Climate change enhanced risk for mass failure of sediment into rivers - how do we manage such events?

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Outline of presentation

• Site description, geological development
• Landslide history and prerequisites for slope failure
• Climate change scenarios and impact on slopes
• Consequences and risks
• Actions
Göta Älv river valley
**Historical slides**

- Jordfall yr 1150, 650 000 m²
- Intagan yr 1648, 270 000 m²
- Ballabo yr 1733, 30 000 m²
- Utby yr 1806, 45 000 m²
- Västerlanda yr ~1830, >50 000 m²
- Surte yr 1950, 240 000 m²
- Göta yr 1957, 320 000 m²
- Agnesberg yr 1993, 2 500 m²
- Ballabo yr 1996, 7 000 m²
Prerequisites for slides

And… QICK CLAY
Simulated precipitation changes, year 2071-2100 compared with the period 1961-1990 (SMHI Rossby Centre, Echam A2)

Map of Sweden showing the frequency of landslides and ravines (www.sgu.se, 2005)
Expected climate change effects

- Increasing precipitation
- Rising groundwater level and pore pressure in the ground
- Need for more outflow from lake Vänern (max 1030 m$^3$/s → 1400 m$^3$/s)
- Increasing water flow → increasing erosion
- Risk for giant landslide (even without CC) → giant surge, damming, flooding …
Changes in slope stability

- Investigation commissioned by the Swedish Government, results:
  - 2-30% lowering of slope stability for shallow cohesive slopes
  - ~15% lowering of slope stability for steep sand/silty slopes

Slope safety after future erosion & increase in pore pressure
Contaminated sites at landslide risk

345 ton Zn in soil (also As, Pb, oil…)

**Freshwater intake (10 km):**
- Time peak: ca 6 h
- Time pulse passage: ca 12 h
- Cons. peak: 1.4 mg/l

**Göteborg C (20 km):**
- Time peak: ca 11.2 h
- Time pulse passage: ca 16 h
- Cons. peak: 1.0 mg/l
Instantaneous and long term effects

- Hydrodynamic consequences
- Flooding
- Damage on infrastructure
- Navigation...
- Huge amounts of sediments released
- Dredging of river and port
Expanded commission

- **Basis for stability analyses**
  - Flow, water levels, topography, sediment transport, land raise, maps

- **Computational methods**
  - FEM analyses with non-linear soil models, statistical methods, pore pressure forecasts, erosion forecasts

- **Investigations**
  - Field (geotechnical, hydrogeological, environmental)
  - Lab (geotechnical, environmental)
  - Slope stability analyses (computations)
  - Slope stability mapping (field control, maps and water studies)
  - Risk analyses (choosing methodology, analyses)
• **Projecting of type solutions**
  - Erosion protection of shoreline (inspections, planning, stability analyses, type drawings)
  - Erosion protection of submerged slope (descriptions of work plans)
  - Embankment, silt-screen (stability analyses, design, work plan, inspection)

• **Surveillance**
  - Movements, erosion, inclination, pore pressure

• **Maintenance**
  - Erosion protection, dredging

• **Presentation and data storage**
A huge work we can not do alone
or
can we do it in another way?