NGV 2022
5th Nordic Ground Vibration Day
24 October 2022 • Aarhus • Denmark

Statens vegvesen
Norwegian Public Roads Administration

Blast triggered landslide at Steinvik, Tana, Norway

Samson A. Degago

Legislation and regulatory authority, Directorate of Public Roads, Norwegian Public Roads Administration (NPRA)

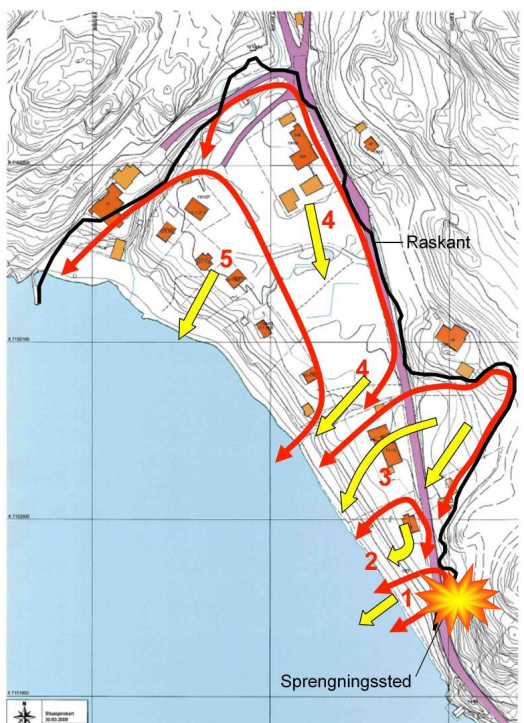
Johan Kristofers[1] & Kaja Krogh[2]

Operations and Maintenance Division, NPRA[1] & Troms & Finnmark County Municipality (TFFK)[2]

Background/perspective – The 2009 Kattmarka slide

Statens vegvesen
Norwegian Public Roads Administration

- Blasting of rock as part of road construction (near quick clay slope)
- Initial slide started immediately (after ca. 0.5 min) and the entire slide activity lasted 6-10 min after blasting
- Destroyed 4 permanent houses and 6 summer residences. 7 persons rescued unharmed.
- Slide volume 300-500 x 10^3 m^3
- A stein block that landed on the slope remoulded the adjacent quick clay material (initial slide!)

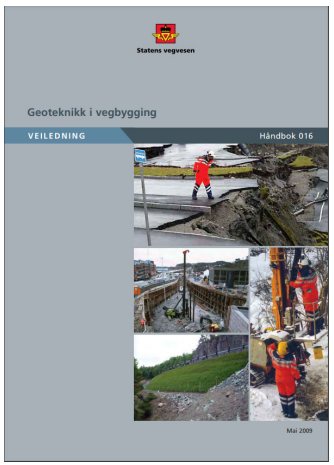


Nordal et al. (2009) (ISBN 978-82-92506-72-1)

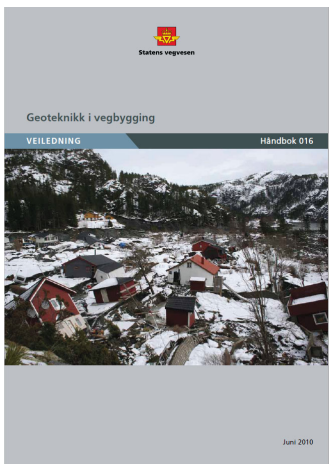
Background – The 2009 Kattmarka slide –> Implications on practice

Statens vegvesen
Norwegian Public Roads Administration

- Key learning points from the slide quickly implemented into regulatory documents
- Geotechnical category (GC) 3 for all projects in quick clay areas = > Independent control of projects in GC3
- Limits for blast induced vibrations near quick clay slopes (cur < 0,5 kPa)
- Emphasis on ensuring blasted materials do not land on sensitive slopes, improved vibration measurement scheme

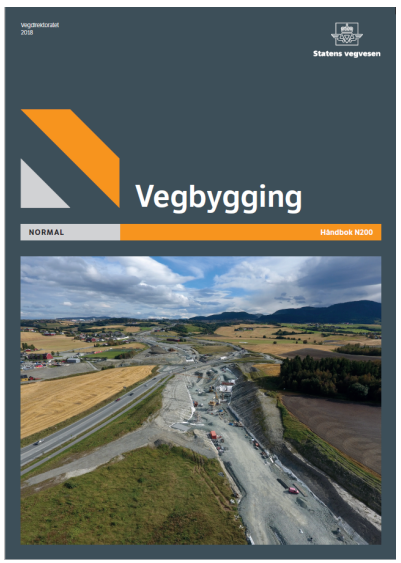


2009 (547 pp)

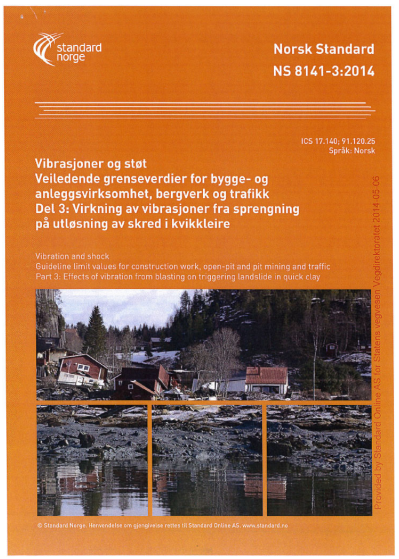


2010 (543 pp)

2022 (653 pp)



NPRA specifications handbook for construction of roads (N200)



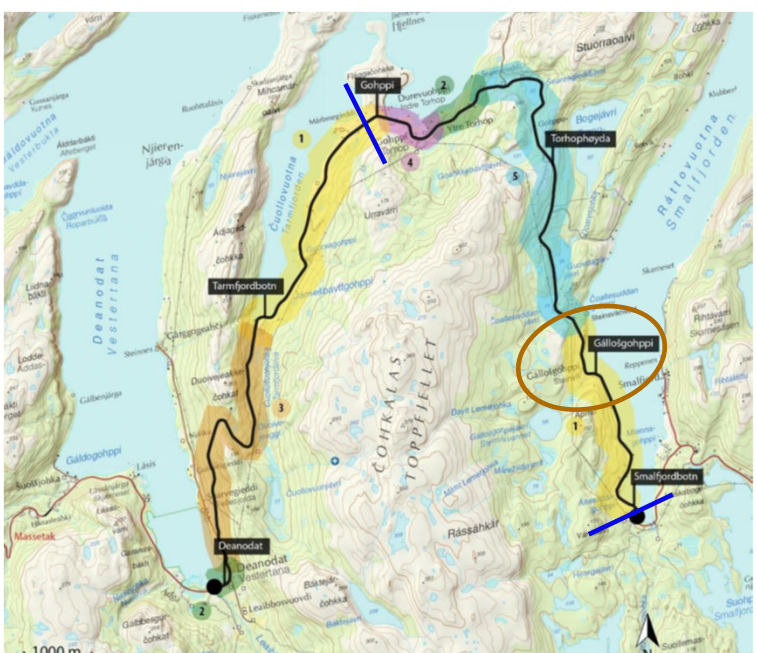
Norwegian standard NS 8141-3:2014

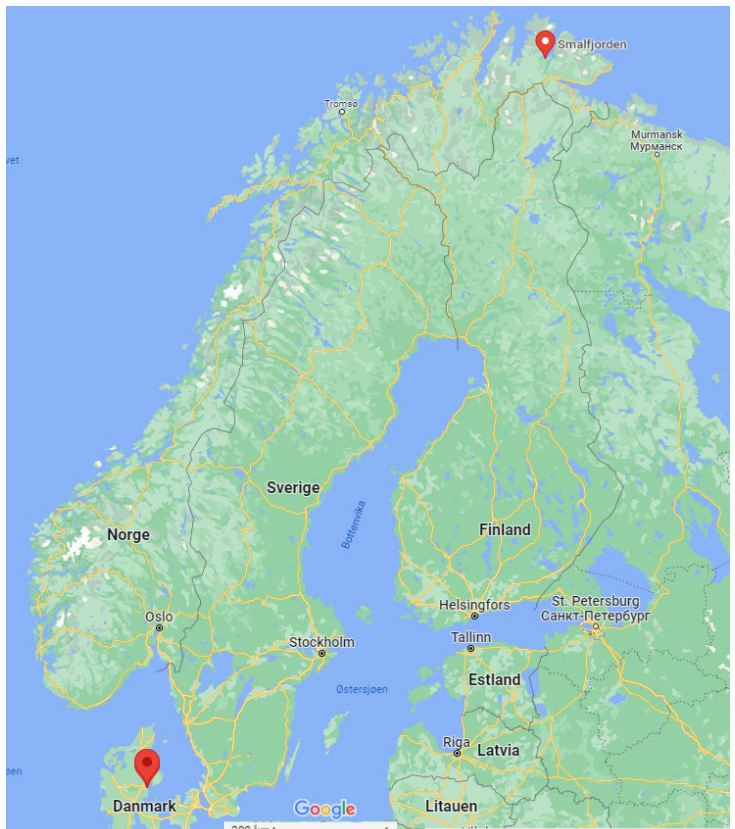
NPRA manual/guideline for construction of roads (Latest version https://www.vegvesen.no/globalassets/fag/handboker/v220-2022.pdf)

The Project Fv. 98 Torhophøyden – Smalfjordbotn (98 MNOK)

Statens vegvesen
Norwegian Public Roads Administration

- Located in Tana municipality, Troms and Finnmark county, Norway
- Aim – to improve and upgrade ca. 10 km long road stretch
- Involved extensive blasting of rock masses - a total of 309 000 m^3.
- Slide area - Steinvik (Gállošgohppi)

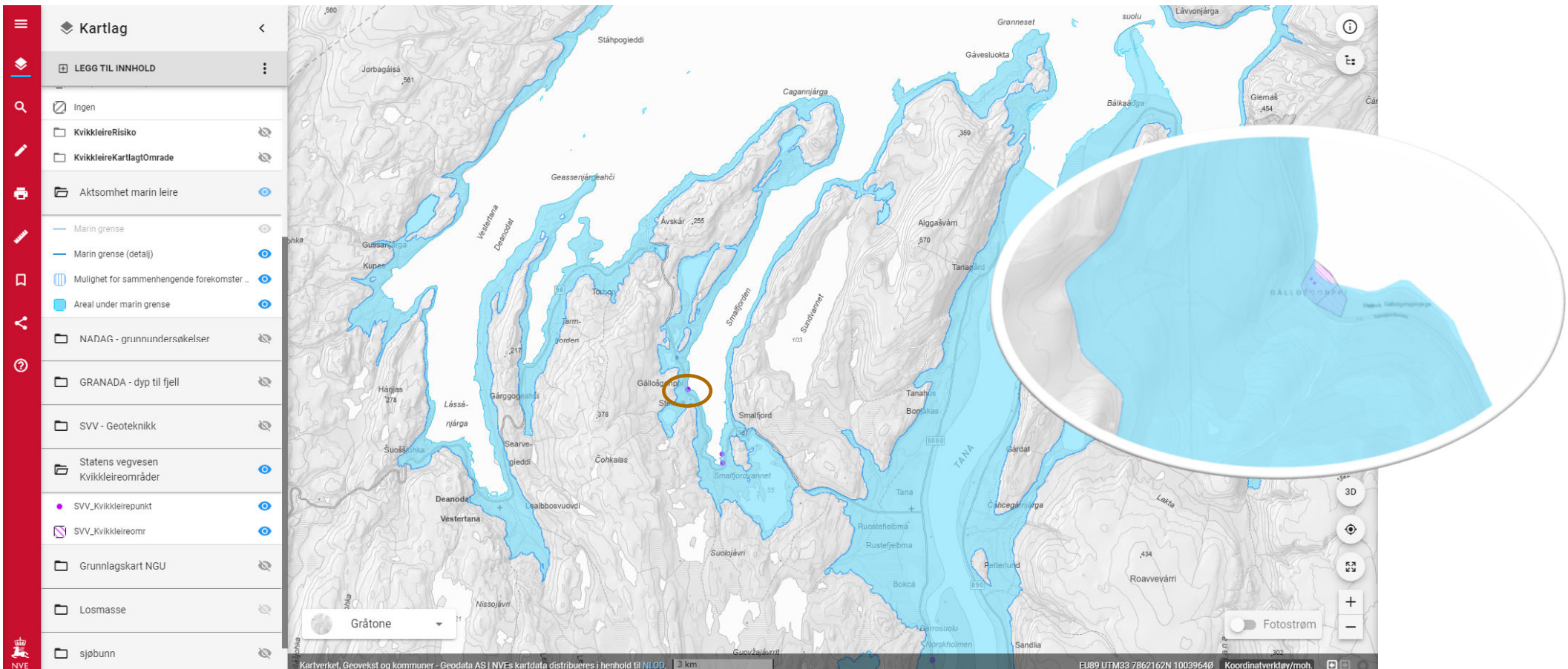




Ground conditions – Areas under marine limit

Statens vegvesen
Norwegian Public Roads Administration

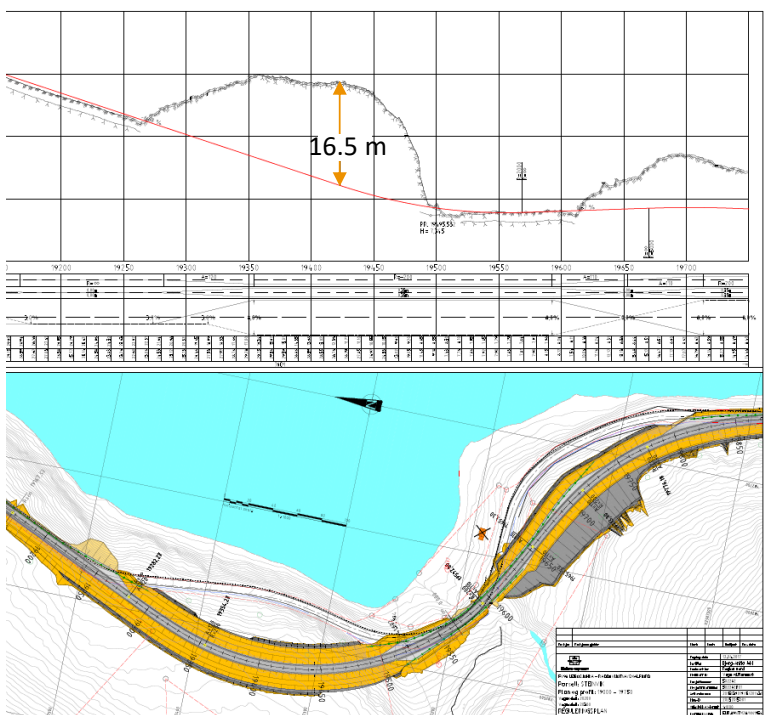
- The prevalence of marine clay (quick clay), is restricted to areas below the marine limit.

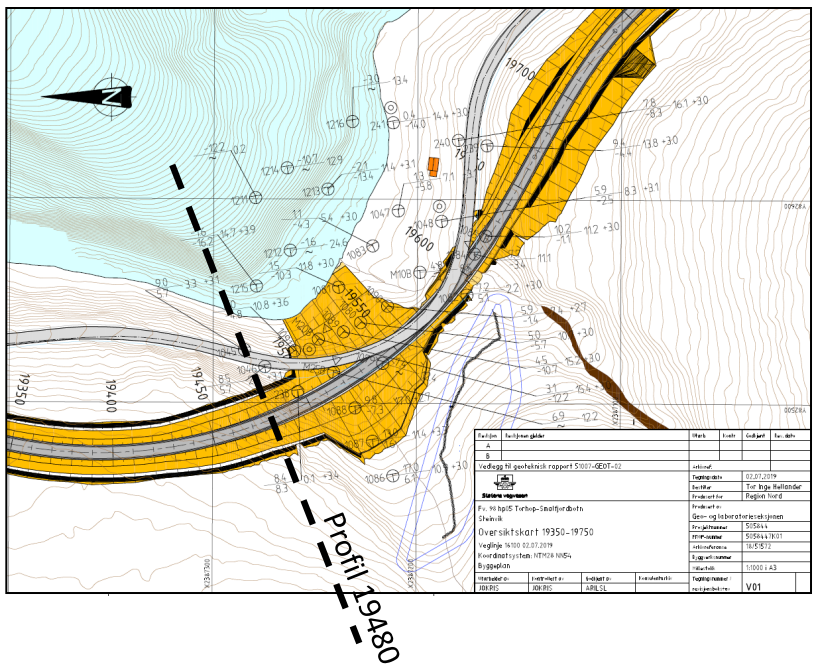


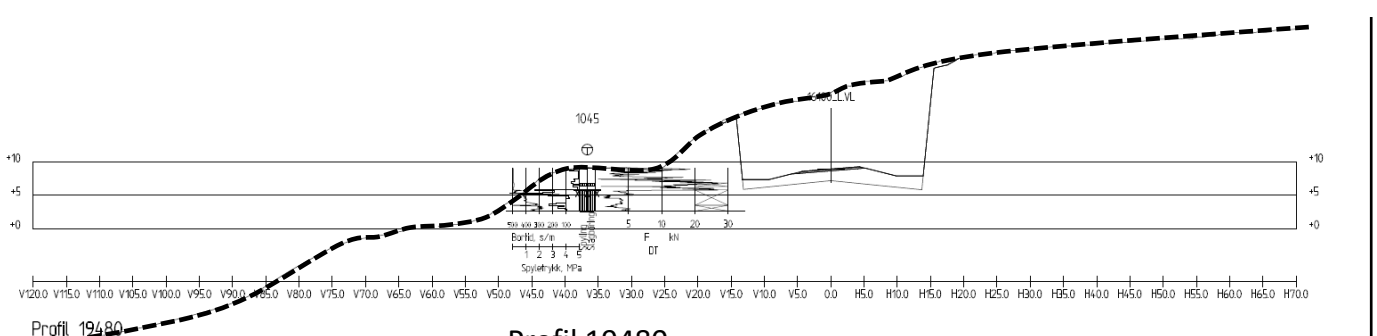
(https://temakart.nve.no/tema/kvikkleire)

Project plan around Steinvik

- Blasting of rock masses
- Excavation (unloading of the slope)





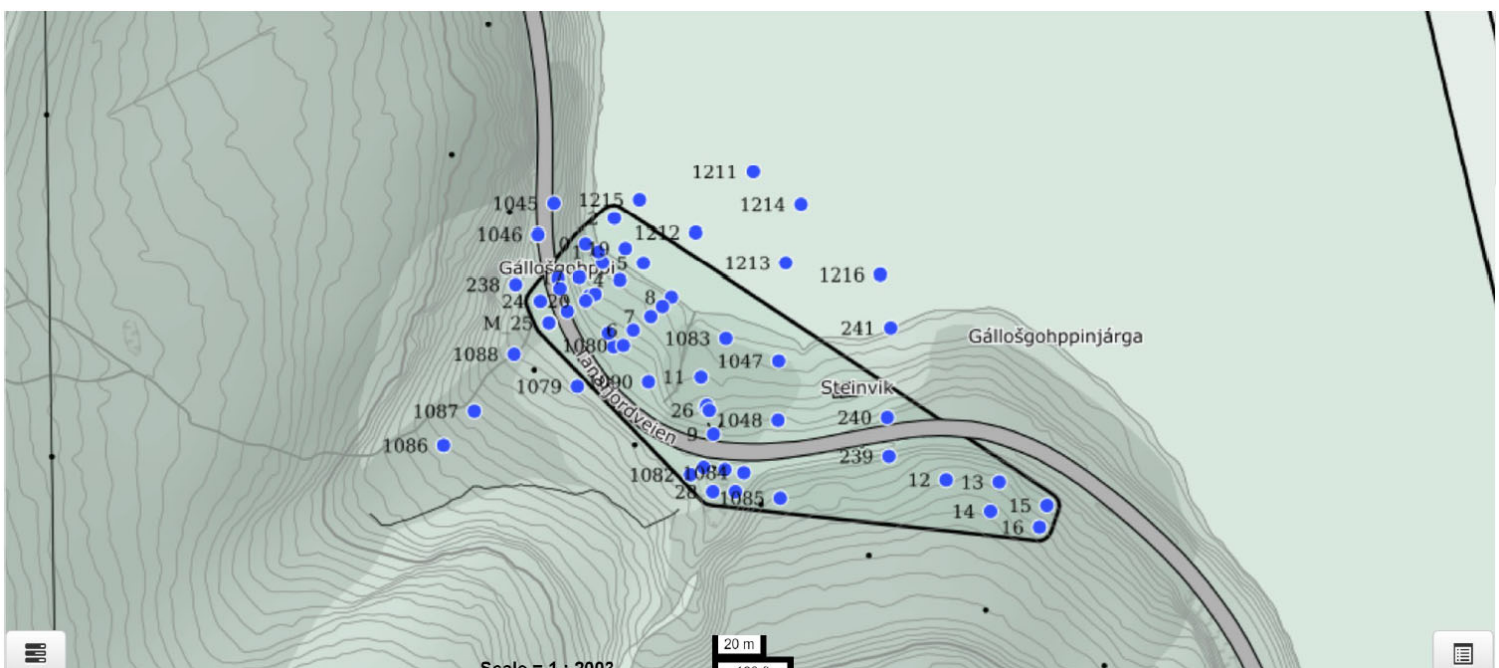


Profil 19480

Steinvik - soil investigations

Statens vegvesen
Norwegian Public Roads Administration

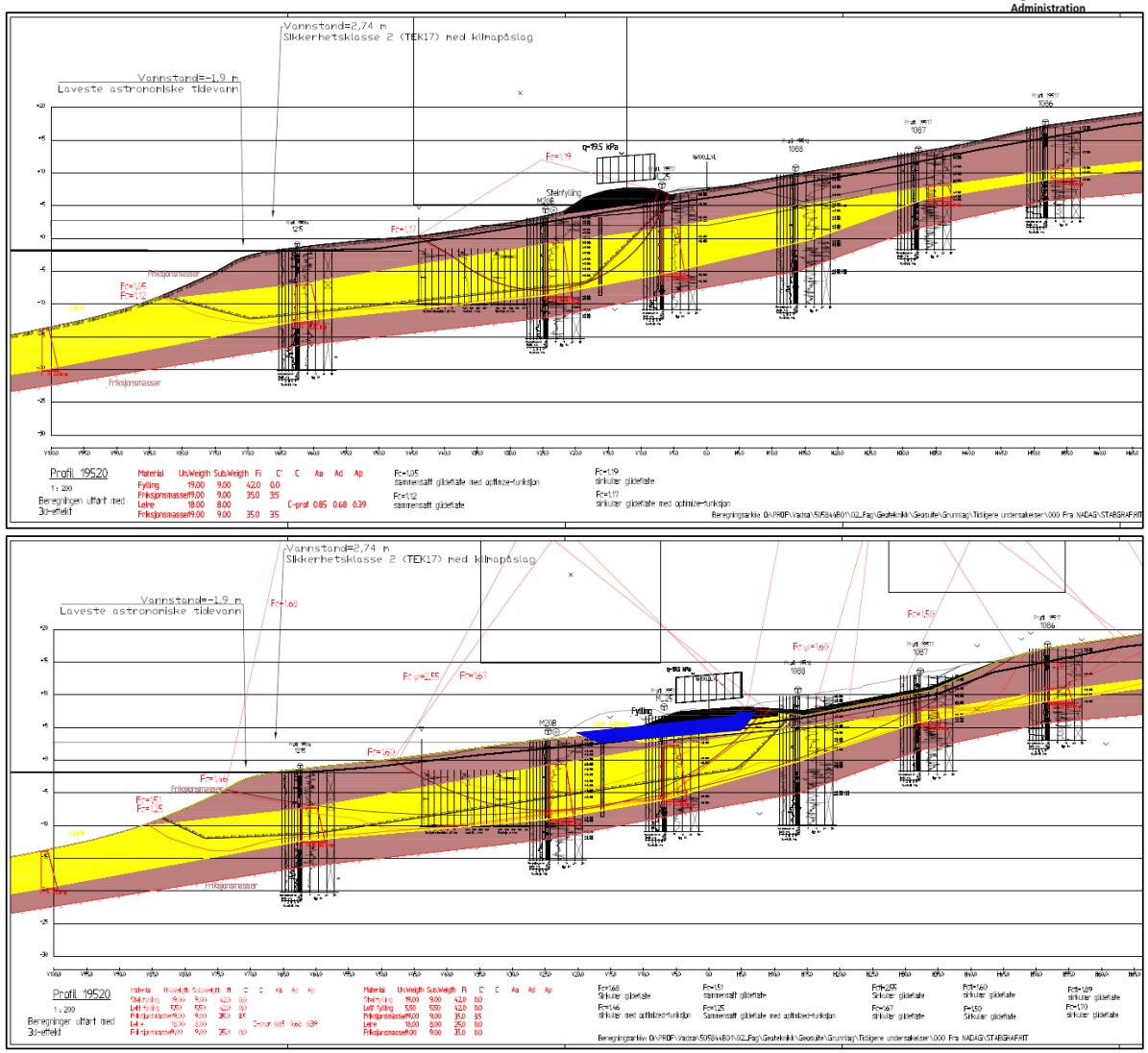
- Steinvik is 150 m wide cove under marine limit
- Total soundings, CPTu, Sampling
- 0 - 25 m thick soil layer – sandy gravel layer (5m) over silty clay and clay of varying shear strength (25 – 37 kPa)
- Contains highly sensitive clay layer – quick clay



Soil investigation points registered in NADAG (National Database for Ground Investigations).
(*geo.ngu.no/kart/nadag-avansert/*)

Ground conditions – slope stability condition

- Existing stability condition gave a factor of safety lower than the requirements (N200)
- Improvement measures (road moved slightly inwards) – mass replacement with light fillings + terrain unloading
- Design control by independent 3.party => similar improvement measures



SVV (2019) Geoteknikk, Fv. 98 Steinvik Byggeplan (51007-GEOT-02)

Geotechnical execution plan

Statens vegvesen
Norwegian Public Roads Administration

- Required to avoid placement of materials on the soil slope – weather temporarily or permanently
- Blasting activity shall be carried out in accordance to Norwegian standard NS 8141-3:2014
- Geotechnical engineer presence during the execution phase and approval for any changes

6 Vurderinger

Det skal ikke lagres masser i Steinvik. Hverken midlertidig eller permanent.

Hvis det oppdages at det må graves i leirholdige masser skal geotekniker kontaktes og gi fortløpende instruks om hvordan arbeidet skal utføres. Det vil da være aktuelt med enten masseutskifting til fast grunn eller legge duk og jordarmering for å få stabilitet i vegfyllingen.

Sprengningsarbeid som skal utføres i nærheten av Steinvik skal utføres etter *NS8141-3:2014 «Vibrasjoner og støt».* Veiledende grenseverdier for bygge- og anleggsvirksomhet, bergverk og trafikk. Del 3: Virkning av vibrasjoner fra sprengning på utløsing av skred i kvikkleire".

8 HMS – FORHOLD

I henhold til byggeherreforskriftene skal det for dette arbeidet lages byggherrens HMS-plan. Dette kapittelet gjelder risiko i forbindelse geotekniske arbeider ved Steinvik.

Ved utførelse av arbeidet må en ta hensyn til fare for utglidninger i Steinvik. Det er derfor et krav at masser ikke får lagres i Steinvik (profil 19500-19630), hverken tilfeldig eller permanent.

I byggefasen skal entreprenøren, lage risikovurdering (sikker jobbanalyse) for arbeid i området. Krav om dette skal fremgå av byggherrens SHA-plan.

SVV (2019) Geoteknikk, Fv. 98 Steinvik Byggeplan (51007-GEOT-02)

Blasting and the resulting masses

Statens vegvesen
Norwegian Public Roads Administration

- Blasting carried out in 3 phases – First ca. 1000 m^3 and second ca. 5000 m^3

- The 3rd blasting involved mass of ca. 40 000 m^3, executed 17.04.21 kl. 18:13 – resulted in 10-15 000 m^3 blast material on the road

Photos: Frank Martin Ingilæ

After blasting

Statens vegvesen
Norwegian Public Roads Administration

- Activity to open re-open the road started immediately after basting and lasted till kl. 01:00

Photos: Frank Martin Ingilæ

The slide

Statens vegvesen
Norwegian Public Roads Administration

- The slide registered at Traffic Control Centre (VTS) @ 03:33 AM –
- Occurred between 01:00 AM and 03:00 AM – at least 6.75 hours after blasting
- The slide took 50 m of the road section.

Photos: Frank Martin Ingilæ

After the slide

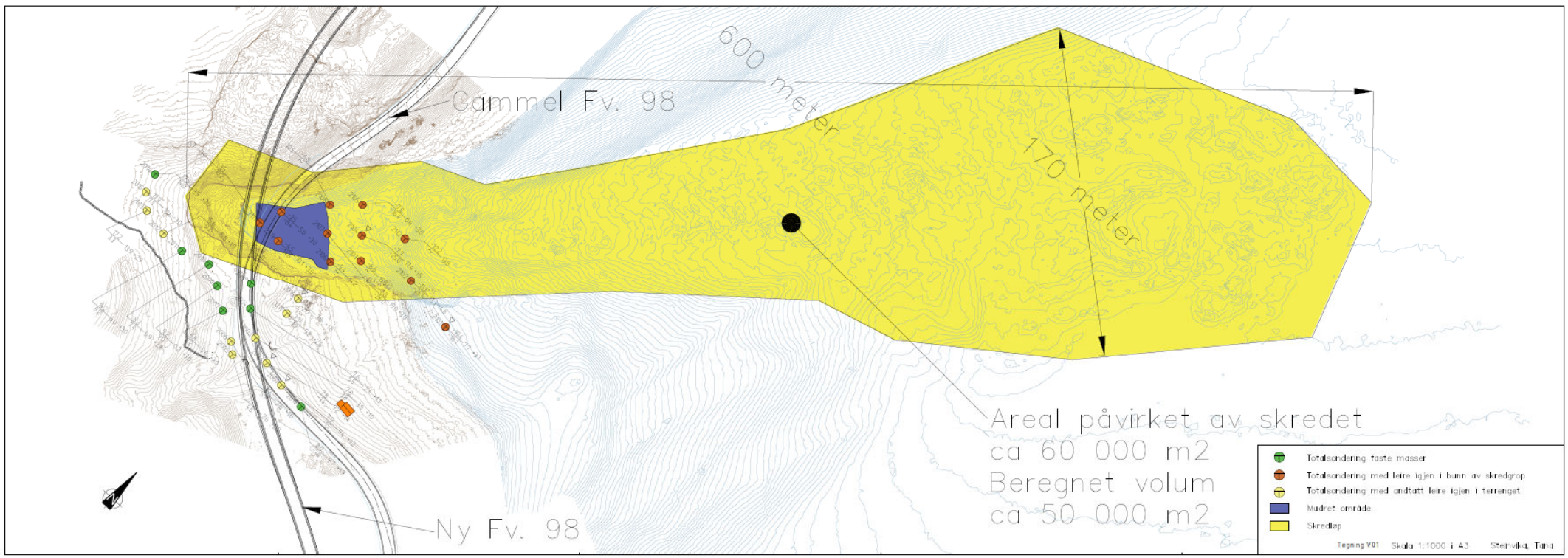
Statens vegvesen
Norwegian Public Roads Administration

- Road closed for 2 months => detour length of ca. 500 km, direct cost of ca. 18 mill. kNOK
- Slide materials excavated and replaced with crushed rocks

Photos: Frank Martin Ingilæ

The slide

- Retrogression + runout distance of the slide = 600 m
- Resulting slide volume 60 000m^3

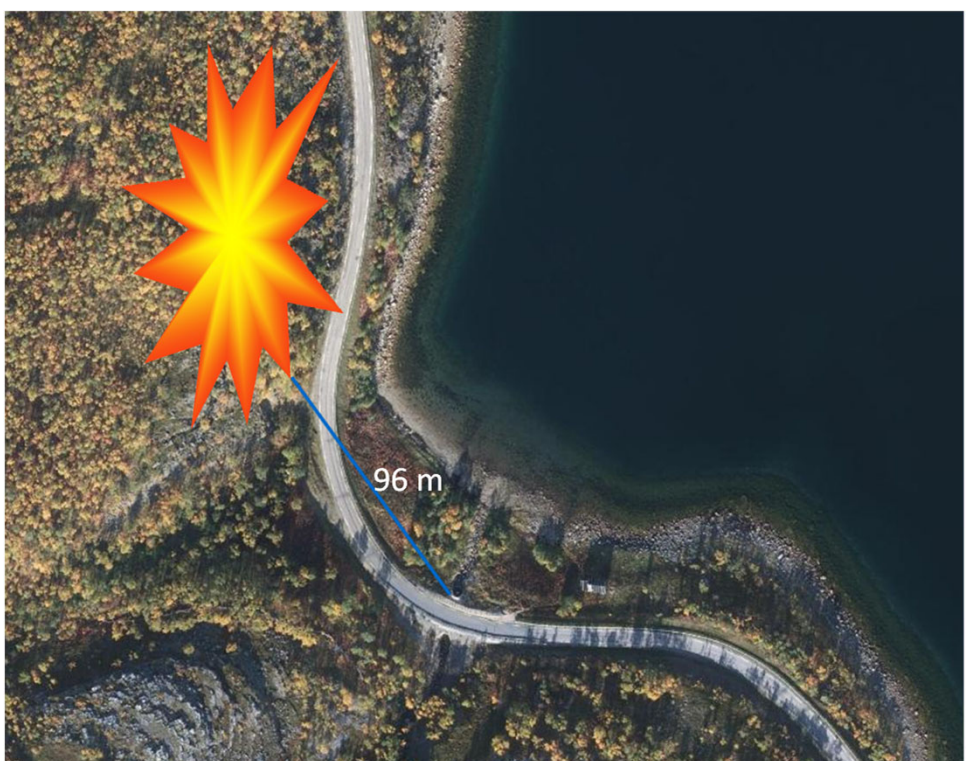


TFFK (2022) Geoteknisk erfaringsrapport skred fv. 98 Steinvik – 2065002-GEOT-03

Vibration measurement

Statens vegvesen
Norwegian Public Roads Administration

- 1 Vibration measurement
- Device mounted on a culvert located ca. 90 –100 m from blasting area



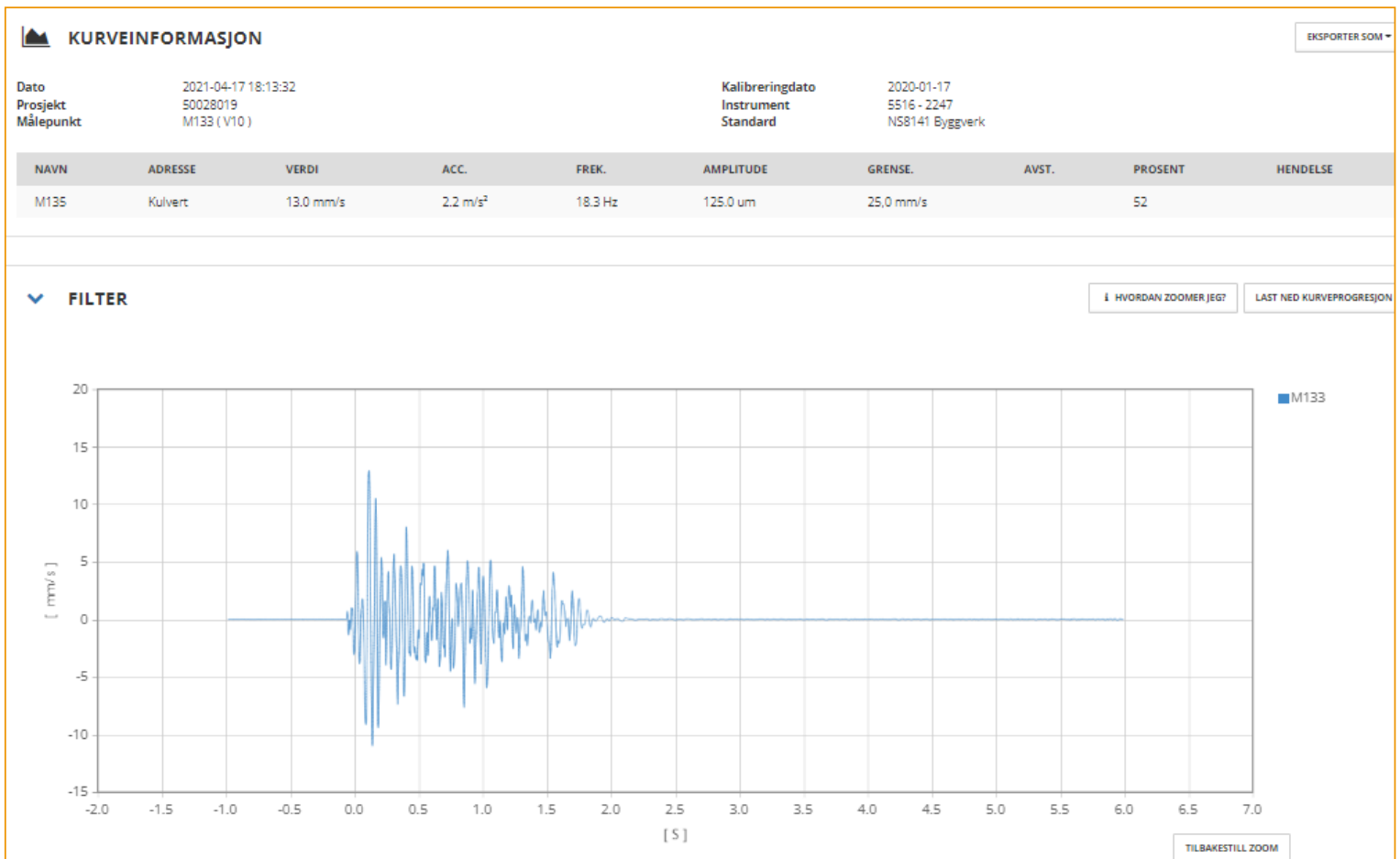
https://kart.finn.no/

Photos: Frank Martin Ingilæ

Vibrations measurements

Statens vegvesen
Norwegian Public Roads Administration

- Peak value 13 mm/s, 18:13:32



Critical reflections/discussion points

Statens vegvesen
Norwegian Public Roads Administration

- In theory, the project had all the essential elements to avoid the slide
  - Relatively small area – straightforward problem
  - Detailed soil investigations and evaluation of stability conditions (3 geotechnical reports)
  - Third party independent design control and verification
  - Enforcement of key requirements from vibration standard and relevant NPRA regulatory documents
  - Knowledge from earlier and relevant incidents – Kattmarka in 2009

- In practice, there were attempts to follow key design elements but with significant deviations from what was expected during design. Shortcoming ? Challenges? Interpretations?
  - Rock type properties in relation to blasting
  - Project execution times/ time needed for careful execution
  - Installation of measuring devices for vibrations
  - Decision on direction of throw of blasted rocks
  - Use of test blasting/earlier blasting than the main one
  - Removing of blast materials without worsening stability conditions

- Important to find explanations and understand where such deviations could emanate from, look into interpretation and use of existing standards.

Final remarks

Statens vegvesen
Norwegian Public Roads Administration

- Lessons learned from the 2009 Kattmarka slide have been crucial – implementation in relevant regulatory documents have often helped addresses similar problems successfully.
- The slide in Steinvik provides an opportunity to re-examine existing regulations in use and to address any shortcomings so that similar incidents are avoided in the future.
- Analyses of vibration and other relevant data from the project are considered to give key insight into the link between vibrations from blasting activity and stability of sensitive slopes. Re-look at existing limit for vibrations?
- Crucial to address ***how*** to execute blasting that results in acceptable vibration limit as well as controlled blast materials.
- Clear communications among all involved in project and follow up during execution phase are crucial.
- Successful blasting near sensitive clay slopes is a multidisciplinary problem (geotechnics, geology, rock drilling & blasting). There is a need to create a better overlap/understanding between these professions for practitioners.