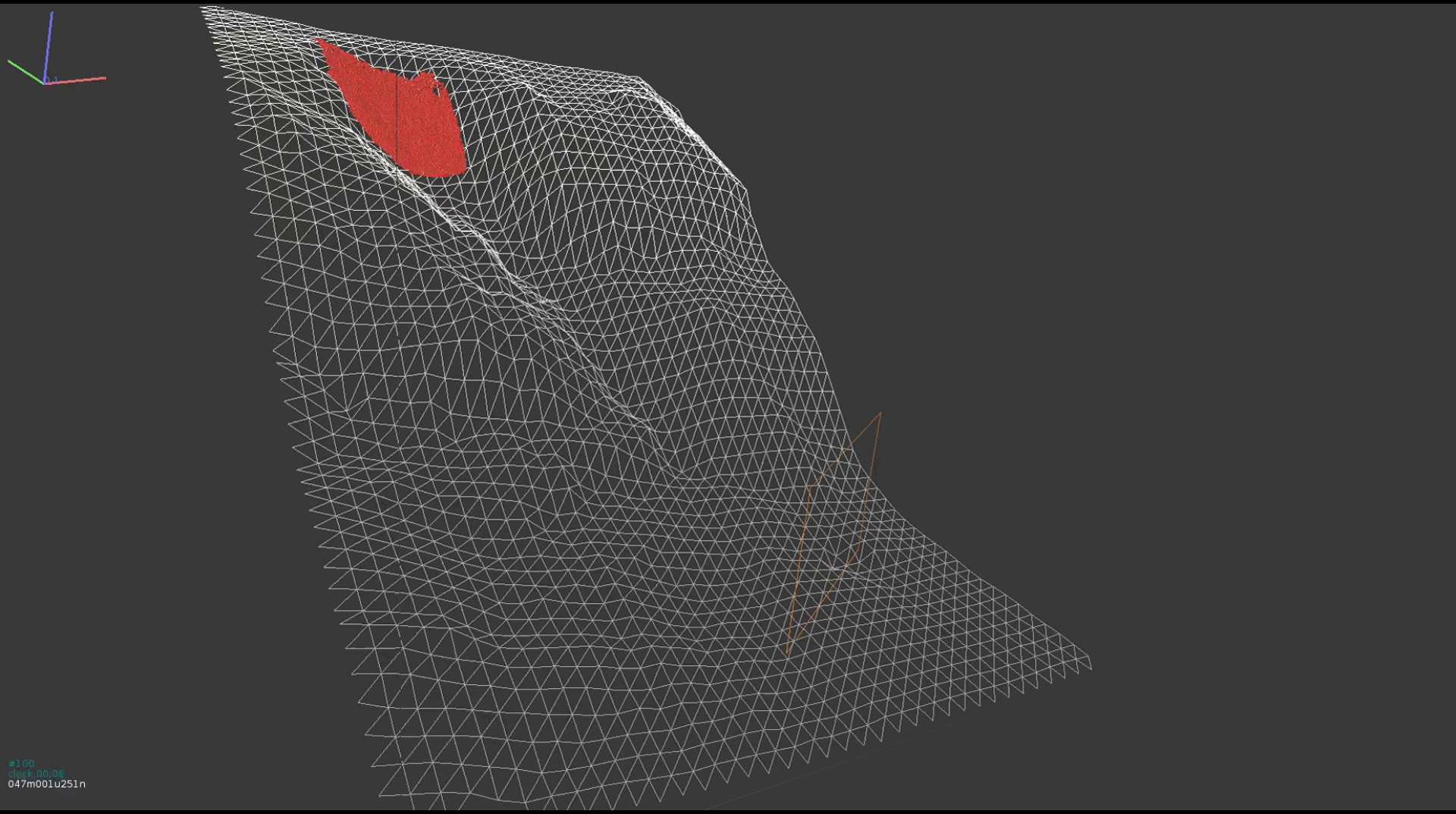
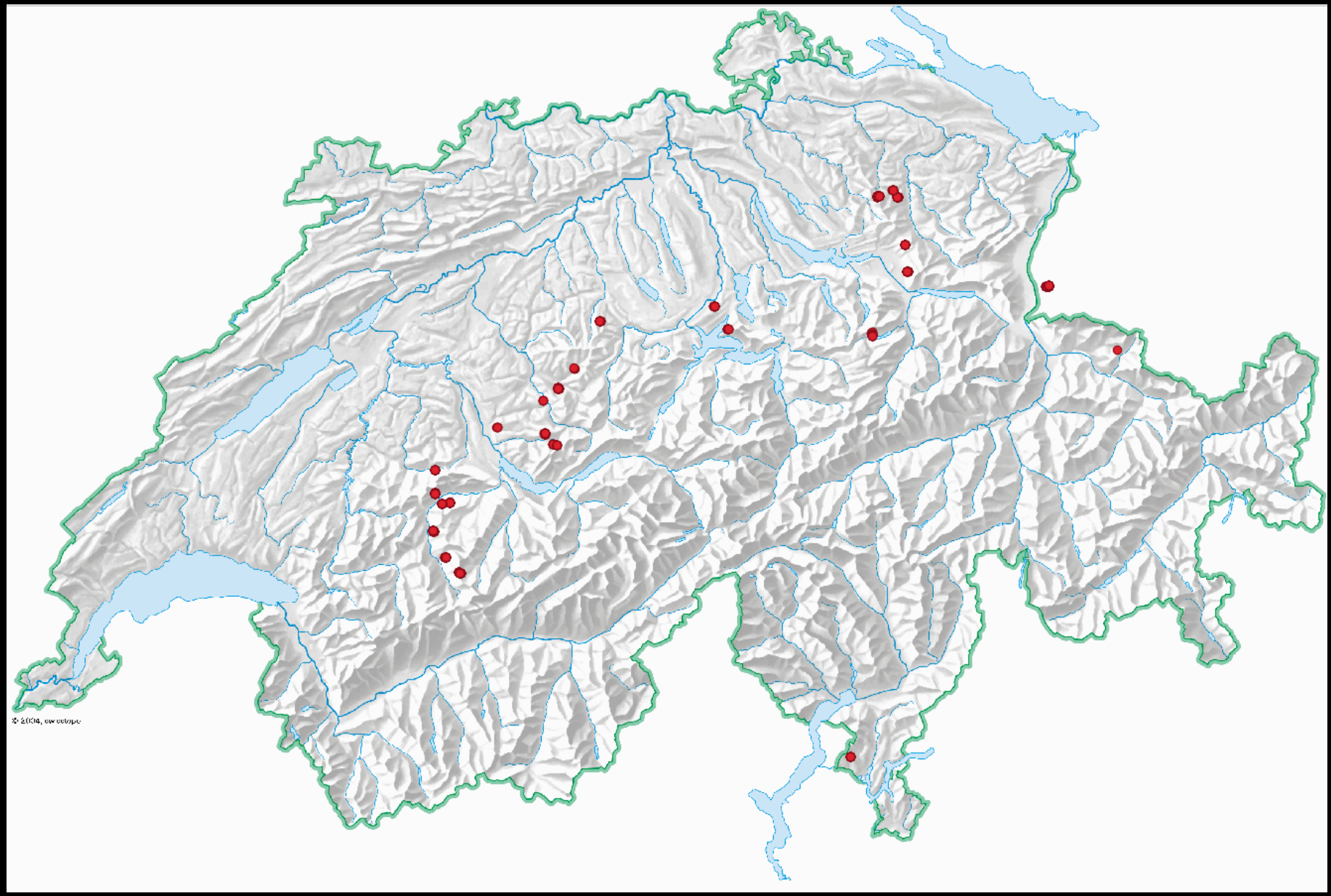


YADE simulation of historical Hill slope debris flow events in Switzerland



Database of historical events in CH



Case studies: Trub (BE)

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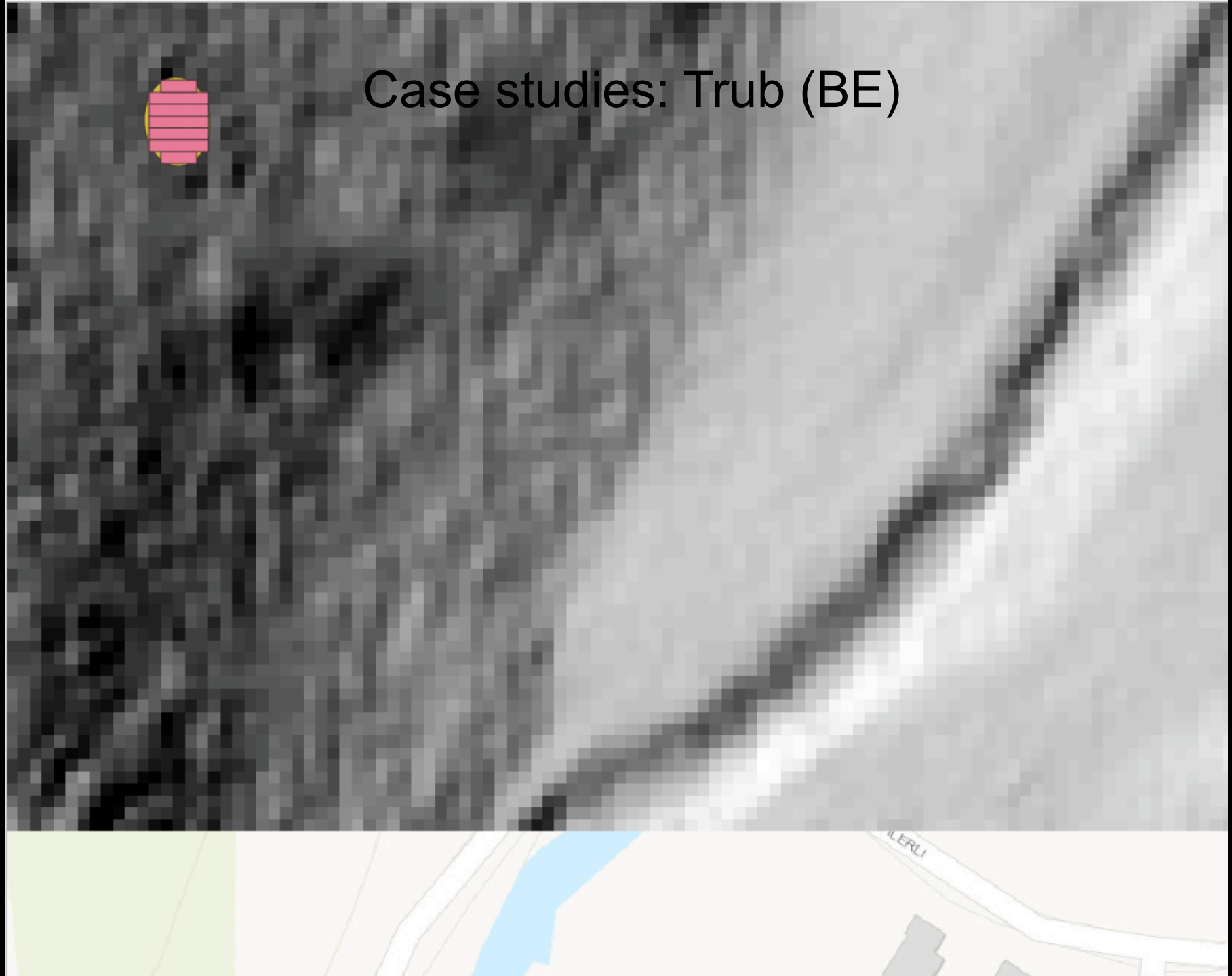


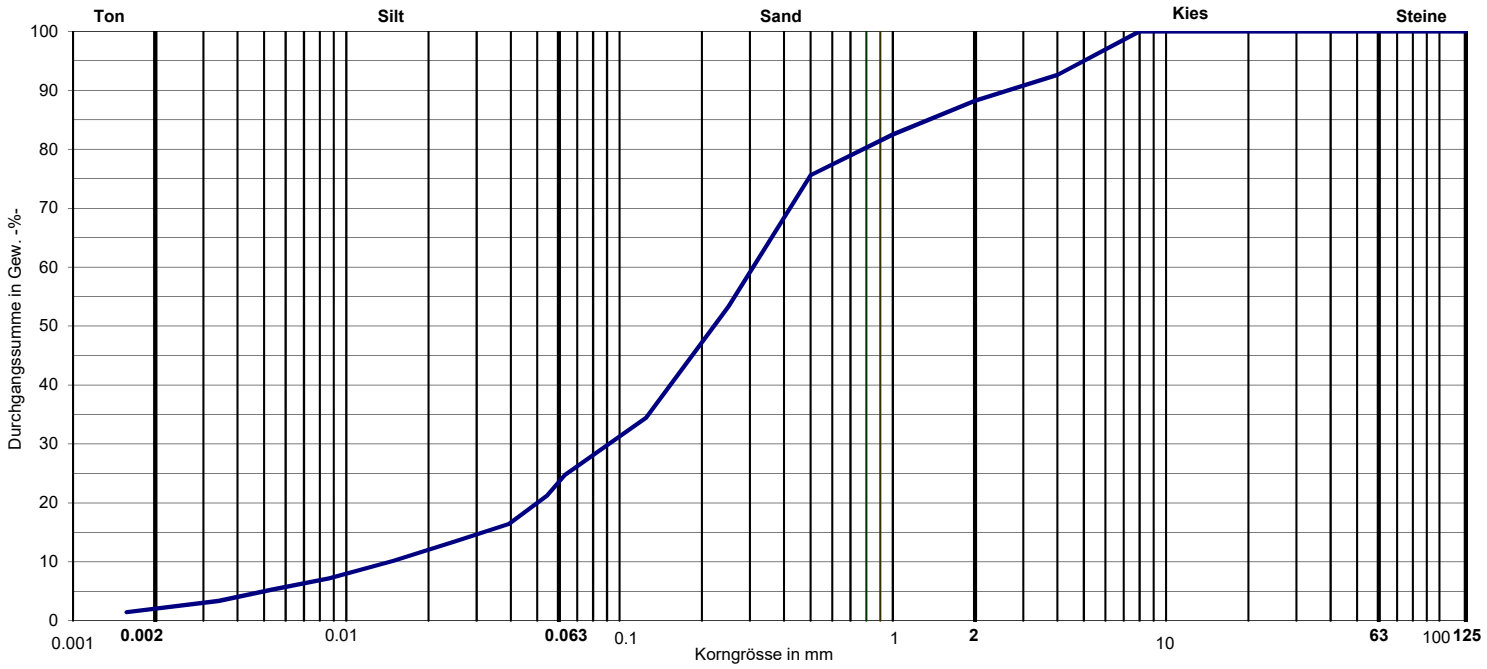
Kornverteilungsdiagramm

Objekt:

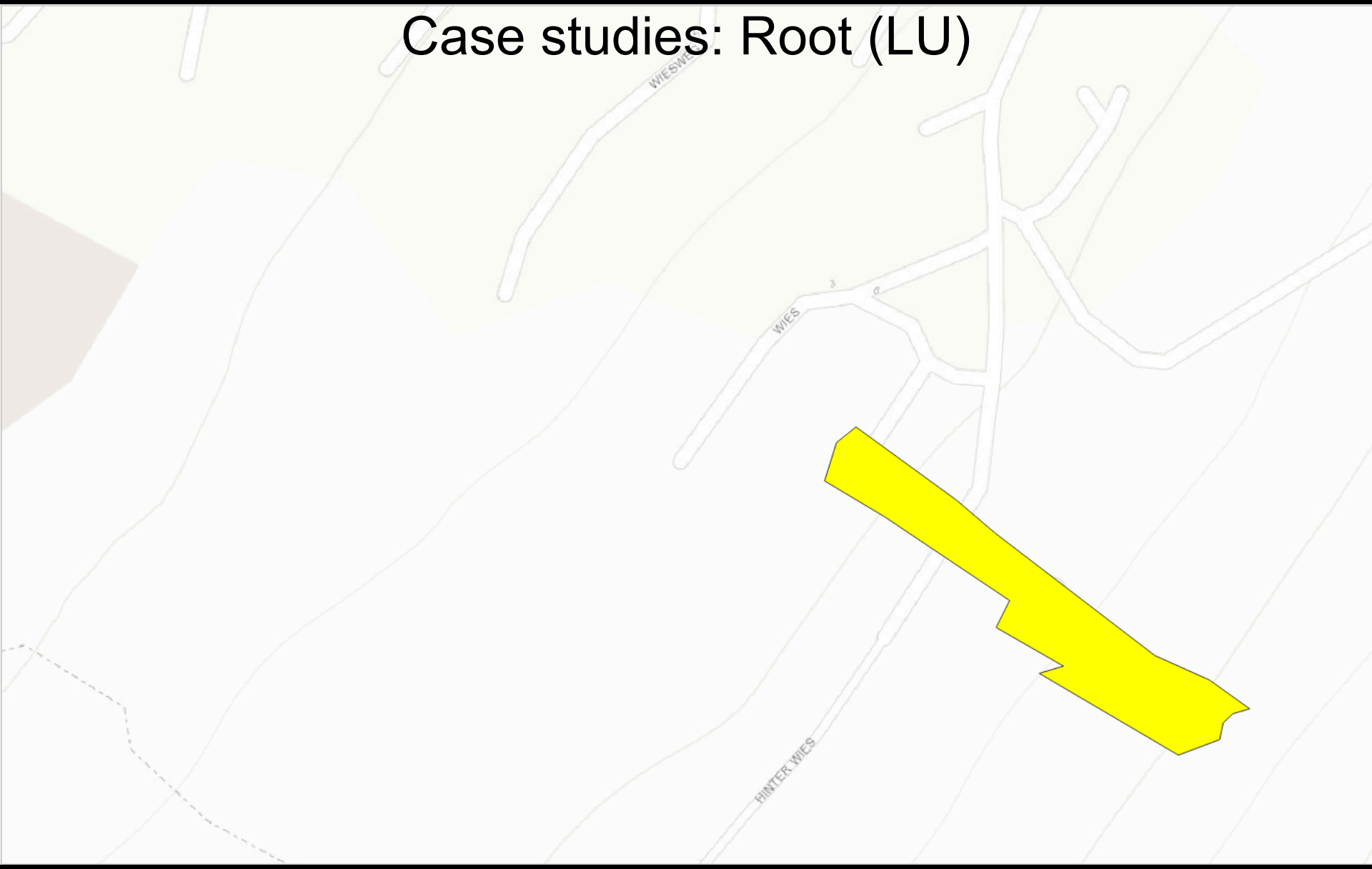
SM	siltiger Sand
Symbol	Gruppenname

Trockensiebung ☐ Nasssiebung ☑ Schlämmanalyse ☐

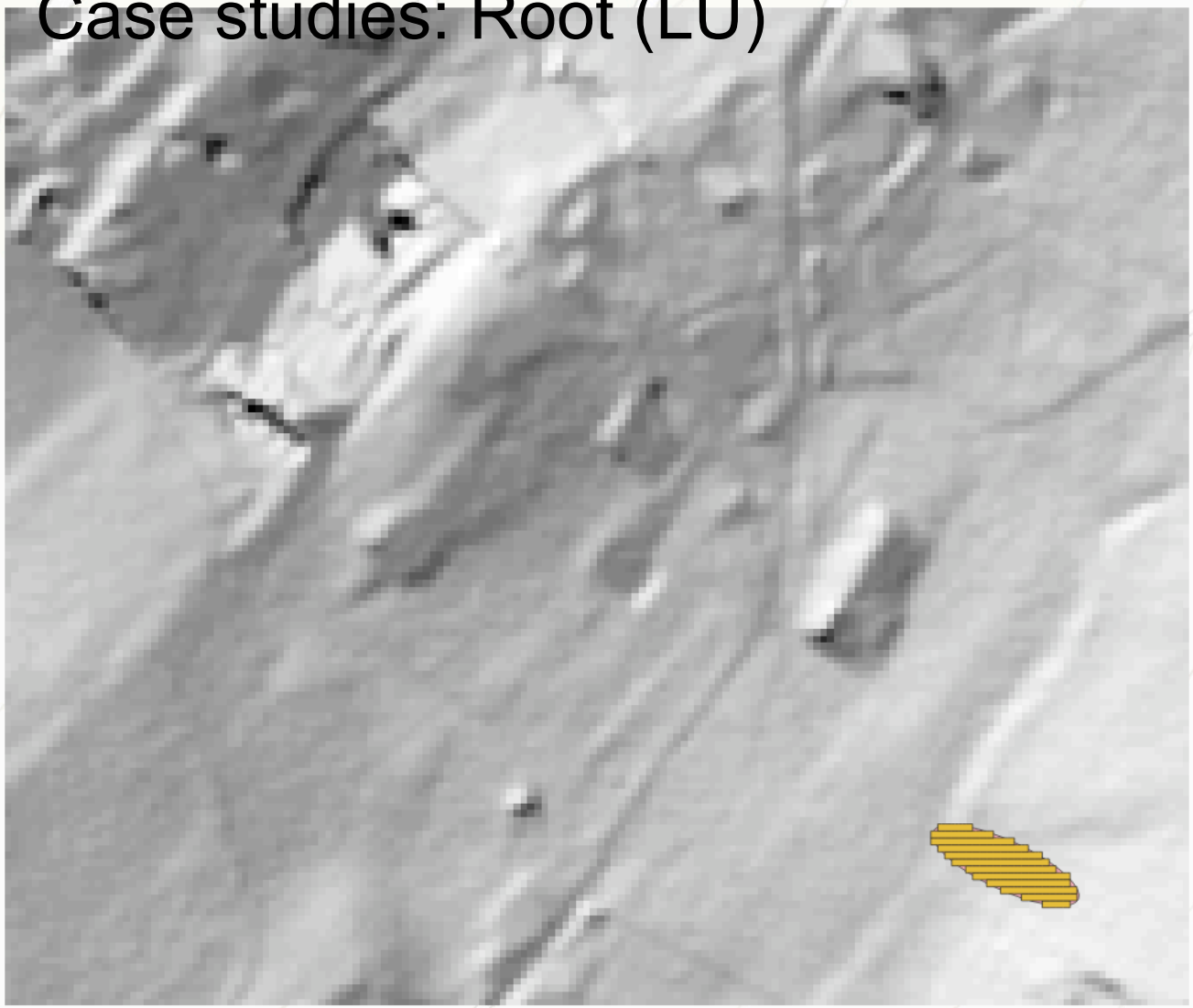
Prüfaufzeichnungs-Nr.	8871-J-PA-4	Durchgang bei 2.000 mm [%]	88.2	D_{60} [mm]	0.325	w_L [%]	28.2
Wareneingangsnummer:	3573	Durchgang bei 0.063 mm [%]	24.7	D_{50} [mm]	0.228	w_p [%]	24.3
Probennummer		Durchgang bei 0.002 mm [%]	1.9	D_{30} [mm]	0.097	I_P [%]	3.9
			C_{cd}	D_{10} [mm]	0.015	w_{Lnat} [%]	
Bezeichnung der Probe:	Hangmure		C_{ud}				



Case studies: Root (LU)



Case studies: Root (LU)



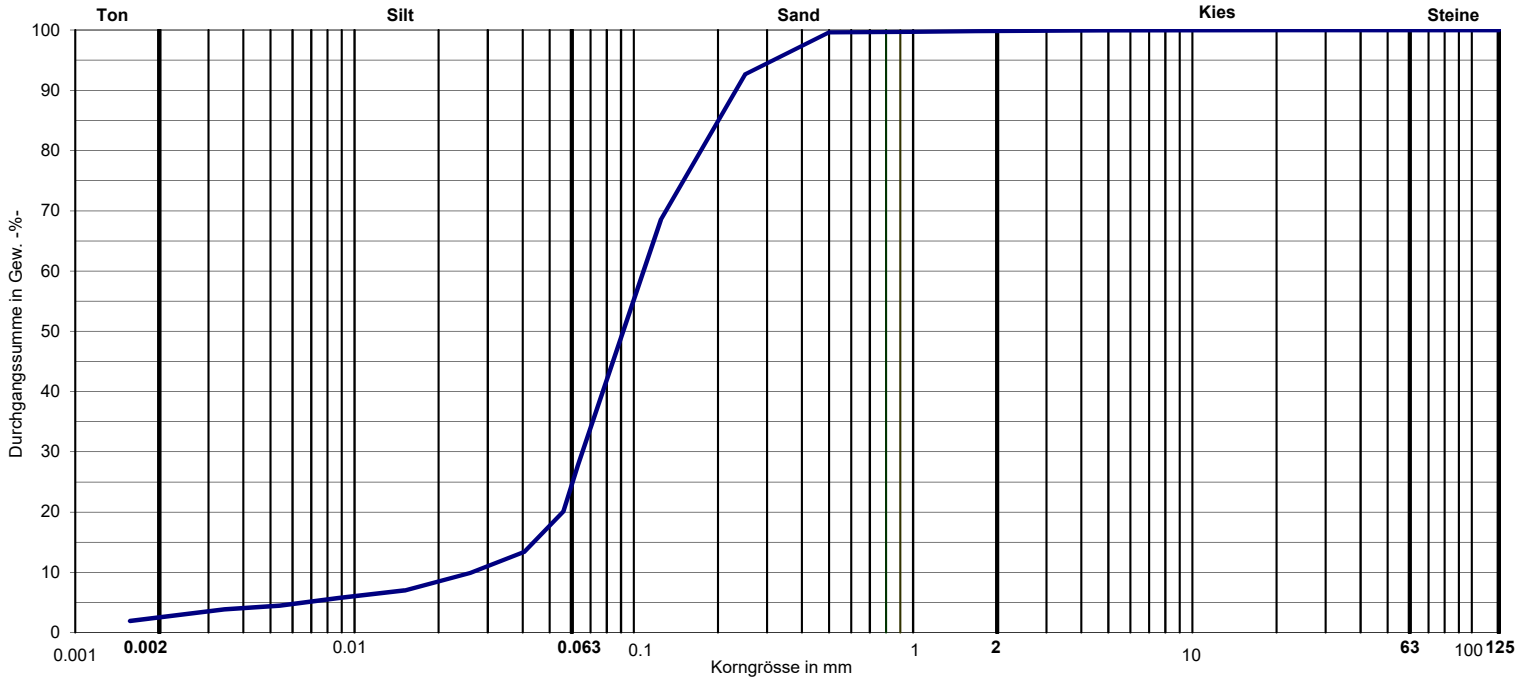
Kornverteilungsdiagramm

Objekt: Hangmure

Trockensiebung ☐ Nasssiebung ☑ Schlämmanalyse ☐

SM	Siltiger Sand
Symbol	Gruppenname

Prüfaufzeichnungs-Nr.	8871-01-PA-42	Durchgang bei 2.000 mm [%]	99.8	D_{60} [mm]	0.112	w_L [%]	24.8
Wareneingangsnummer:	3583	Durchgang bei 0.063 mm [%]	27.7	D_{50} [mm]	0.097	w_p [%]	21.7
Probennummer	2	Durchgang bei 0.002 mm [%]	2.4	D_{30} [mm]	0.066	I_P [%]	3.1
Bezeichnung der Probe:	Root	C_{cd}		D_{10} [mm]	0.026	w_{Lnat} [%]	
		C_{ud}					



Case studies: Root (LU)

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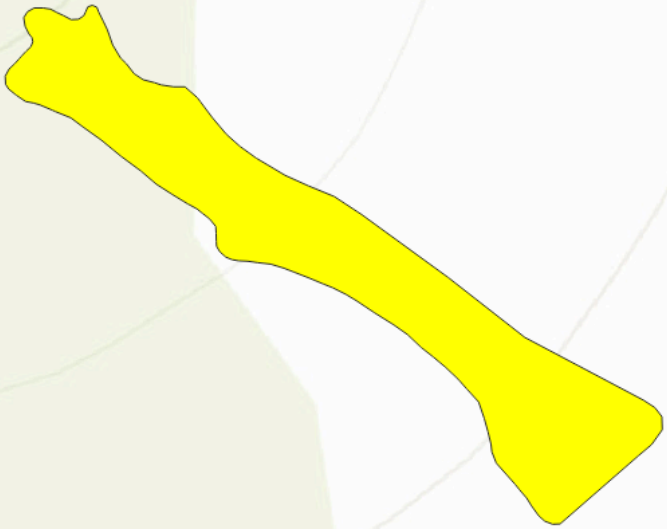
Case studies: Curio (TI)



Case studies: Curio (TI)

Kornverteilungsdiagramm

SW-SM	gut abgestufter Sand mit Silt und Kies
Symbol	Gruppenname

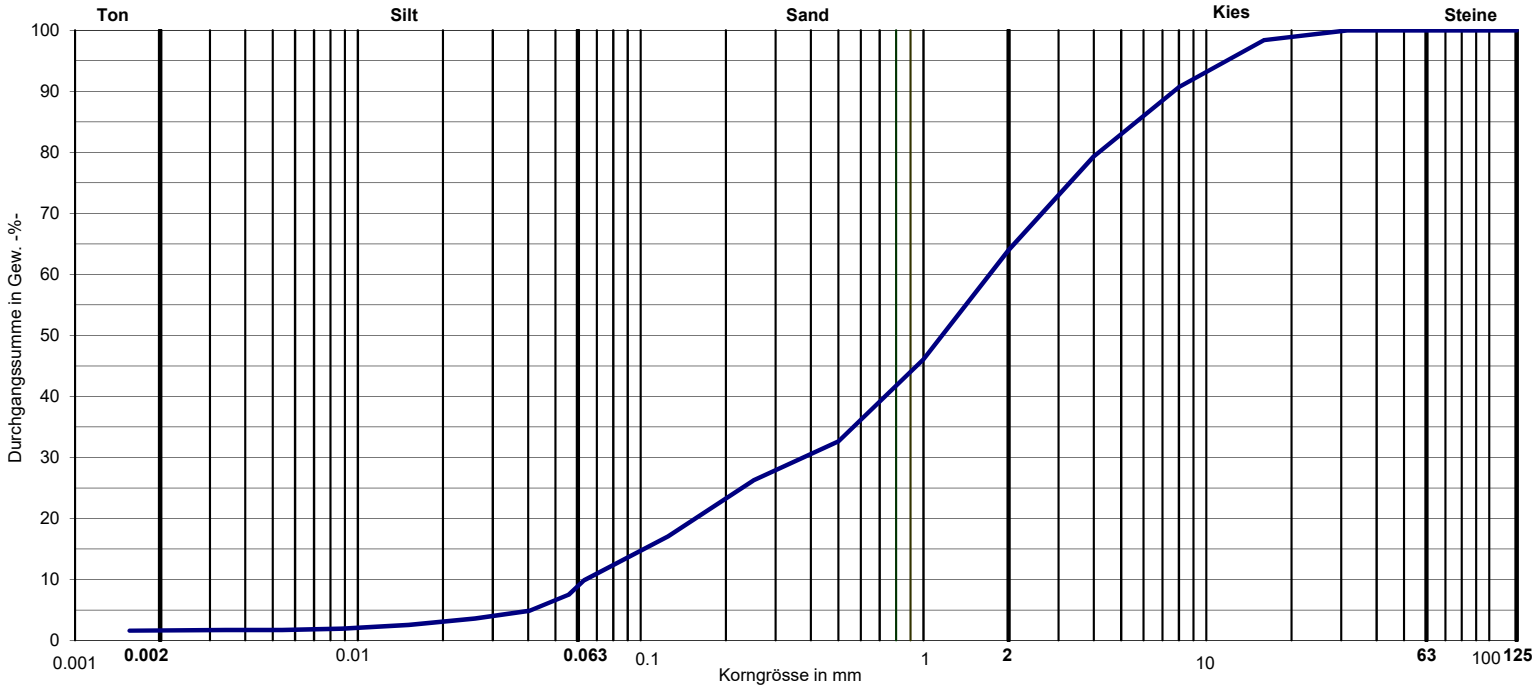
Objekt: Hangmure

Trockensiebung ☐ Nasssiebung ☑ Schlämmanalyse ☐

Prüfaufzeichnungs-Nr.	8871-01-PA-44
Wareneingangsnummer:	3594
Probennummer	4
Bezeichnung der Probe:	Curio Rutschmasse

Durchgang bei 2.000 mm [%]	64.0
Durchgang bei 0.063 mm [%]	9.8
Durchgang bei 0.002 mm [%]	1.6
C_{cd}	1.4
C_{ud}	27.6

D_{60} [mm]	1.778	w_L [%]	36.3
D_{50} [mm]	1.219	w_p [%]	33.5
D_{30} [mm]	0.398	I_P [%]	2.8
D_{10} [mm]	0.064	w_{Lnat} [%]	34.6



Case studies: Curio (TI)

Ciglio di stacco della colata detritica di versante. Larghezza del ciglio: 16 m (in rosso). La freccia blu indica il punto di fuoriuscita di acqua sorgiva dopo l'evento.

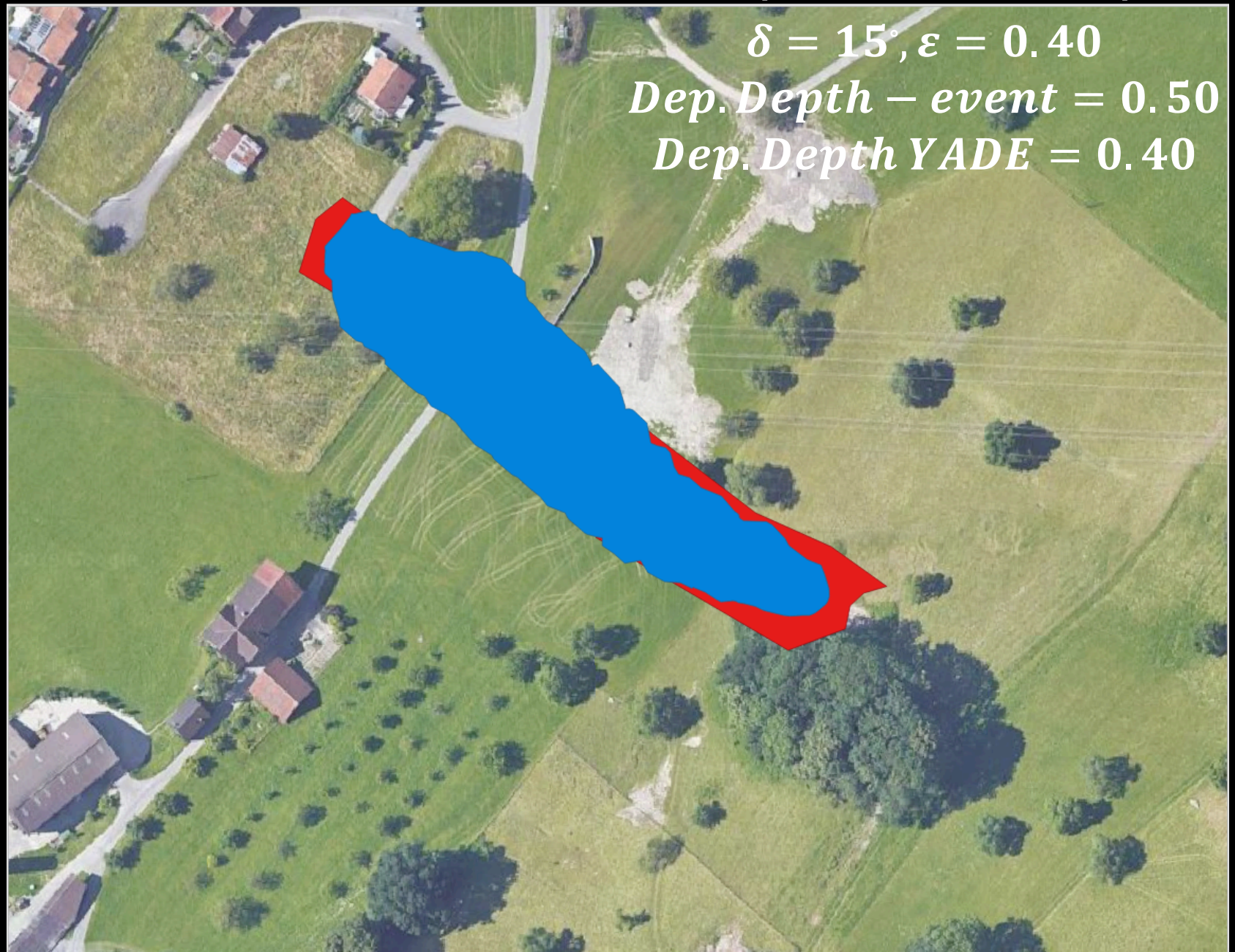
Case studies: Curio (TI)

Vista dall'altro della zona di scorrimento.

Case studies: Curio (TI)

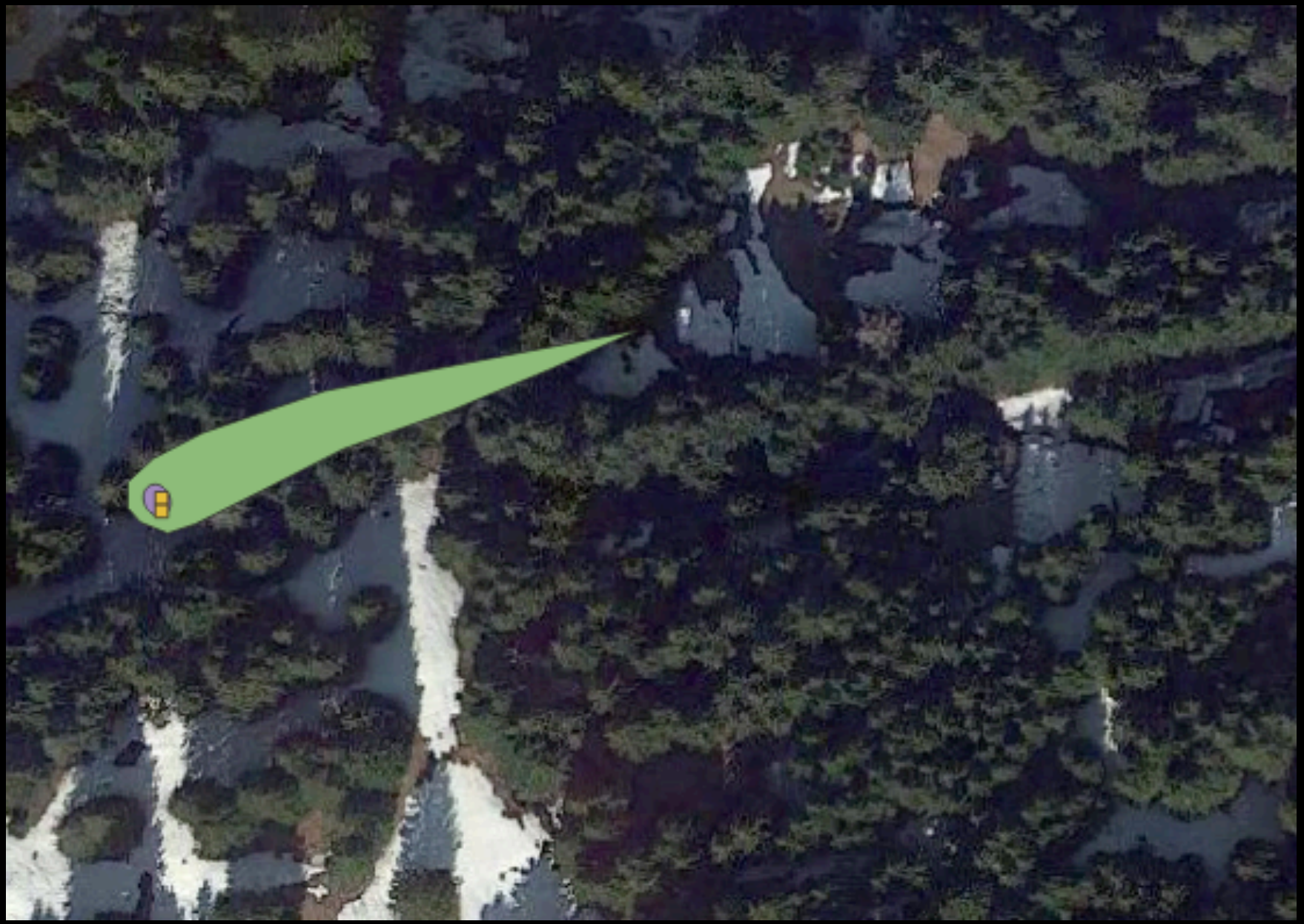
Best fit sim. YADE (TRUB-BE)

Best fit sim. YADE (ROOT-LU)

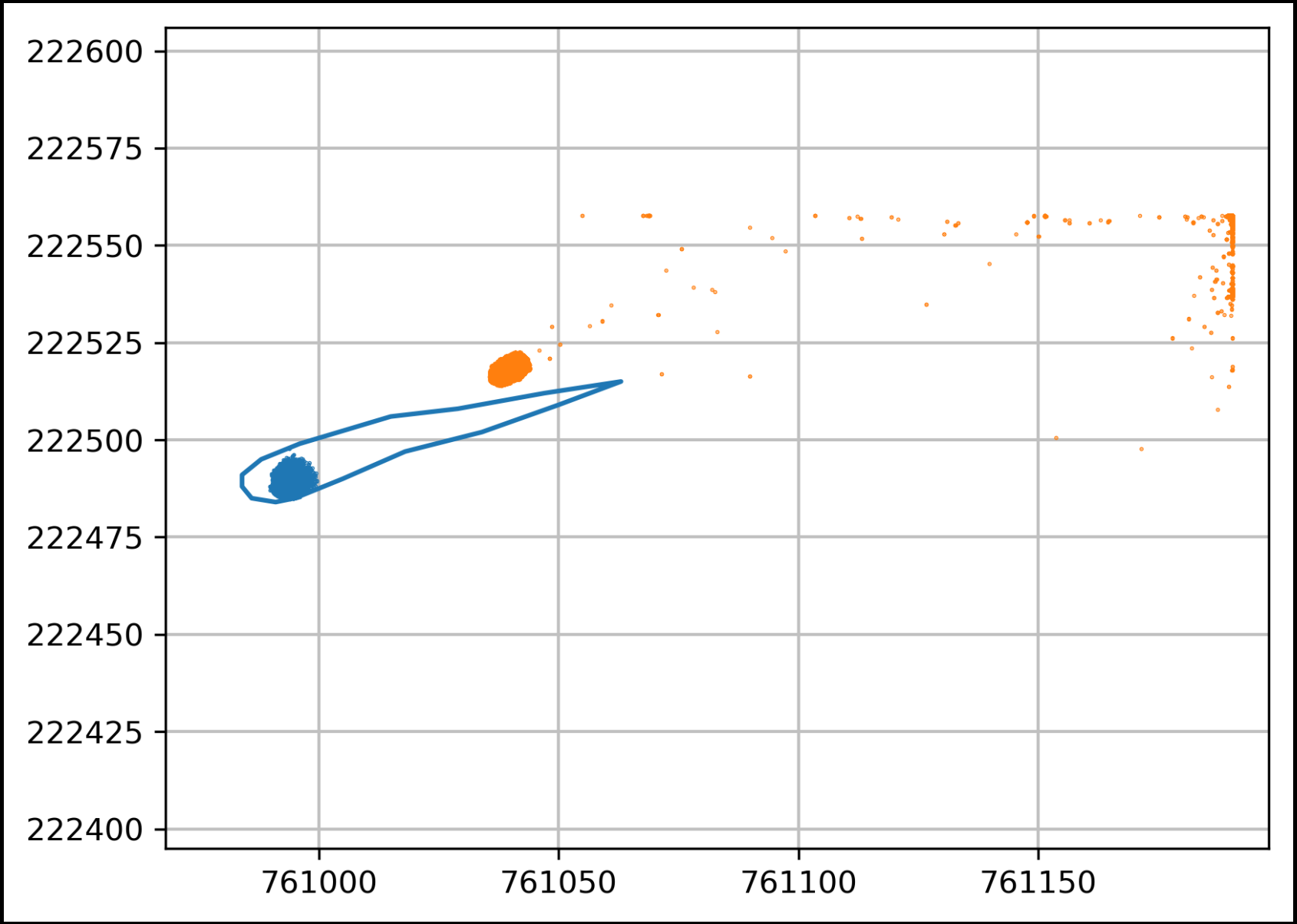


Best fit sim. YADE (CURIO-TI)

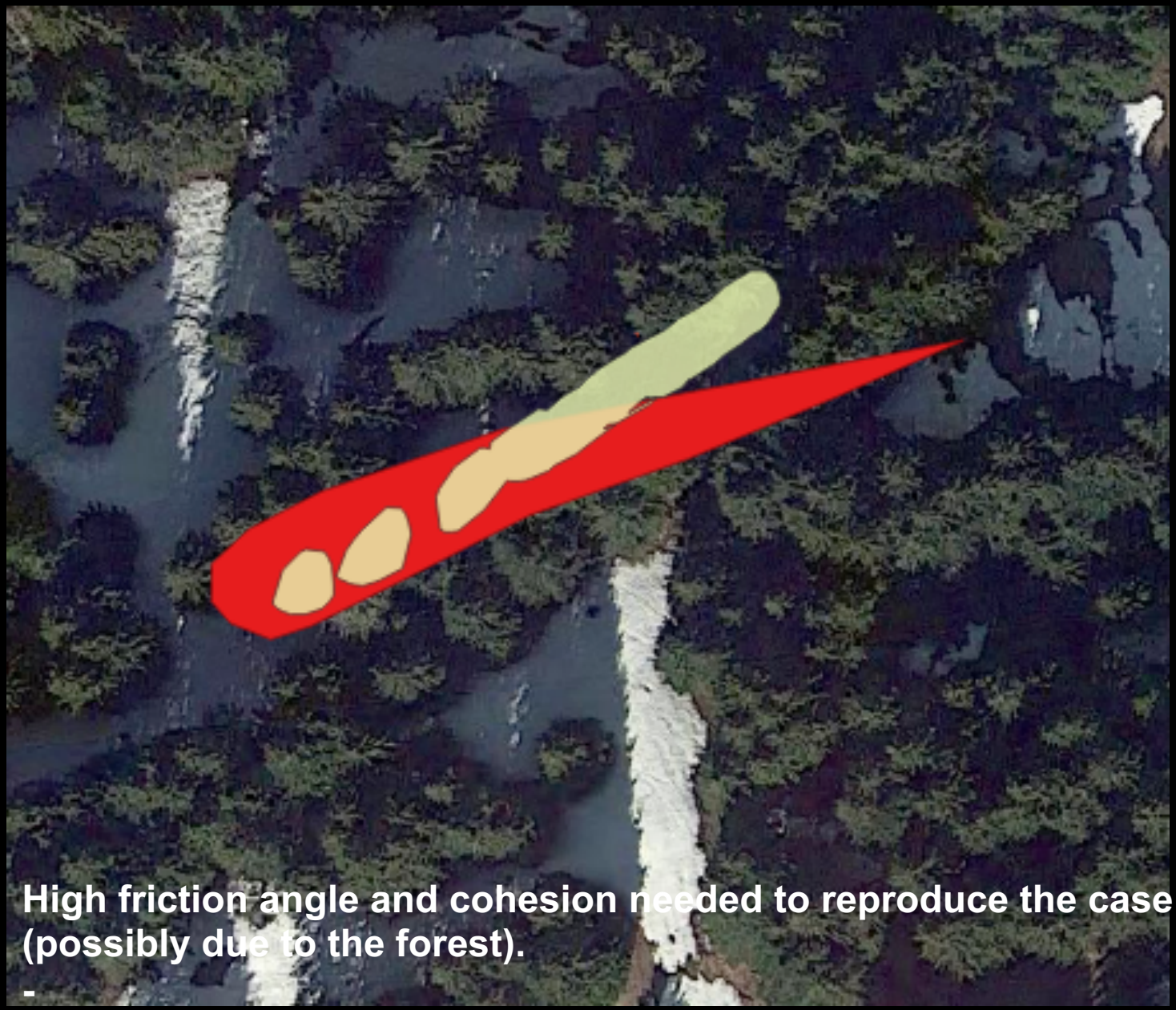
Forest effect ?



Forest effect ?



Forest effect



High friction angle and cohesion needed to reproduce the case (possibly due to the forest).

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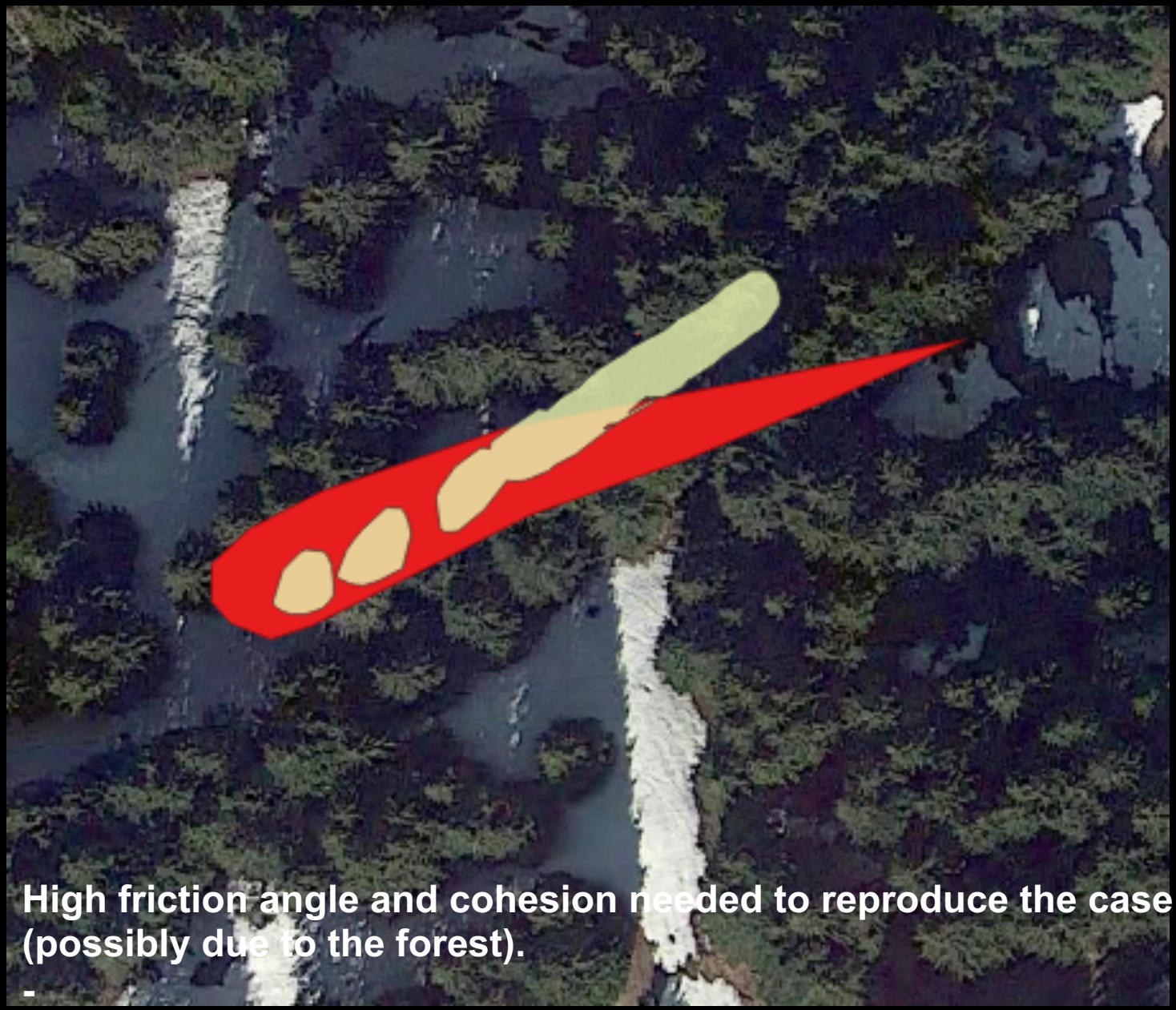
Forest effect



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