

# Regional early warning for soil slides, debris flows, and slush flow in Norway



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# The application of the landslide early warning along transportation lines in Norway



**Statens vegvesen**

**Tore Humstad**

Engineering geologist

Geotechnical division  
Norwegian Public Roads Administration



**Statens vegvesen**  
Norwegian Public Roads  
Administration

# Is it a problem?



Sør-Trøndelag 2012 Photo: O.J. Kjellmark, Adressa.no





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# Is it a problem?



Kvam 2011 Photo: NVE





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# Is it a problem?

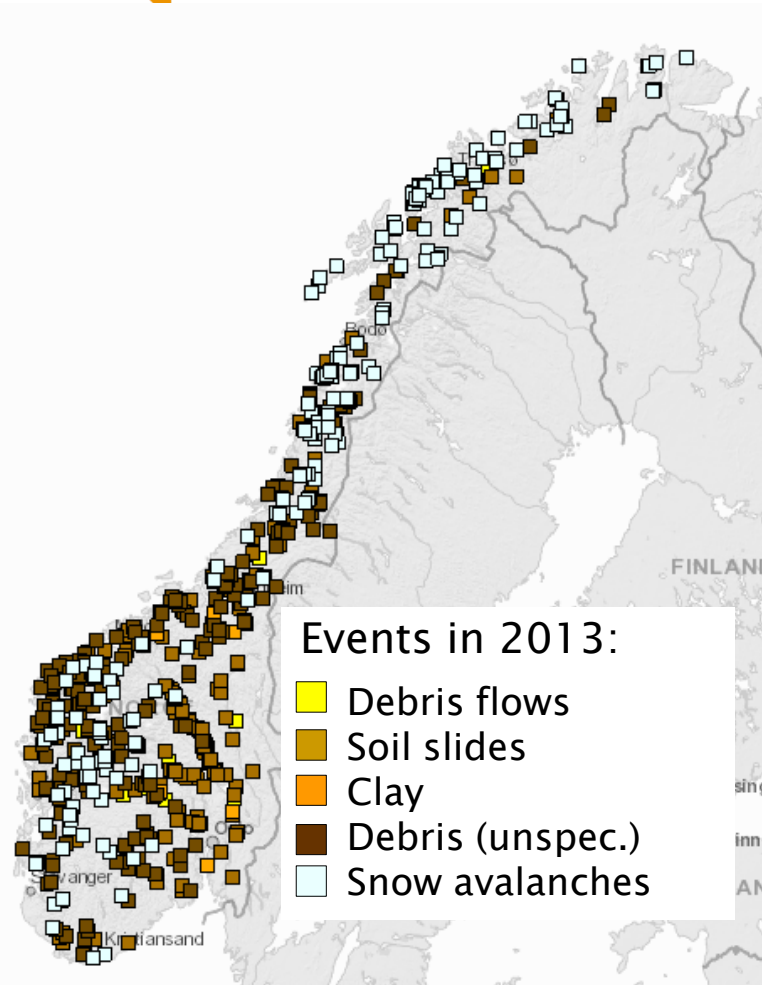


Dovrefjell, Snøhetta 2010 Photo: Adressa.no



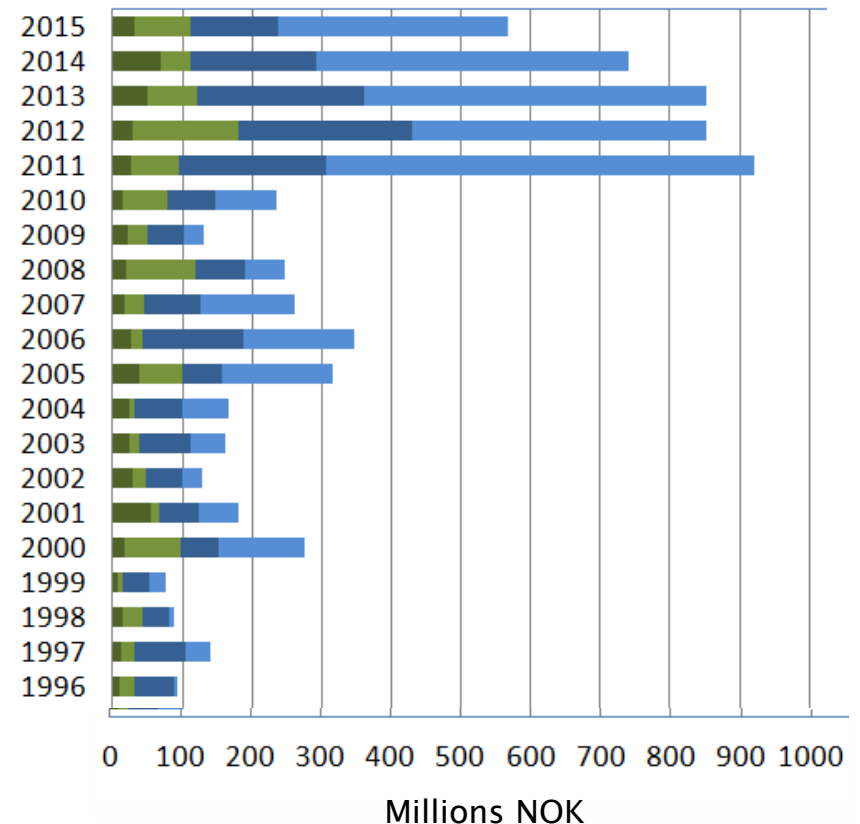
Statens vegvesen

# Growing problem?



## Compensations paid 1996–2015

Skred: Statens naturskadefond  
Skred: Norsk Naturskadepool  
Flom: Statens naturskadefond  
Flom: Norsk Naturskadepool





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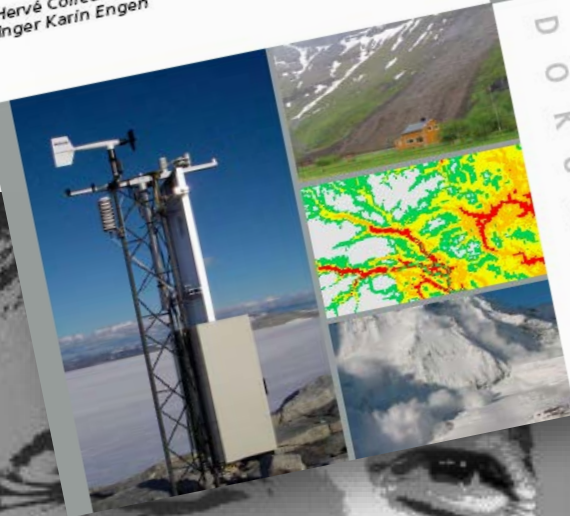


Utredning om overvåking og  
varsling av løsmasse- og snø-  
skredfare på regionalt nivå

Hervé Colleuille  
Inger Karin Engen

16  
2009

D O K U M E N T



## «Can we solve it together»?

- Weather station
- Meteorological and hydrological models
- Weather forecast and flood warning
- Expertise (internal and external)
- Responsible for same professions in different industries





Varsom.no



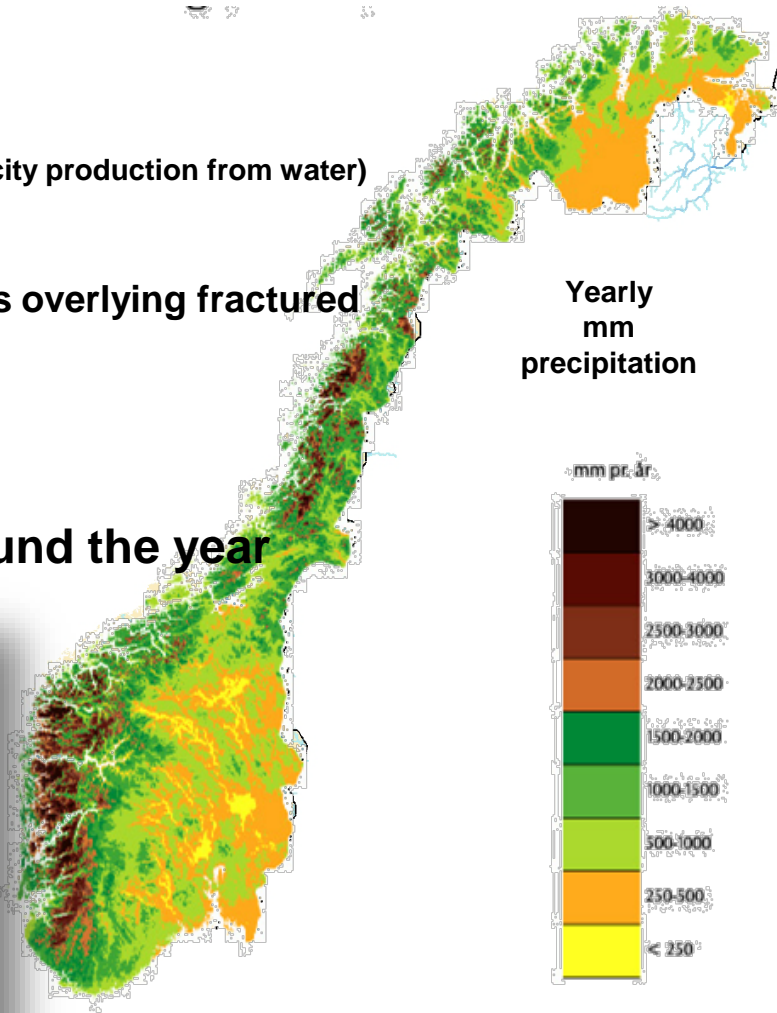
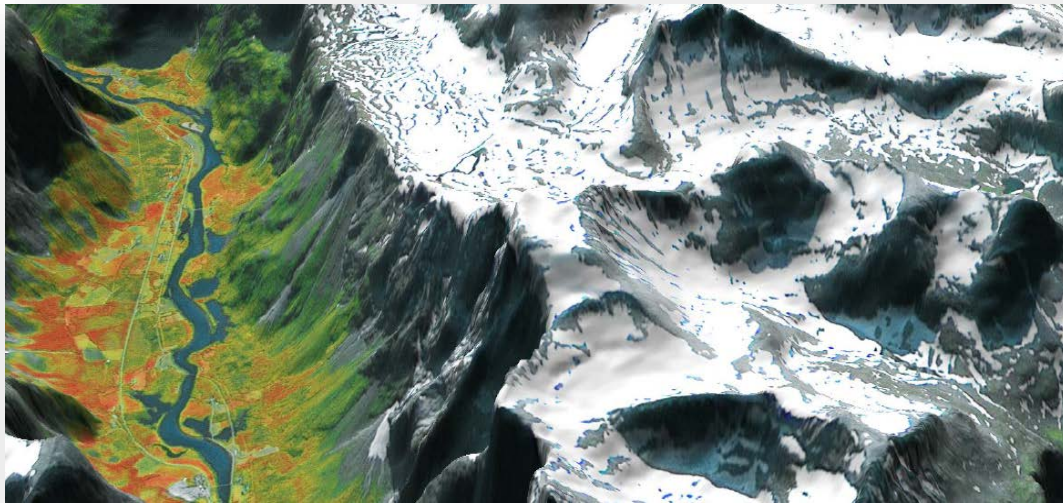
- After some years of development of regional warning services:
  - Snow avalanche warning, launched in 2013
  - Landslide warning, launched in 2013





# Basic information

- About 500 000 km rivers and streams (99% electricity production from water)
- Landscape: Fjords, U-shaped valleys, mountains, bogs
- Shallow soils and aquifers: Moraine or marine deposits overlying fractured bedrocks (crystalline & metamorphosed hard rocks)
- Large climatic contrasts from West to East
- >1/3 precipitation as snow
- Rainfall and snowmelt induced events all around the year



- **Area:** 324 000 km<sup>2</sup> (+ Svalbard)
- **Population:** 5.2 mill.    **Density:** 16 people per km<sup>2</sup>



# NVEs Early Warning Systems (EWS)

## Three warning services

### ■ Flood warning (1989)



Operated in close cooperation



### ■ Landslide warning (2013)

Debris slides, debris flows & slush flows



Established as a joint initiative across public agencies



### ■ Snow avalanche warning (2013)



# 3 years to establish operating EWS for landslides and snow avalanches



Norwegian Public  
Road Administration



Norwegian  
National Rail  
Administration



Norwegian  
Meteorological  
Institute

- Expanding the hydrological and meteorological station network
- Strong development of IT- tools (decision tools, database...)
- Common research and development
- Synergy effect with the existing flood warning service using same observations, forecasts, hydrological models, warning portal...



# What are we doing?

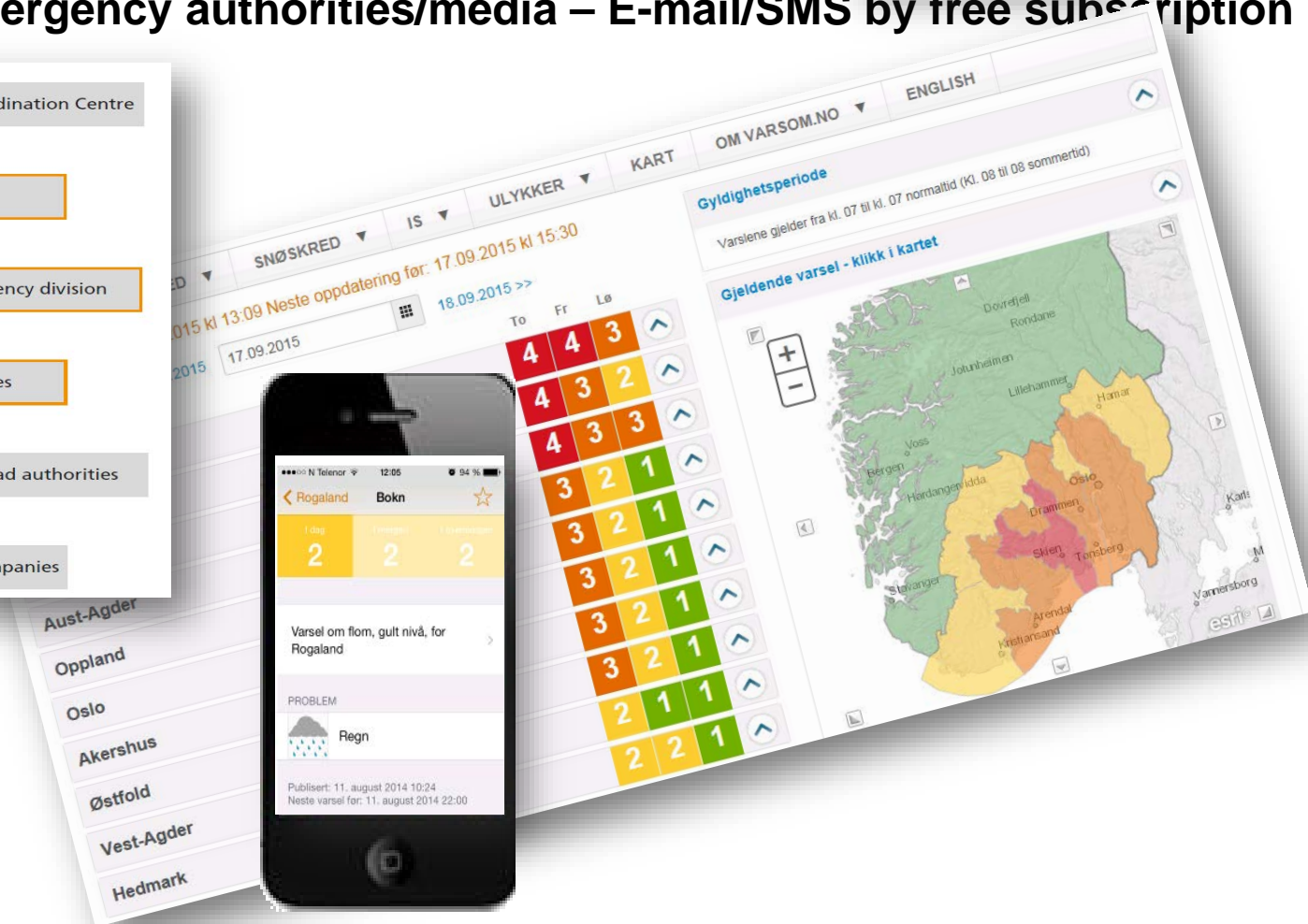
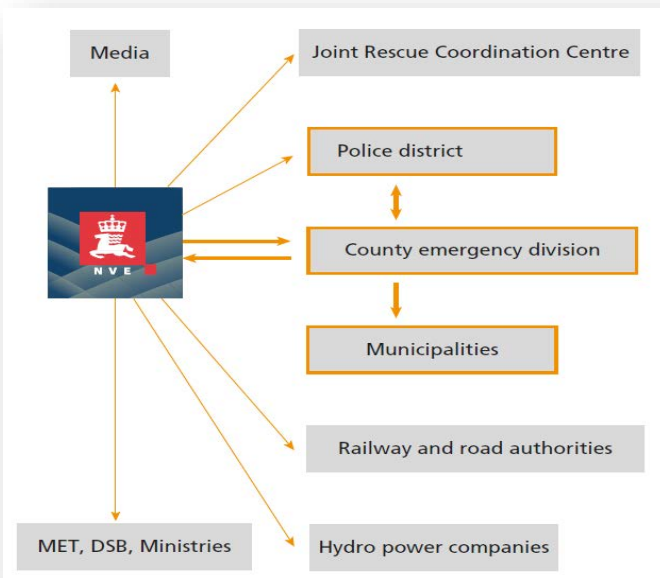
- Notify on potentially dangerous hydrological situations (for 3 days ahead);
- Inform about ongoing situation and expected development so that the situation can be handled best possible locally
- Warnings are issued at [www.varsom.no](http://www.varsom.no) web & mobil
- E-post send to emergency authorities/media – E-mail/SMS by free subscription

Man Thu Wed

1

2

4



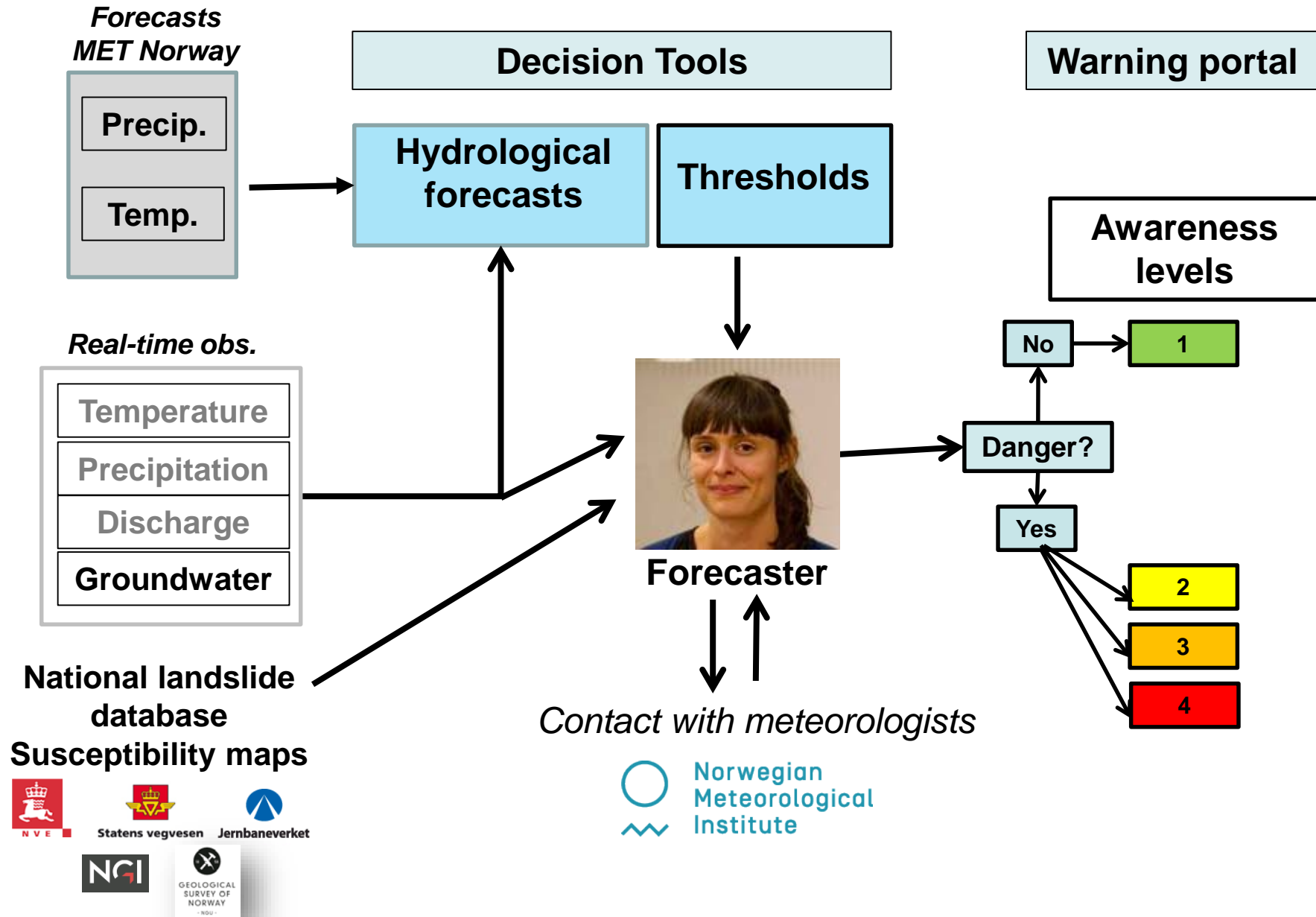
# Organization

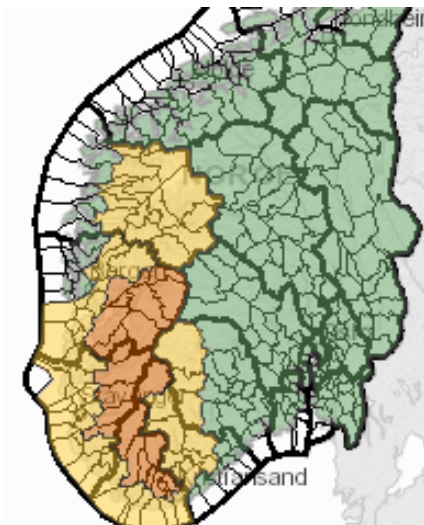
- 8-21 hours nationwide forecasting and warning service
- About 12 forecasters from NVE and 2 from NPRA (Roads Administration)  
Multidisciplinary teams: Hydrologists, hydrogeologists, geologists
- 1 forecaster on duty for one week (+ 1 second call in working time) working with the flood forecaster
- Daily briefing at 9:00 with a meteorologist from MET Norway





# How we assess landslide hazard?





***Extreme situation!***

***Be prepared!***

Several events  
< 50 year flood



0-2 days

***Be aware!***

Some events  
< 5 year flood



4-8 days



About 30-60 days



About 300 days/year

Number of days in period 2012-15

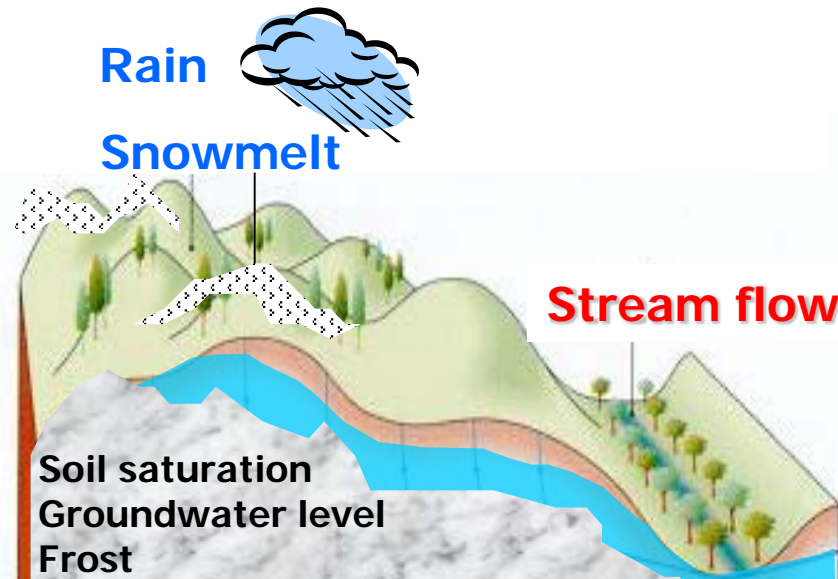


# Landslide awareness levels

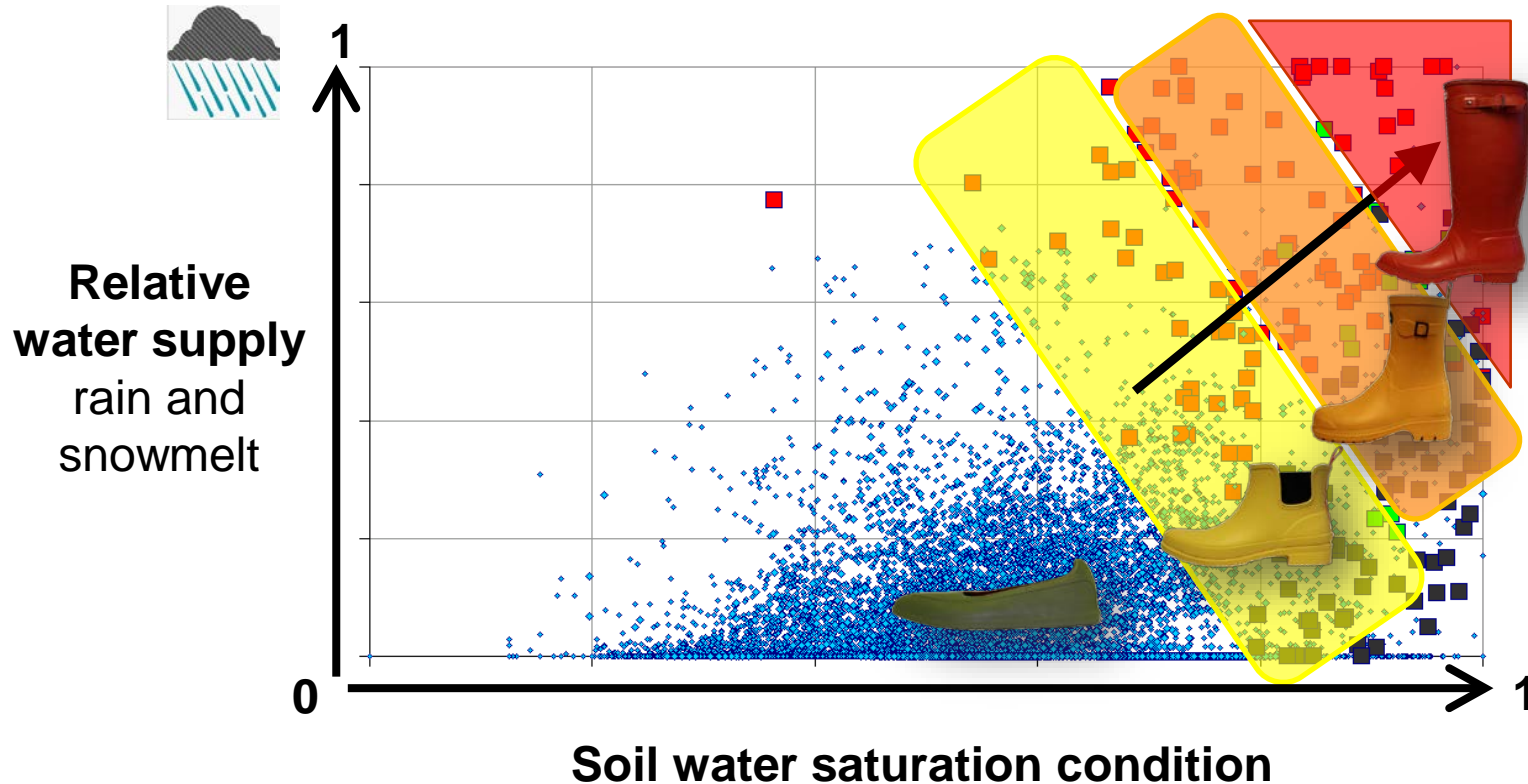


# Early warning system for landslides:

- The methodology is based primarily on threshold values for water supply (rain & snowmelt) and soil/groundwater conditions based on analysis of historical events
- Warning messages are issued when a combination of threshold values are exceeded



# Thresholds from statistics of hydro-meteorological variables at days with and without landslides

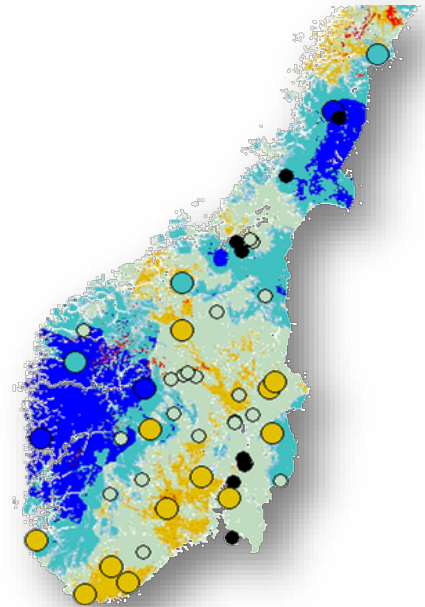


## Examples of other thresholds:

- Index of water supply + soil saturation + soil frost
- Water supply as % max or normal supply (1 day and for 3 days)
- Precipitation as % of max precipitation for a 5 year return period (3 hours and 1 day)

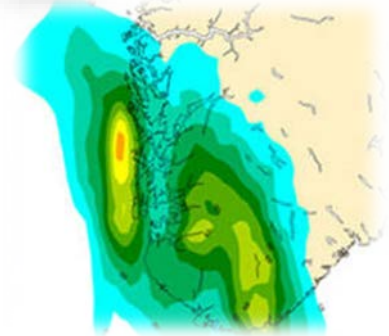
# Hydrological models

- **A spatially distributed version of the conceptual rainfall-runoff HBV-model** *Beldring et al. 2003*
  - 24h – 1x1 km<sup>2</sup> 322.000 cells
  - Water supply, snow melt/depth, groundwater depth, frost, soil saturation, threshold values to evaluate landslide hazards
- **A physically based 1-D soil water and energy balance model S-FLOW:** An adapted version of COUP-model *Jansson & Karlberg, 2004*



## Weather forecast (Precipitation & temperature)

- **AROME - MetCoOp** 66 hour forecasts every six hours (2.5 km resolution)
- **ECMWF** (10 days, 16 km resolution)



## Observations (real-time update hourly or daily)

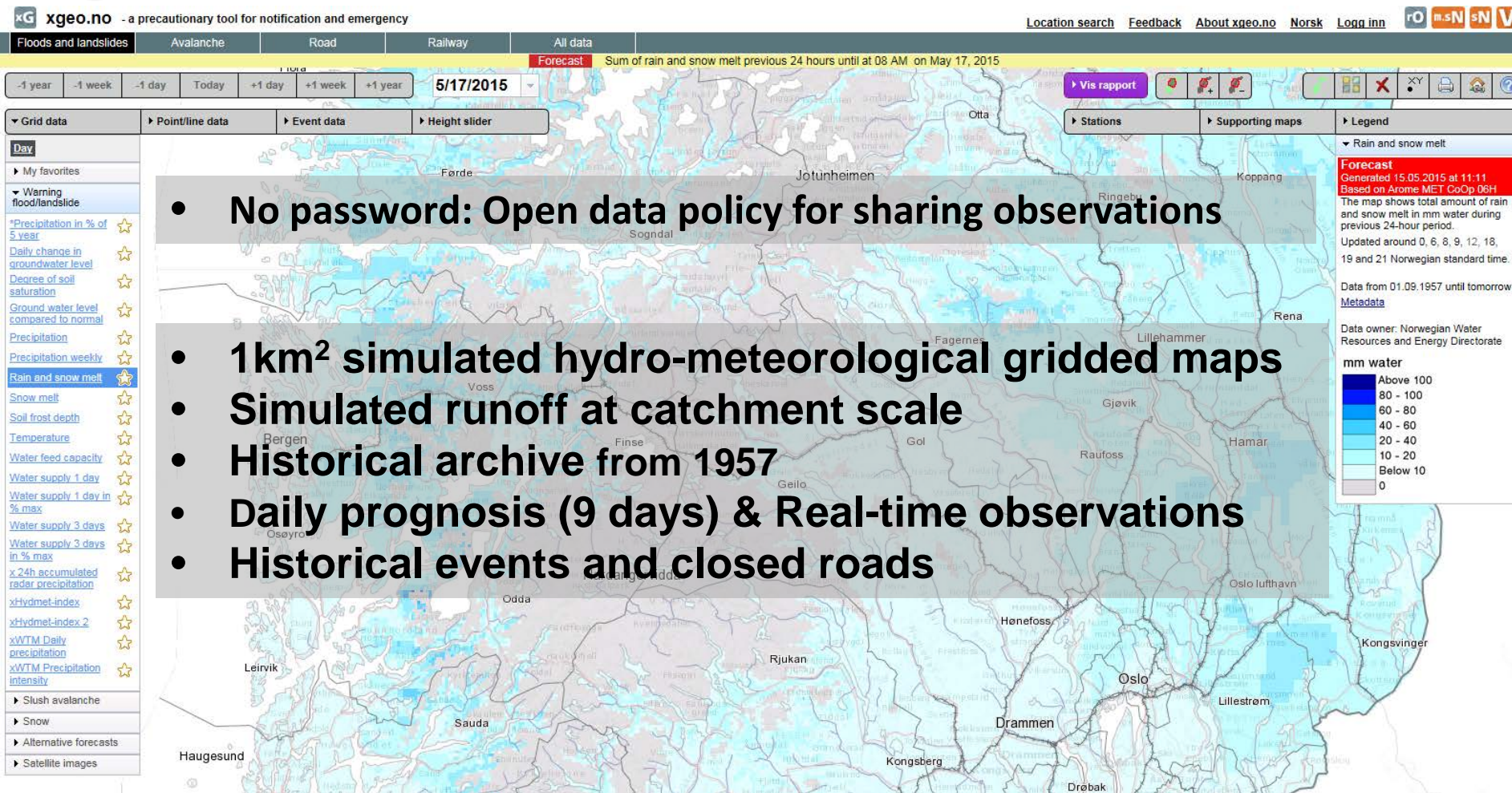
- **Discharge/water levels: > 400**
- **Groundwater levels: 70**
- **Precipitation: 400 – Temperature: 230**



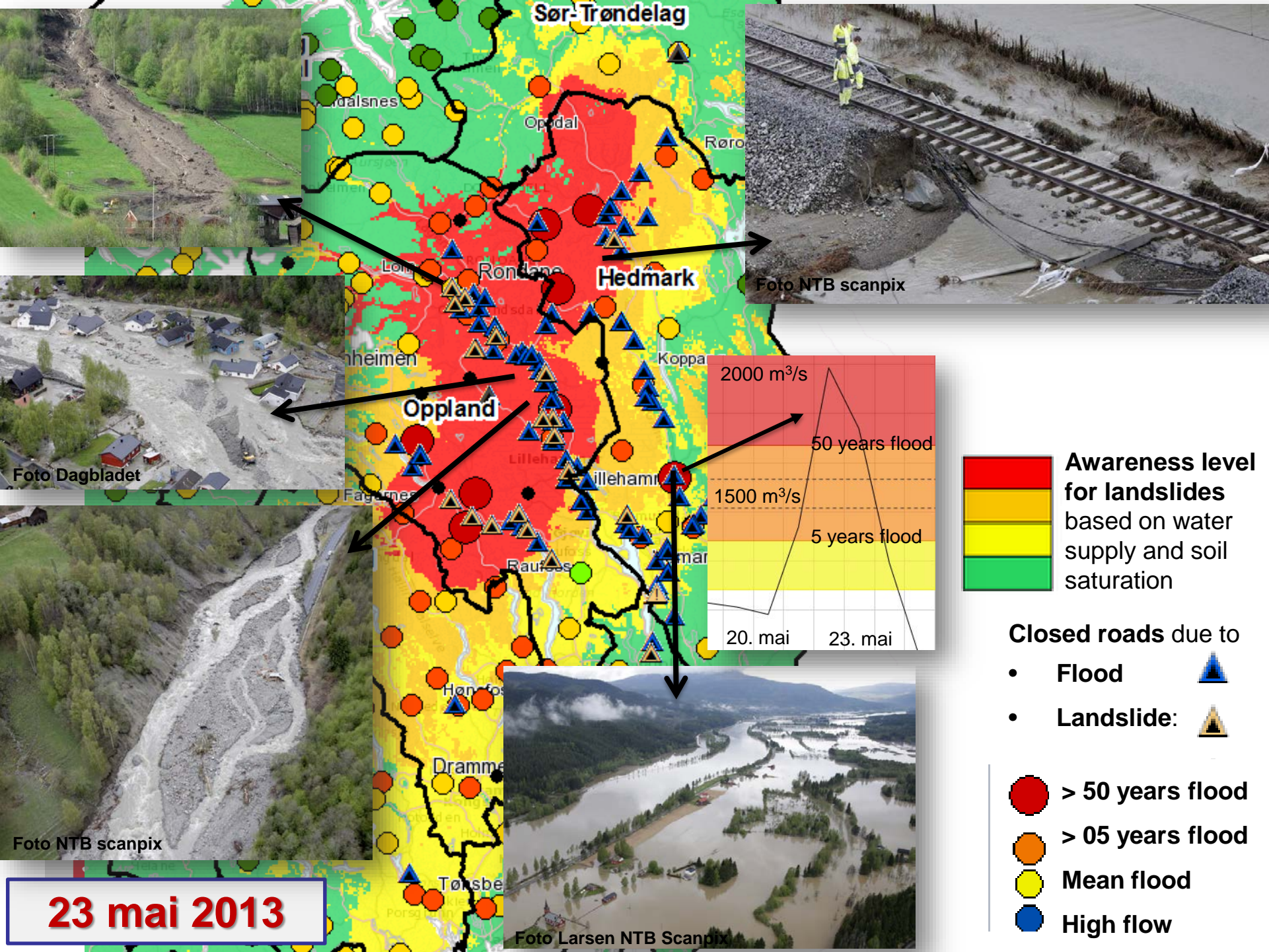




# Xgeo.no: A GIS & web-based decision tool



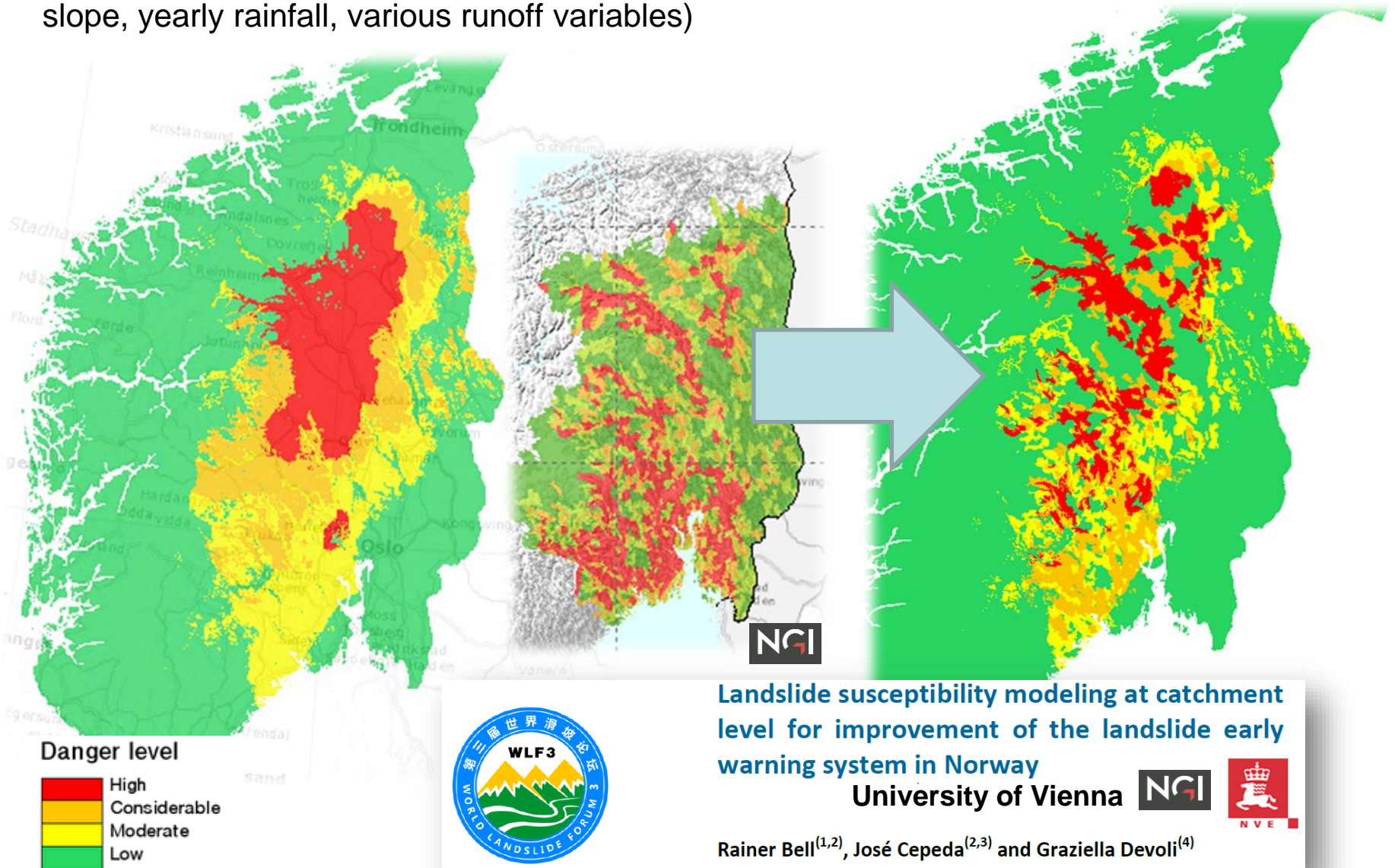






# Work in progress to increase precision in warnings:

Forecasted hydro-meteorological index (soil saturation and rain & snowmelt) combined with a susceptibility maps at catchment level (geology, geomorphology, slope, yearly rainfall, various runoff variables)



Landslide susceptibility modeling at catchment level for improvement of the landslide early warning system in Norway

University of Vienna

Rainer Bell<sup>(1,2)</sup>, José Cepeda<sup>(2,3)</sup> and Graziella Devoli<sup>(4)</sup>



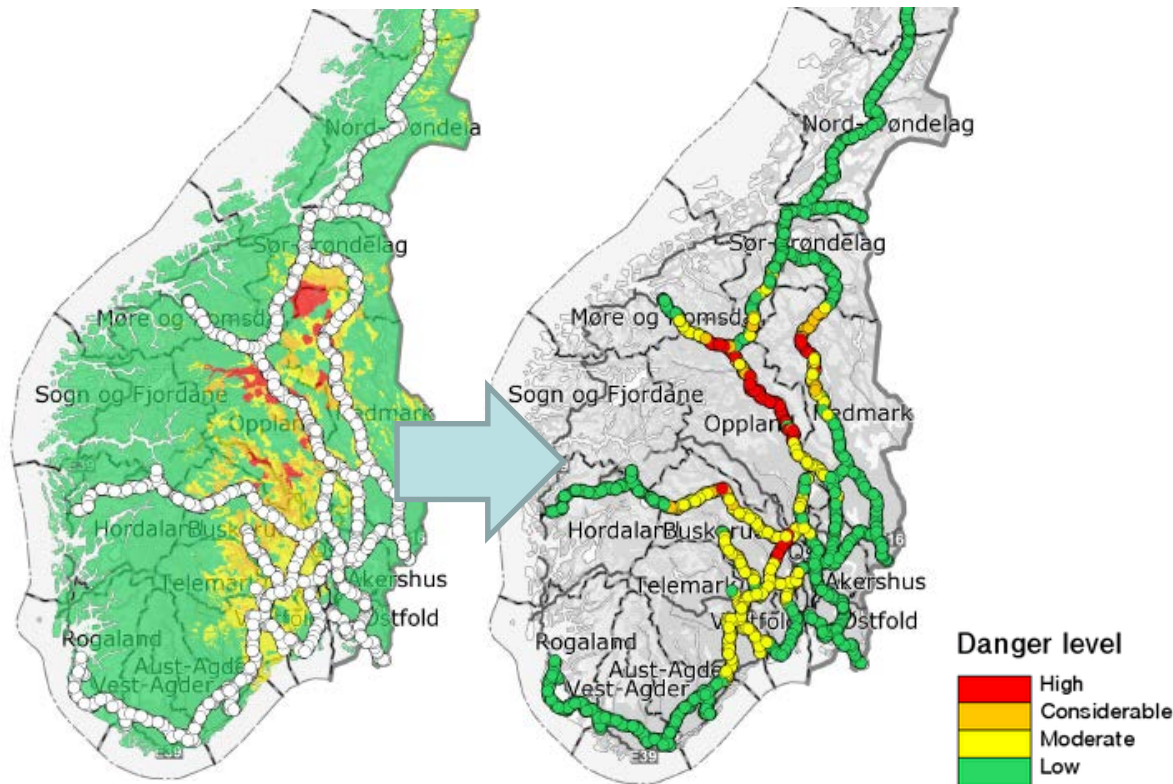
# Work in progress to increase warnings usefulness:



Norwegian  
National Rail  
Administration

## Railways combined with:

- Warning levels or Hydro-meteorological index
- Susceptibility maps and culverts



# Challenges after 3 years experiences

- **EWS requires reliable overview of landslide events** (type, date, place, triggering). This is a prerequisite both for establishment of thresholds and post-evaluation
- **Evaluation for improvement of the EWS:**
  - **Warning performance** (false alarms, missed events, wrong levels)
  - **Recipient survey:** Warning should trigger preparedness or action, and improve generally awareness to risk
- **Perception of landslide warning:** Debris flows and slides are often considered as flood damages. Difficult to understand the need for different warnings for flood and landslides although warnings may be applies to different locations and times

# Conclusions

- **Synergy with the flood warning service was also significantly for a rapid establishment and a rational operation** (organization, hydrological monitoring and models, automatic collection of MET observations & forecasts, decision tools, warning routines & communication)
- **The joint initiative with the Norwegian Meteorological Institute and the Norwegian Public Roads and National Rail Administrations was crucial for the establishment of the warning service and are still important for the operating of the service** (economy, collecting of landslide events, research and development...)



**Thank you for your attention**

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Norwegian Public Roads  
Administration



# and contributions to The application of the landslide early warning along transportation lines in Norway

Tore Humstad, engineering geologist  
Roald Aabøe, head of Geotechnical division



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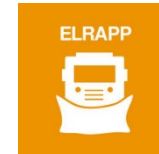
# NPRA's role in landslide warning service

## The structure of data exchange



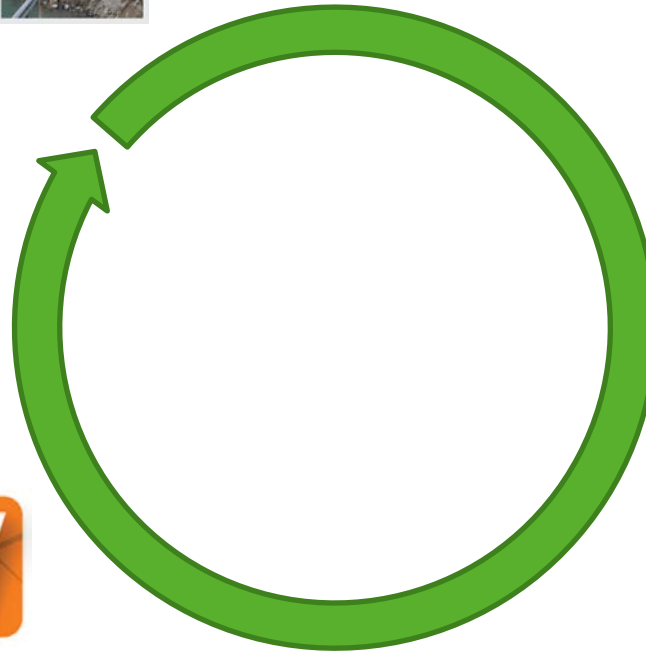
### Natural hazard operation manual

Contracts and procedures  
Roles and responsibilities  
Contingency plan  
Natural hazard atlas



### Elrapp application

Registration tool  
Internal news feed  
Communication between  
contractor and road owner



### Varsom.no

Landslide warning service  
Flood warning service  
Avalanche warning service





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# NPRA's role in landslide warning service

## Natural hazard operation manual (ABC)



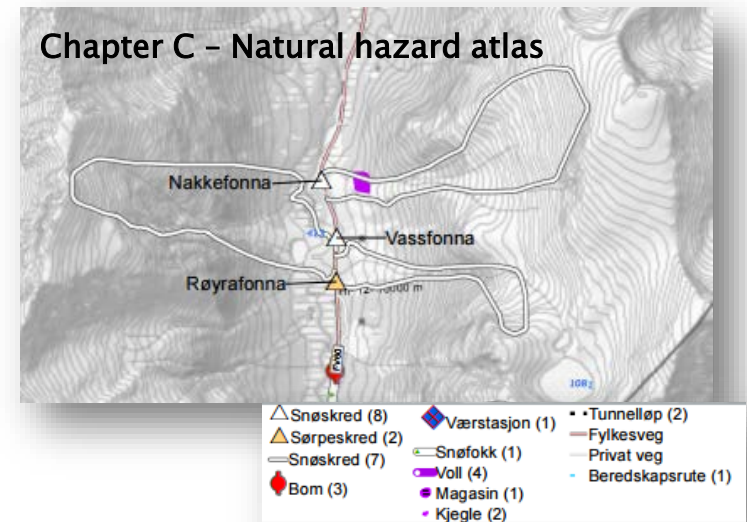
### Chapter A – general

1. Introduction
2. Roles
3. Procedures
4. Preparedness levels
5. Warning services



### Chapter B – local exposure

6. People involved
7. Area involved
8. Hazard exposure
9. Roads' resilience
10. Local criteria



### Bonus material

Web map services → [xgeo.no](http://xgeo.no)



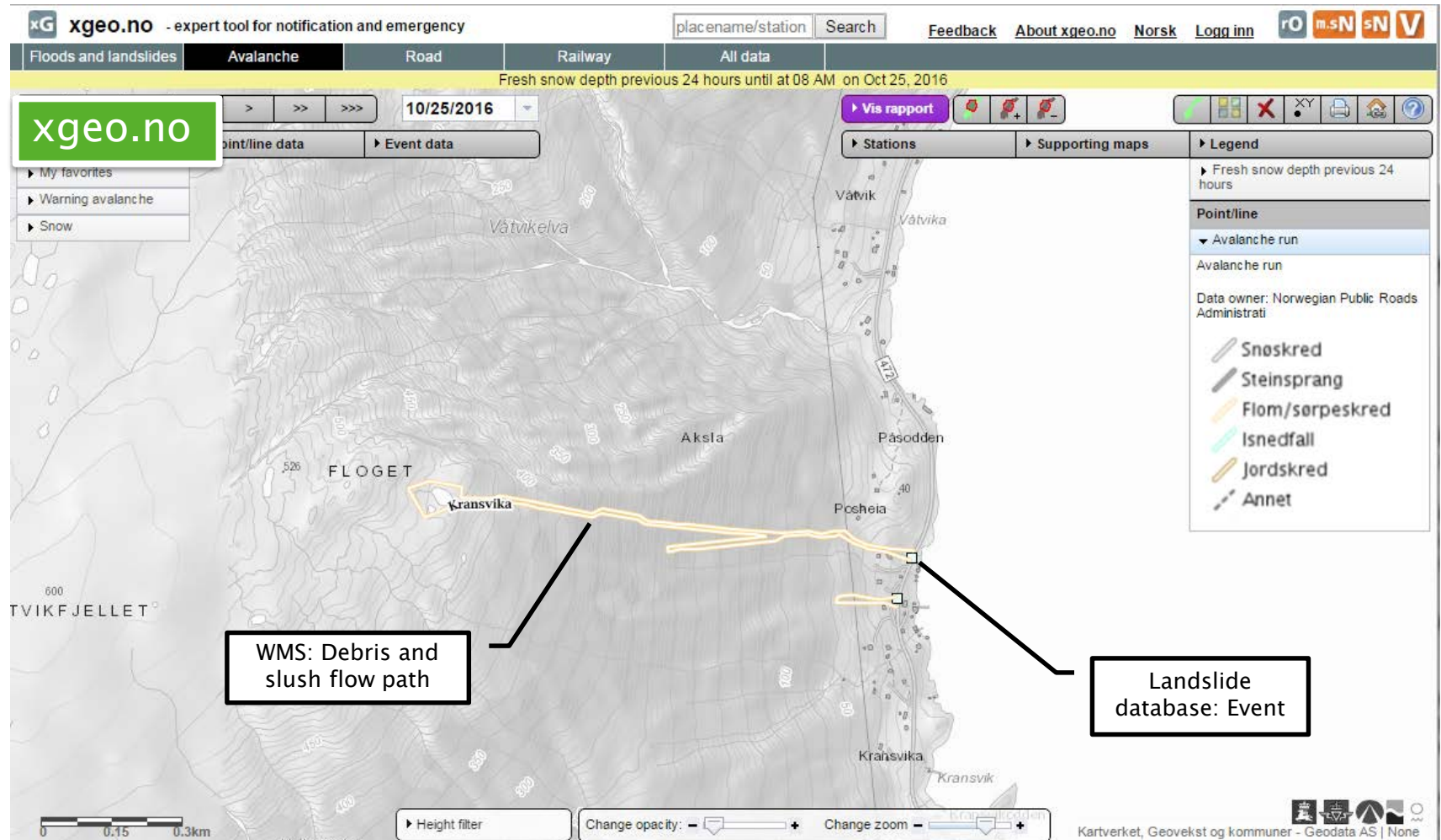
Vassfonna  
Skredtyper...  
Værforhold...  
Skredfrekvens...  
Skadepotensiale...  
Naboskred...  
Sikringseffekt...  
Drift og vedlikehold...





## NPRA's role in landslide warning service

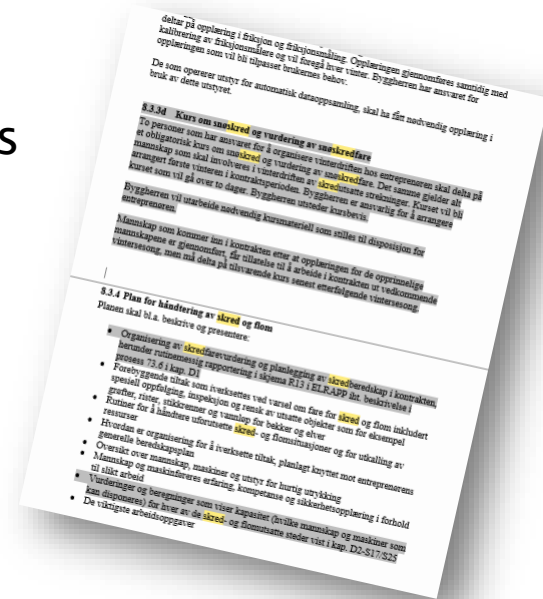
# Landslide/avalanche paths from wms



# NPRA's role in landslide warning service

## Contracts and regulations

- Operation and maintenance contracts regulates:
  - Standard industry courses
  - Use of natural hazard atlas
  - Registration of danger signs and landslides snow avalanches
- Main focus has been on snow avalanches
- More focus on landslides in the next years





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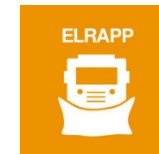
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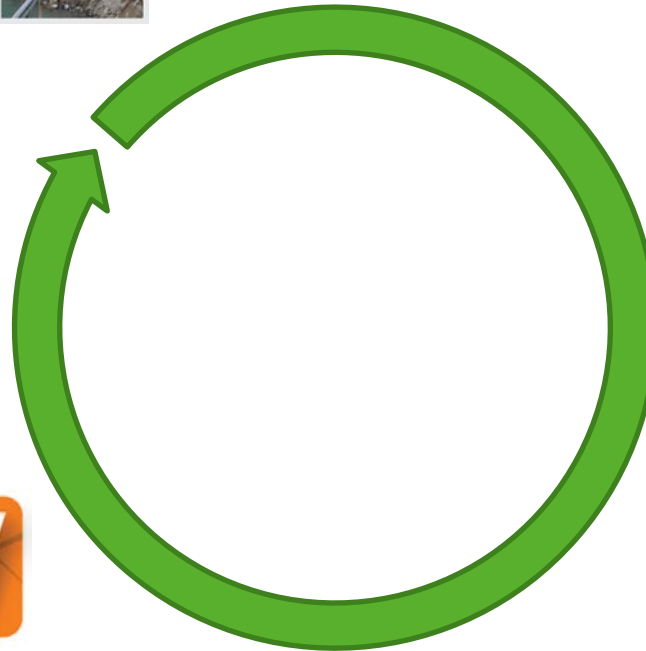
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### Elrapp application

Registration tool  
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Communication between  
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### Varsom.no

Landslide warning service  
Flood warning service  
Avalanche warning service







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# NPRA's role in landslide warning service

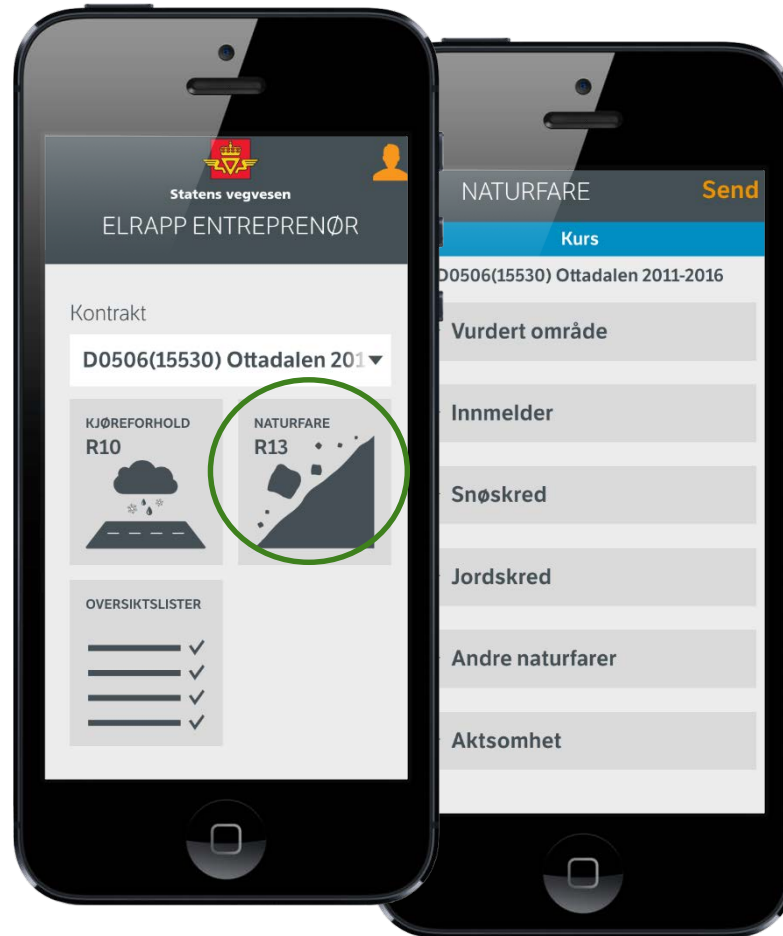
## Elrapp application

### Used by

- Contractors in areas with roads exposed to natural hazards

### Why?

- Contracts tell them to
- Document own observations and decisions
- Multi-use of data



### Which data?

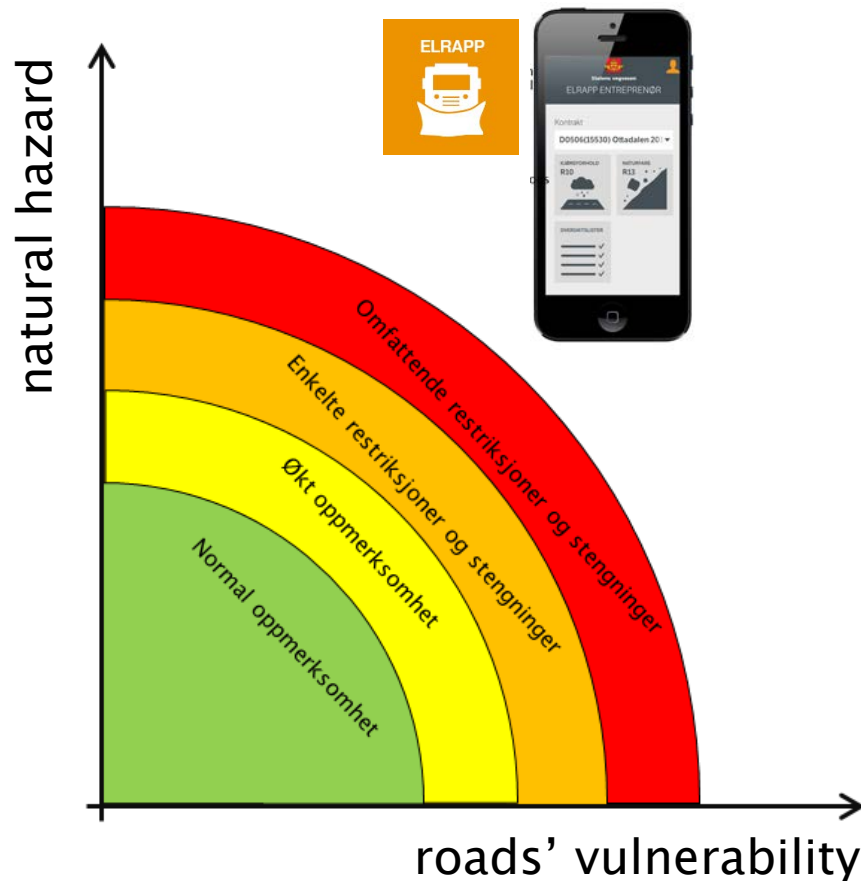
- Signs of danger
- Evaluation of natural hazard level
  - Avalanches
  - Landslides
  - Rock fall
  - Flood
  - Wind
  - Storm surges
  - Forest fire
- Level of concern

### When? :

- As a routine
- Before, under and after extreme events

## NPRA's role in landslide warning service

# Elrapp application – Level of concern



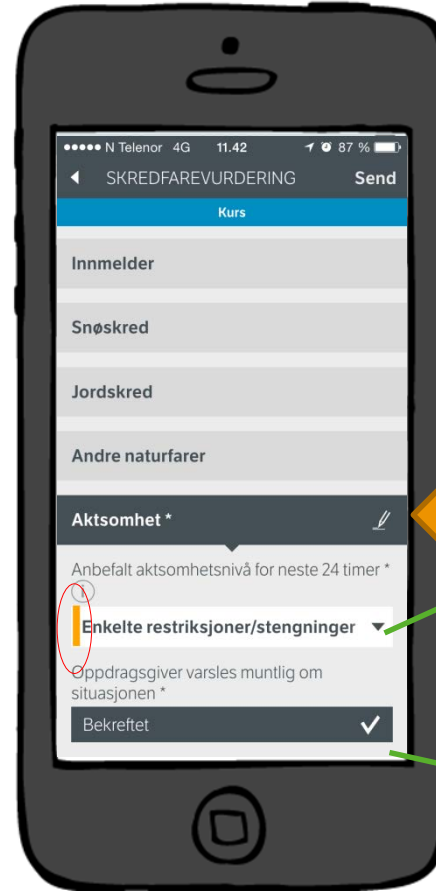
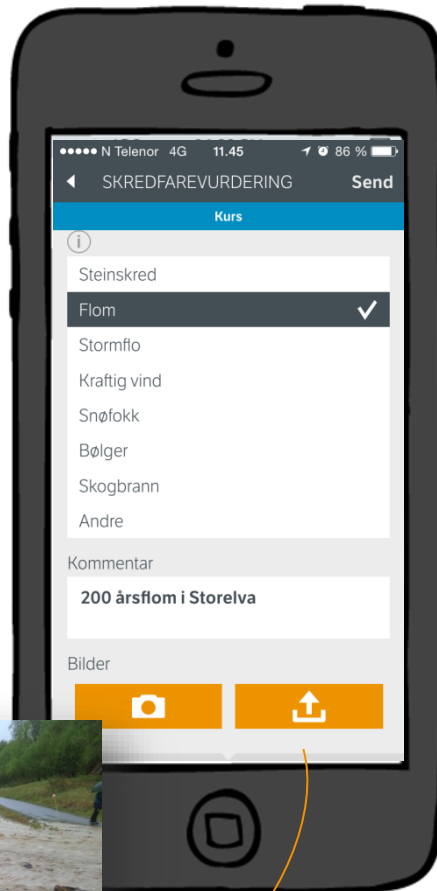
- Normal level of concern:**  
Business as usual
- Increased level of concern:**  
Continuous monitoring of weather conditions, inspections
- High level of concern:**  
Some restrictions and/or closures likely
- Very high level of concern:**  
Extensive restrictions and/or closures likely



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# NPRA's role in landslide warning service

## Elrapp application – Level of concern



concern for roads (expanded)

Suggested level of concern  
(green, yellow, orange or red)

Confirmation: High level of  
concern (orange )  
communicated directly to road  
owner.

Advice: *Some roads must be  
closed*





# NPRA's role in landslide warning service

## Elrapp – output

**For contractors**  
(news feed with own entries):



**For client (NPRA):**  
Alerts based on thresholds  
(e.g. “red level” of concern)



**For forecasters (NVE++):**  
Data integration from Elrapp to regObs

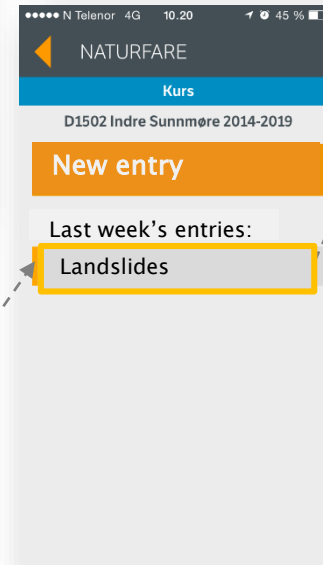




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# NPRA's role in landslide warning service

## Elrapp – registration

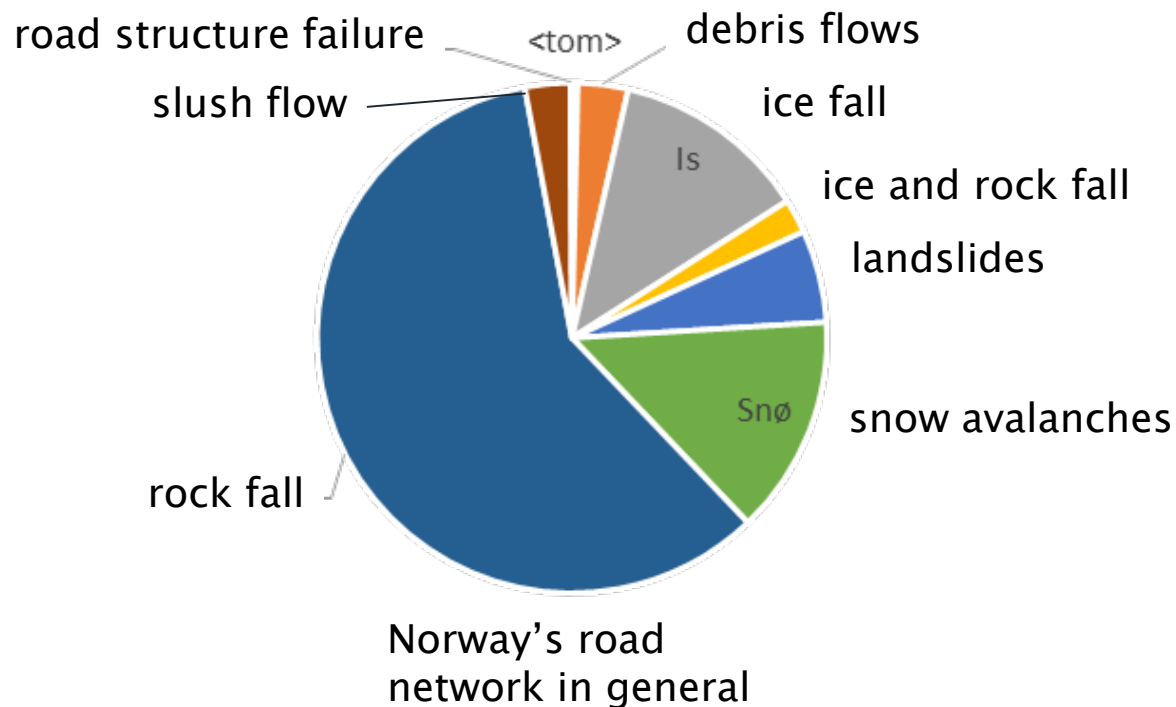




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## NPRA's role in landslide warning service

### Landslide and avalanche events (2000–2015)

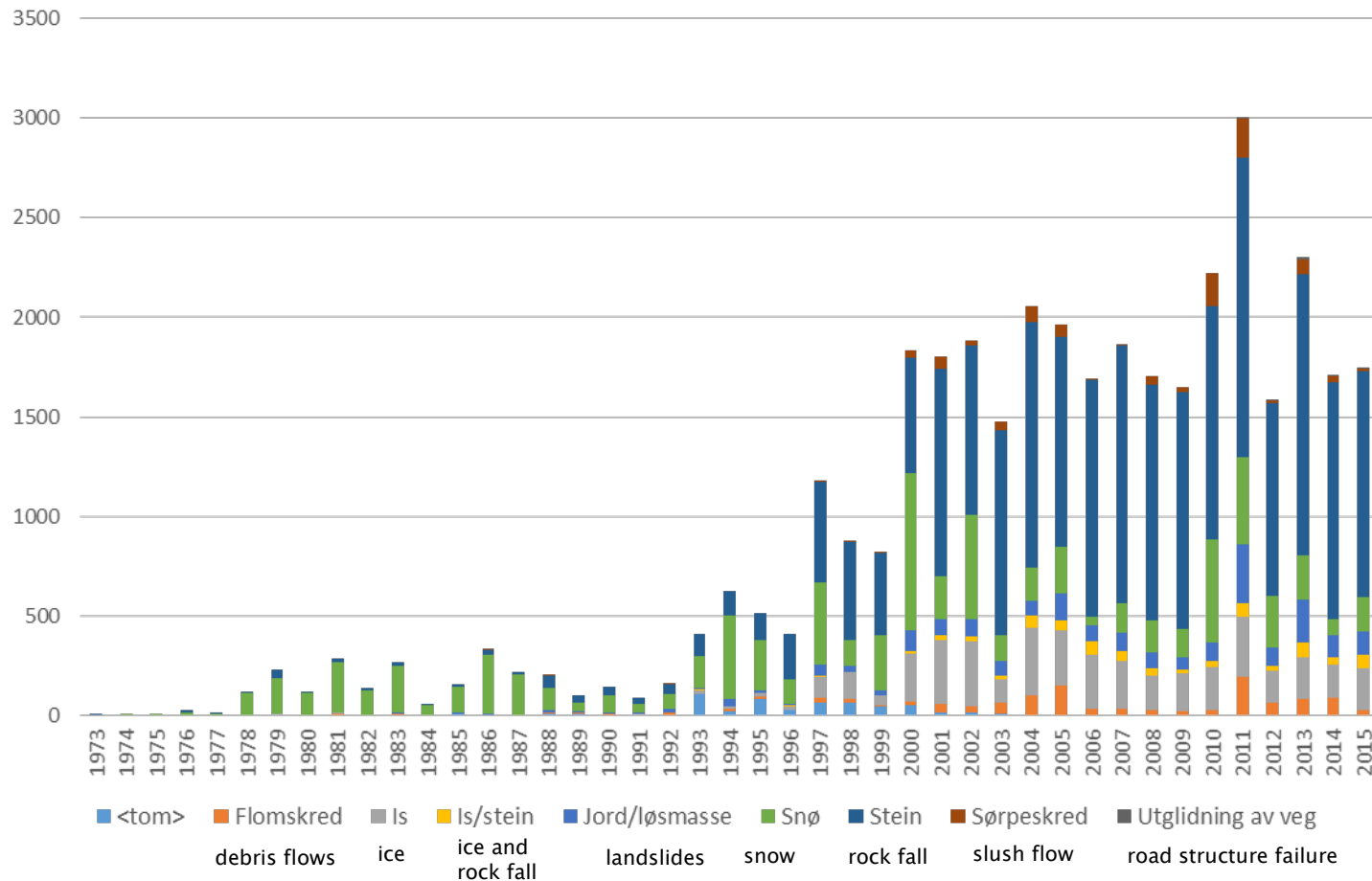




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# NPRA's role in landslide warning service

## Landslide and avalanche events (on roads)

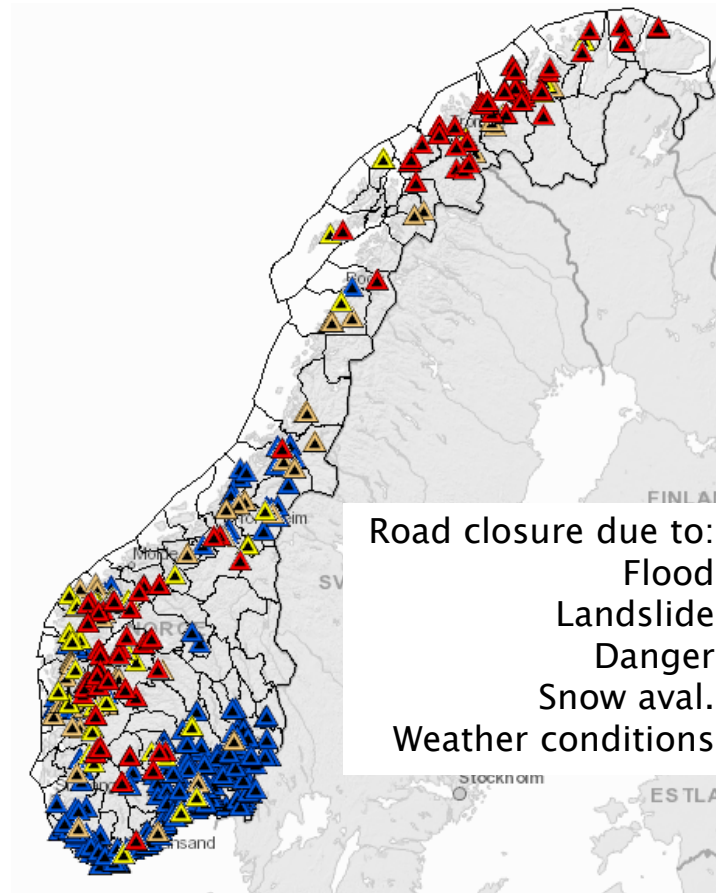




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## NPRA's role in landslide warning service

# From traffic information (20.4.15–20.4.16)







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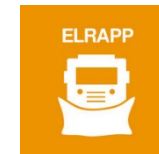
# NPRA's role in landslide warning service

## The structure of data exchange



### Natural hazard operation manual

Contracts and procedures  
Roles and responsibilities  
Contingency plan  
Natural hazard atlas



### Elrapp application

Registration tool  
Internal news feed  
Communication between  
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**regObs.no**  
NVE's database

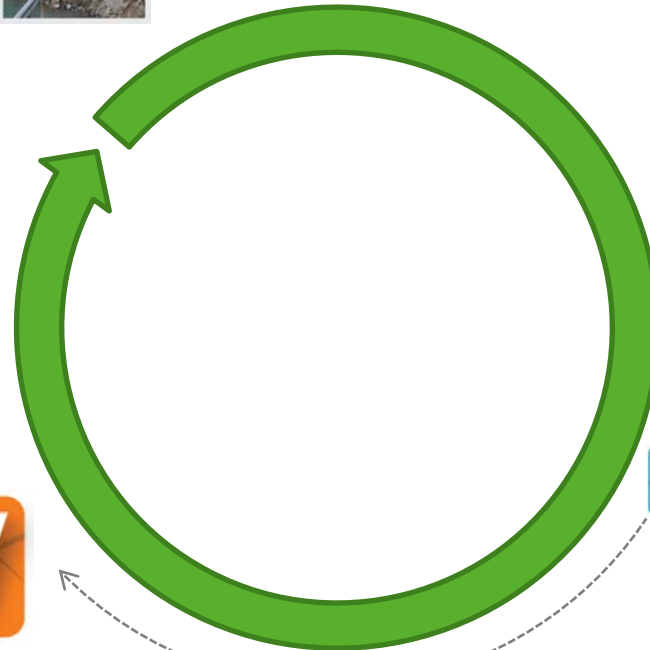


**Xgeo.no**  
NVE/MET/Road/Railway map



### Varsom.no

Landslide warning service  
Flood warning service  
Avalanche warning service





# NPRA's role in landslide warning service

## Use of landslide warning

|                  |   |   |   |   |
|------------------|---|---|---|---|
| Møre og Romsdal  | 1 | 2 | 1 | ⬆ |
| Sogn og Fjordane | 2 | 2 | 1 | ⬆ |
| Hordaland        | 2 | 2 | 1 | ⬆ |
| Rogaland         | 2 | 2 | 1 | ⬆ |
| Finnmark         | 1 | 1 | 1 |   |
| Troms            | 1 | 1 | 1 |   |
| Nordland         | 1 | 1 | 1 |   |
| Nord-Trøndelag   | 1 | 1 | 1 |   |
| Sør-Trøndelag    | 1 | 1 | 1 |   |
| Vest-Agder       | 1 | 1 | 1 |   |
| Aust-Agder       | 1 | 1 | 1 |   |
| Telemark         | 1 | 1 | 1 |   |
| Vestfold         | 1 | 1 | 1 |   |
| Buskerud         | 1 | 1 | 1 |   |
| Oppland          | 1 | 1 | 1 |   |
| Hedmark          | 1 | 1 | 1 |   |
| Oslo             | 1 | 1 | 1 |   |
| Akershus         | 1 | 1 | 1 |   |
| Østfold          | 1 | 1 | 1 |   |



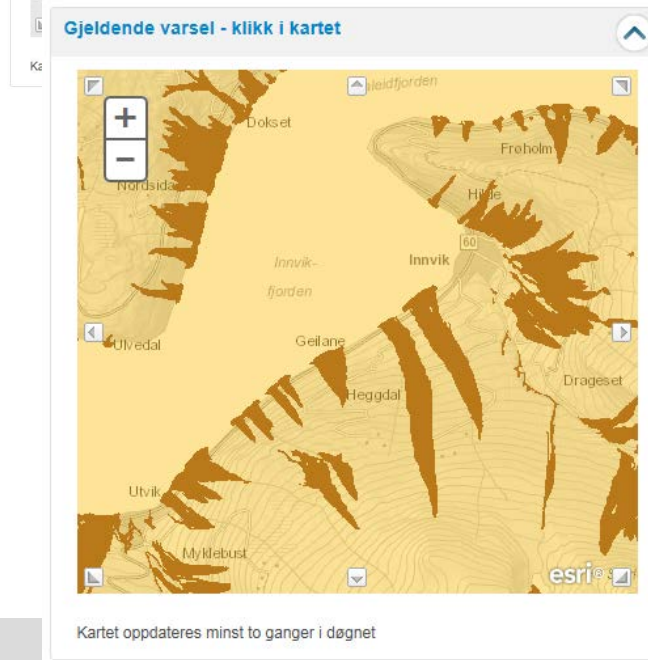
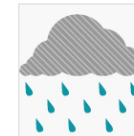
### Varslingstekst

#### Varsel om jord- og flomskredfare, gult nivå for Vestlandet, grunnet mye regn

Det ventes mye regn fra tirsdag ettermiddag til onsdag ettermiddag. Faren for jord- og flomskred blir størst natt til onsdag og onsdag formiddag der de største nedbørmengdene faller. Skredfaren blir raskt avtagende etter at nedbøren har passert onsdag. Bratte skråninger, samt bekker og elvelep med stor vannføring er spesielt utsatt. Rensing av dreneringsveier og stikkrenner anbefales.

### Skredtype/årsak

#### Flomskred - Jordskred



Kartet oppdateres minst to ganger i døgnet



# NPRA's role in landslide warning service

## The structure of data exchange





## NPRA's role in landslide warning service

# Conclusions

### Benefits:

- Shared systems – mutual contribution is possible
- Contributing is applying
- The service has increased the organizational awareness to all natural hazards

### Further work

- A greater evaluation is suggested next year
- More flood and landslide focus in the operation and maintenance contracts would be useful (as it is for snow avalanches)





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Thanks for the attention!

