SafeLand guidelines for monitoring and early warning systems in Europe:

Design and required technology

Sara Bazin and the SafeLand team

EGU 2012, NH3.12

SafeLand Project and other research on effects of global change on spatial and temporal patterns of landslide risk

Description of work to compile the guidelines

1. Review of existing monitoring technologies
2. Case histories : analysis of real monitoring data
3. Overview of landslide EWSs in operation
4. Development of an operational software for EWS
5. Development of a toolbox to design an EWS
6. Stakeholder example studies (Norway and Slovenia)

1. Review of monitoring technologies

Overview of 30 different remote sensing techniques

Digital total station surveys

B1

Sensor type	Platform	Recording system	System names	Contributing institution	A analy
Active optical sensor	Ground-based	Distance meters and digital theodolite	Total stations	UNIL	Repea meas (D4.1

Accuracy level	Alternatives
cm, mm	Max. to 5 k prism

Spatial resolution	Temporal resolution	
0.01-1 points/m²	Depending on survey intervals, seconds-years	100-500 km²

Additional costs for rapid response

Additional costs for p

Estimated elaboration time

Advantages
- High accuracy
- Temporal and spatial resolution demand
- Considerable maximum range
- 3D information
- High flexibility
- Feasibility of automation of the process
- suitable for early warning system

Displacement rates

Typical velocity		Detection: suitable in few cases	Detection: suitable in some cases	Detection: suitable in many cases	Fast Characterization: suitable in few cases	Fast Characterization: suitable in some cases	Fast Characterization: suitable in many cases	Rapid mapping: suitable in few cases	Rapid mapping: suitable in some cases	Rapid mapping: suitable in many cases	Long-term monitoring: suitable in few cases	Long-term monitoring: suitable in some cases	Long-term monitoring: suitable in many cases
none			B3 (*)			B3 (*)					B3 (*)		
Extremely slow	16 mm /year	C6	B3, C7, C8, C9, C10, D1		A1, B1, C1	C7, C8, C9, C10, D1	B2, B3, C2, C3, C4, D2, D3	B3, D2	B2, C2, C3, C4, C7, C8, C9, C10	B1, C1	A1, A2, A8	C7, C8, C9, C10, B3, D2, D3	A4, B1, B2, C1, C2, C3, C4
Very slow	1.6 m /year	A5, A6, A8, C6, C8, C9	B3, C10, D1, D2, D3		A5, A6, A8, B1, B2 C1, C8, C9,	A1, A2, A12, C10, D1	B2, B3, C2, C3, C4, D2, D3	C8, C9, B3, D2	A4, 8, B2, C2, C3, C4, C10	B1, C1	A5, A6, C8, C9	A1, A4, A8, C10	A2, B1, B2, B3, C1, C2, C3, C4
Slow	13 m /month	A7, A8, A9,A10, A11, A12, A13, A14	B3, D1		A3, A4, A5, A8, A12, A13, B1, B2, C1-C4	A2, D1	B2, B3, C2, C3, C4	10, A13, A14, B3	A4, A8, B2, C2, C3, C4	B1, C1	A3, A10, A12, A13, A14, B3	A4	A2, B1, B2, C1, C2, C3, C4
Moderate	1.8 m /hour	A7, A8, A9, A10, A12	A13, A14, B3		A3, A4, A5, A8, A12, A13, A14 B1, B2, B3, C1-C4	2		A9, A10, A12-A14, B2, B3, C2-C4	A2, A4, B1, C1		A3, A5, A9 A10, A12-A14, A14, B1, B2, B3, C1-C4	A2, A4	
Rapid	3 m /minute	A7, A8, A9, A10, A12	A13, A14, B3		A3, A4, A5, A8, A12, A13, A14 B1, B2, B3, C1-C4			A9, A10, A12-A14, B2, B3, C2-C4	A4, B1, C1		A2, A3, A4, A5, A9,A10, A12-A14, B1, B3, C1		
Very rapid	5 m /sec	A7, A8, A9, A10, A12	A13,A1A 4, B3		A3, A4, A5, A8, A12, A13, A14 B1, B2, B3, C1-C4			A9, A10, A12-A14, B2, B3, C1-C4			A3, A5, 9,A10, A12-A14, B3		
Extremely rapid	> 5 m /sec	A7, A8, A9, A10, A12	A13, A14, B3		A3, A4, A5, A8, A12, A13, A14 B1, B2, B3, C1-C4			A9, A10, A12-A14, B2, B3, C1-C4			A3, A5, A9, A10, A12-A14, B3		

Landslide types

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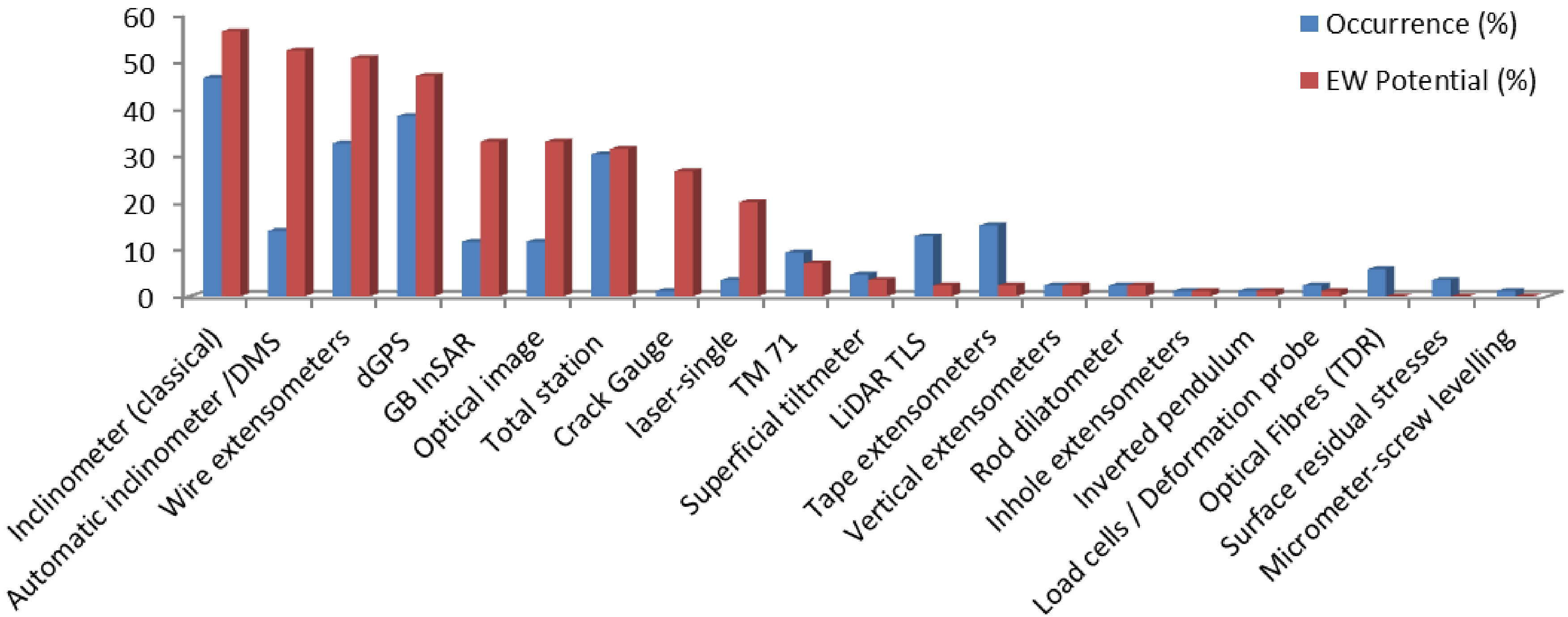
Fall	B3, 7	D2, D3		A8, B1, C1, D2, D3		B2	D2	A4	B1, B2, C1, C2, C3, C4 precursory	A1 ,A5, B3, D2, D3	A4	B1, B2, C1, C2, C3, C4 precursory
Topple	B3, 7	D2, D3		B1, C1, D2, D3		B2	D2	A4	B1, B2, C1, C2, C3, C4 precursory	A1, A5, B3	A4	B1, B2, C1, C2, C3, C4 precursory, D2, D3
Rotational slide	A6-A9, A12, A13, C6	A10, A14, C7, C8, C9, C10, D2, D3	B3,	A2, A5, A6, A8, A13, B1, C1	C7, C8, C9,	A12, B2, B3, C2, C3, C4 C10, D2, D3	A8-A10, A14 C7, C8, C9, B3	A4, B1, B2, C1, C2, C3, C4, C10		A1, A5, A6, A8, A10, A12, A13	[illegible], A4, A14, B1, C1	B2, B3, C2, C3, C4, C7, C8, C9, C10, D2, D3
Translational slide	A6-A13, C6, C7, C8, C9, C10,	A10, A14, D2, D3	B1, B3,	A2, A5, A6, A8, A13, B1, C1, C7, C8, C9, C10	A12, B2, B3, C2, C3, C4, D2, D3		A8-A10, A14, C7, C8, C9, C10, B3, D2	A4, B1, B2, C1, C2, C3, C4,		A1, A5, A6, A8,A10, A12, A13	A4, A14, B1, C1, C7, C8, C9	A2, B2, B3, C2, C3, C4, D2, D3
Flow	A6-A9, A12, A13, C6, C7, C8, C9, C10	A10, A14, D2, D3	B3,	A2, A3, A5, A6, A8, A13, B1, C1, C7, C8, C9, C10, D2, D3	12, B2, B3, C2, C3, C4		A8-A10, A14, B3, C7, C8, C9, C10, D2	A4, B1, B2, C1, C2, C3, C4		A1, A3, A5, A6, A8,A10, A12, A13	A2, A4, A14, B1, B3, C1, C7, C8, C9	B2, D2, D3
Complex landslide	A6-A9, A12, A13, C6	A10, A14, C7 C8, C9, C10, D2, D3	B3	A2, A5, A6, A8, A13, B1, C1, D1*, D2, D3	A12, B2, B3, C2, C3, C4, C7, C8, C9,	C10	A8-A10, A14, B3, C7, C8, C9, C8, D2	A4, B1, B2, C1, C2, C3, C4, C10		A1, A5, A6, A8, A10, A12, A13, D1*	A2, A4, A14, B1, C1, C7, C8, C9	B2, B3, C2, C3, C4, C10, D2, D3

1. Review of monitoring technologies

Sensors of displacement and deformation monitoring - relative occurrence within 89 monitoring sites & early warning potential



Same review for hydro-meteorological and geophysical monitoring

2. Case histories : analysis of real monitoring data

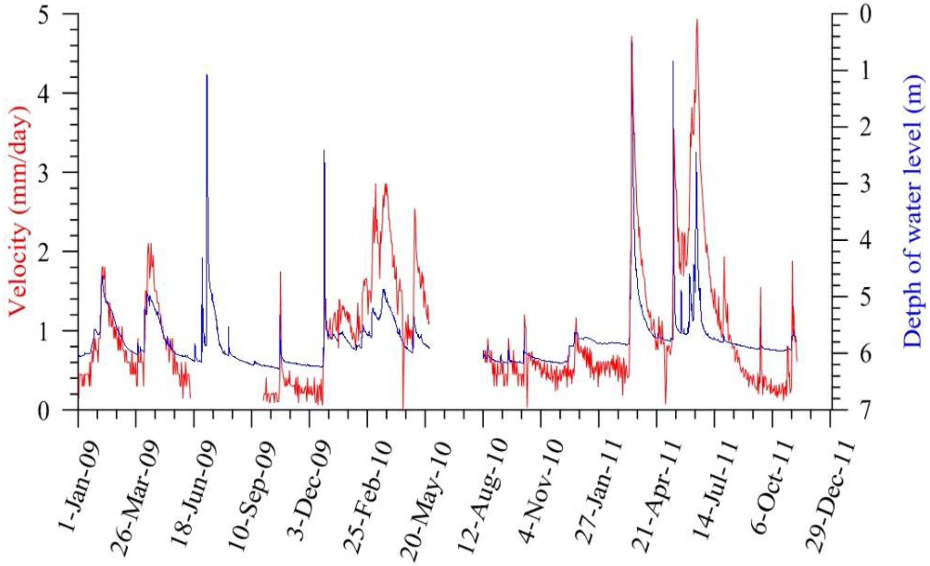
- Compile and interpret monitoring datasets from 14 test sites obtained mainly from 2009 to 2011.
- investigate the correlation between the monitoring parameters : geo-indicators
- find their critical values/thresholds based on the background and geological setting

2. Case histories

SafeLand test sites	Displacement								Hydro(geo)meteorological parameters					Geophysical parameters			
	DGPS	Total station	TLS	GB InSAR	crack- / extensio-meter	tiltmeter	Inclino-meter	DMS	Piezo-meter	DMS	dis-charge	tempe-rature	precipi-tation	Seismic emissions	resistivity	self potential	soil tempe-rature
Aknes (Norway)	X	X	X	X	X	X		X		X		X	X	X			
Ampflwang (Austria)								X		X		X	X		X	X	X
Ancona (Italy)	X	X					X	X	X	X		X	X		X	X	
Bagnaschino (Italy)							X	X	X	X		X	X		X	X	X
Bindo (Italy)		X					X		X			X	X				
Casella site (Italy)								X		X		X	X				
Gschliefgraben (Austria)					X		X	X	X	X	X	X	X		X	X	X
La Valette (France)																	
Jettan (Norway)	X		X		X	X						X	X				
Mannen (Norway)	X		X	X	X			X		X		X	X				
Rosano (Italy)								X		X		X	X				
Ruinon (Italy)	X			X	X		X		X			X	X				
Sonnblick & Mölltaler Glacier (Austria)												X	X		X		X
Super Sauze (France)	X													X	X	X	
Vallcebre (Spain)	X			X			X		X			X	X				
Villerville (France)																	

2. Case histories : analysis of real monitoring data

Vallcebre site: Correlation between displacement velocity and groundwater



Conclusions on geo-indicators:

- In most cases a correlation between rainfall/snowmelt/groundwater table variations and displacement is observed, with a delay of 0 to several days
- The most reliable parameter for early warning is displacement
- Other parameters (resistivity, seismic…) help to interpret surface displacement results; necessary for decision making in case of emergencies.

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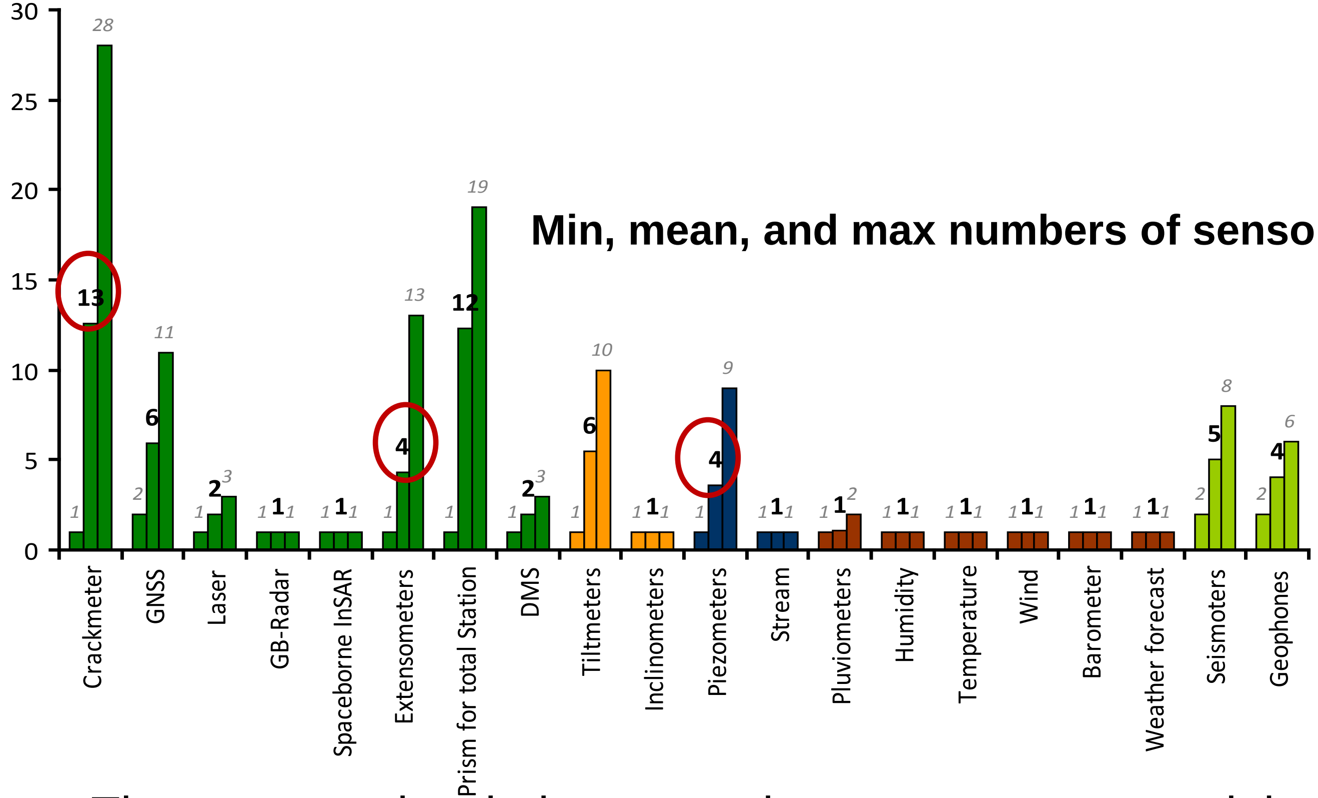
3. EWS screening study

- Aim: analyse existing EWSs to base the guidelines on
- Questionaire sent to ~**100 organizations** in charge of EWSs - 23 answered with **14 operational units** (11 have a EWS in operation, 1 damaged, 1 under construction, 1 stopped)
- Poster by Clément Michoud (UNIL) this afternoon

3.EWS screening study

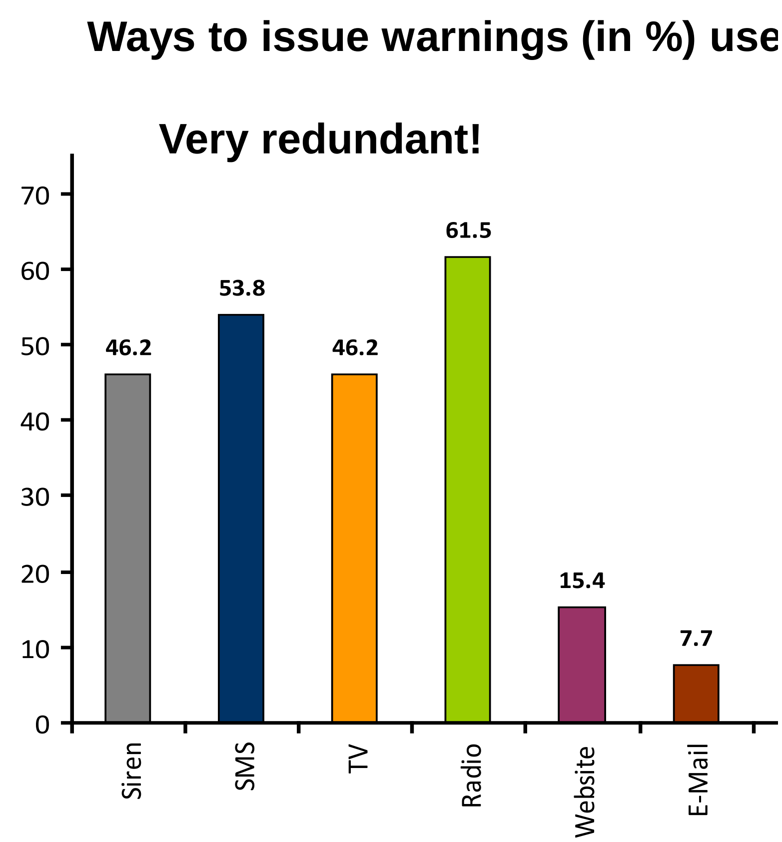
Monitoring parameters, thresholds and sensors evaluation



- The most used techniques are the extensometers and the pluviometers
- When these two are used only a few sensors (4 in average) are installed.
- Crackmeters are less often used, but when they are, you need many sensors (13 in average) –> Redundancy is important but variable.

3.EWS screening study

Warnings, communication and decision making process



Conclusions of EWS screening

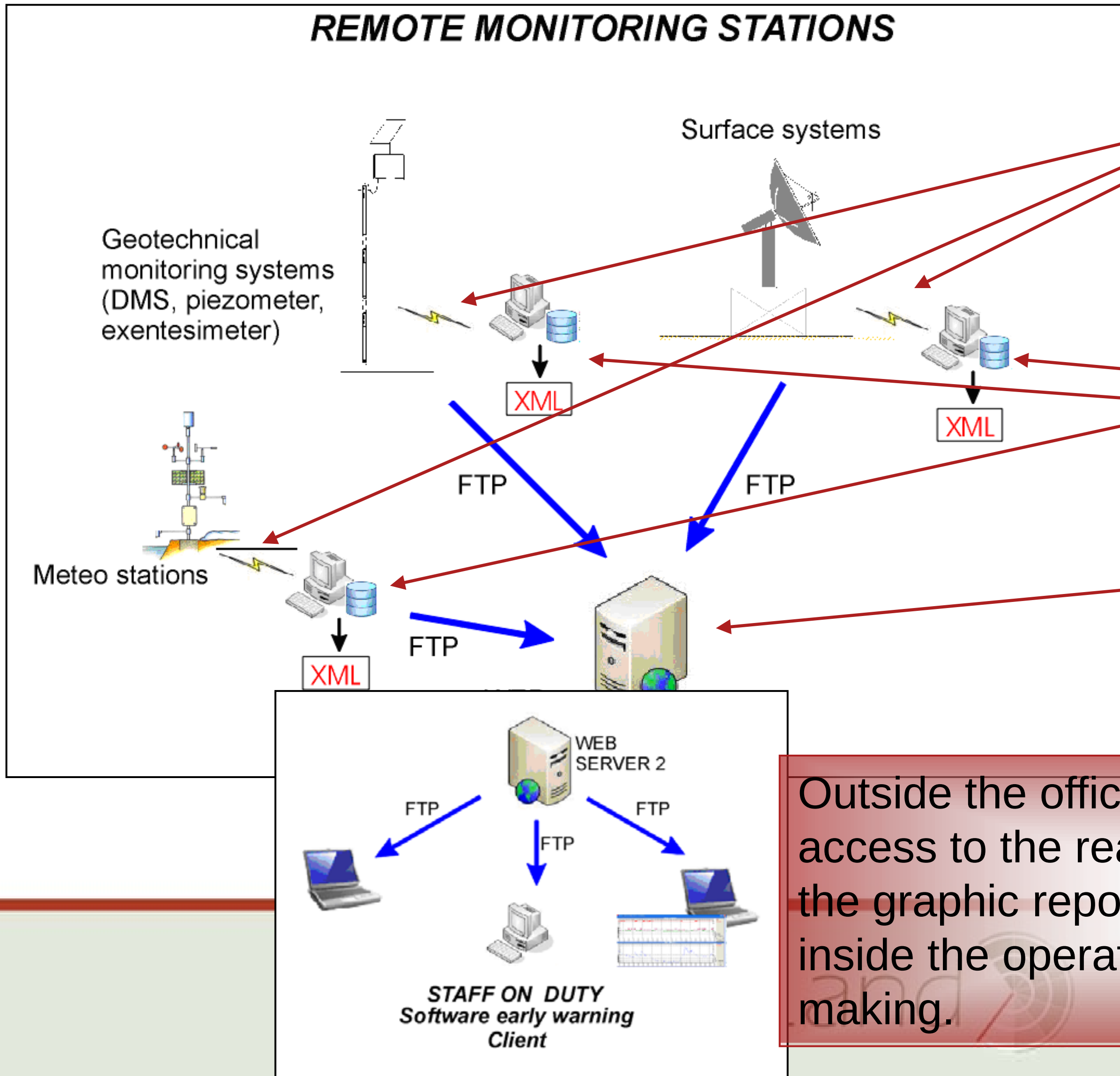
An EWS should:

- be redundant
- be robust
- be simple
- be protected from power and communication loss
- monitor more than one parameter
- integrate all data for good overview

An EWS should not be:

- vulnerable to the landslide
- based only on surface displacement data

4. SafeLand operational software



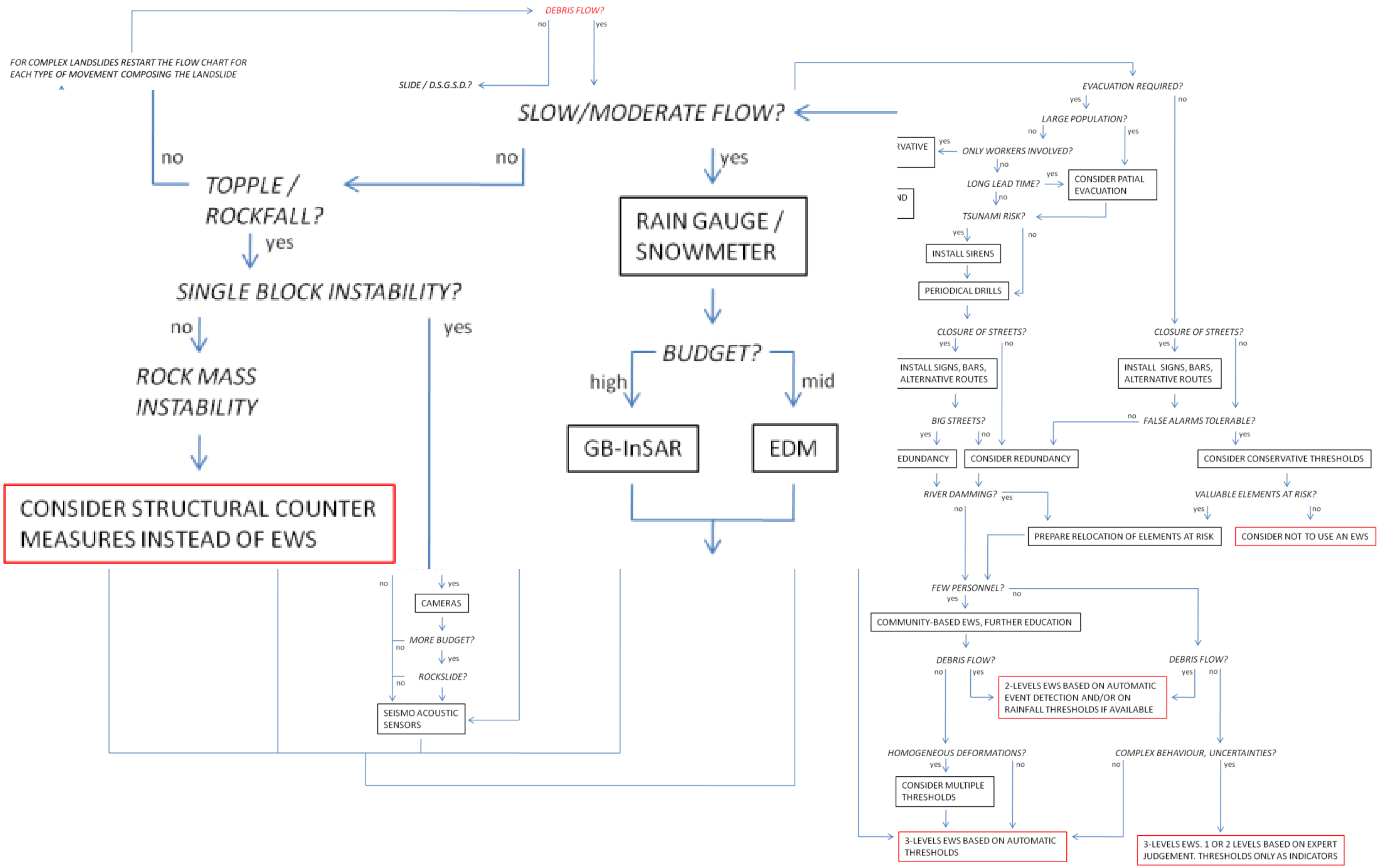
Automatic data download from sensors

Output file conversion to a XML file

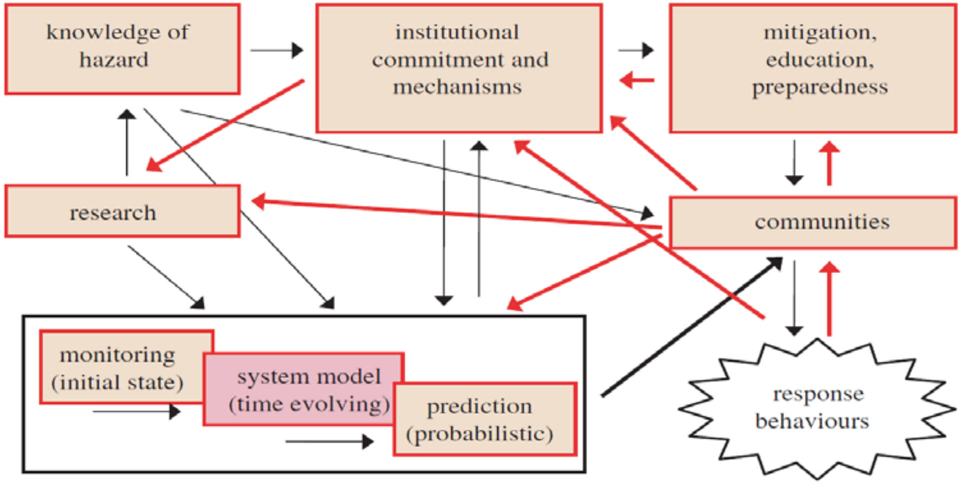
Data availability on a web server

Outside the office, the staff on duty has access to the real time data and can view all the graphic reports, supporting the staff inside the operational centre for decision making.

5. Development of a generic EWS toolbox



6. Community and response capability



An EWS is an integrated system

- A EWS should be designed to guide a proper response behavior
- One should consider:
    - the community and response capability
    - understand the relationship between risk perception and risk communication
    - education, regular drifts, long-term funding to secure that residents feel safe
- A social study in Norway shows that:
    - the community favors a local decision (locals working in the operational unit)
    - openness, involvement and good communication with the residents at an early stage has a positive effect on people’s perceived risk

Partners

33 contributors, 14 institutions and 1 end-user

8 countries

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- Ancona , **Italy**: *Stefano Cardellini*
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Thank you for your attention!

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