

2015 Earth structures and retention conference

Design and construction of rock fall protection embankments

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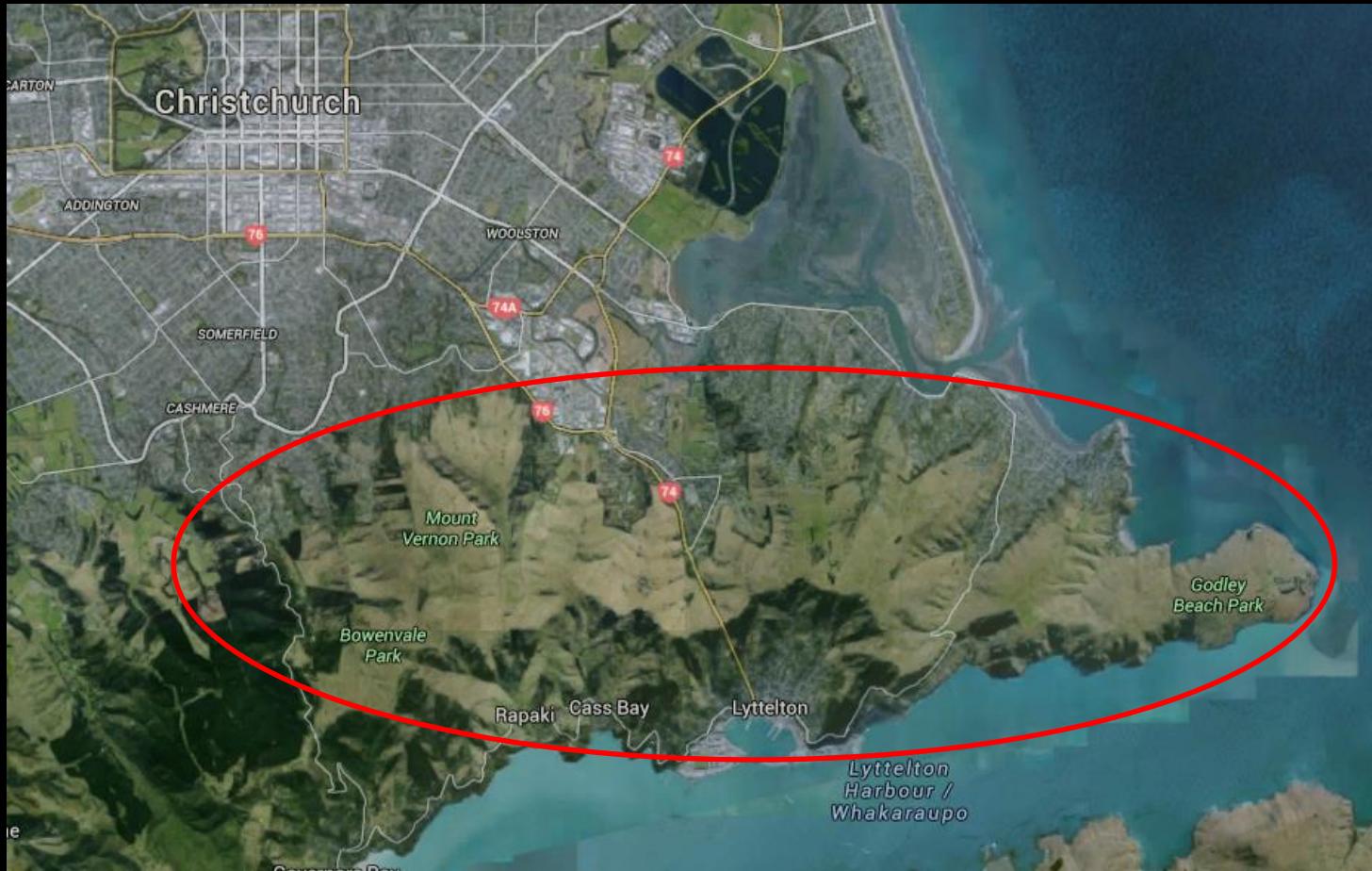
24th November 2015



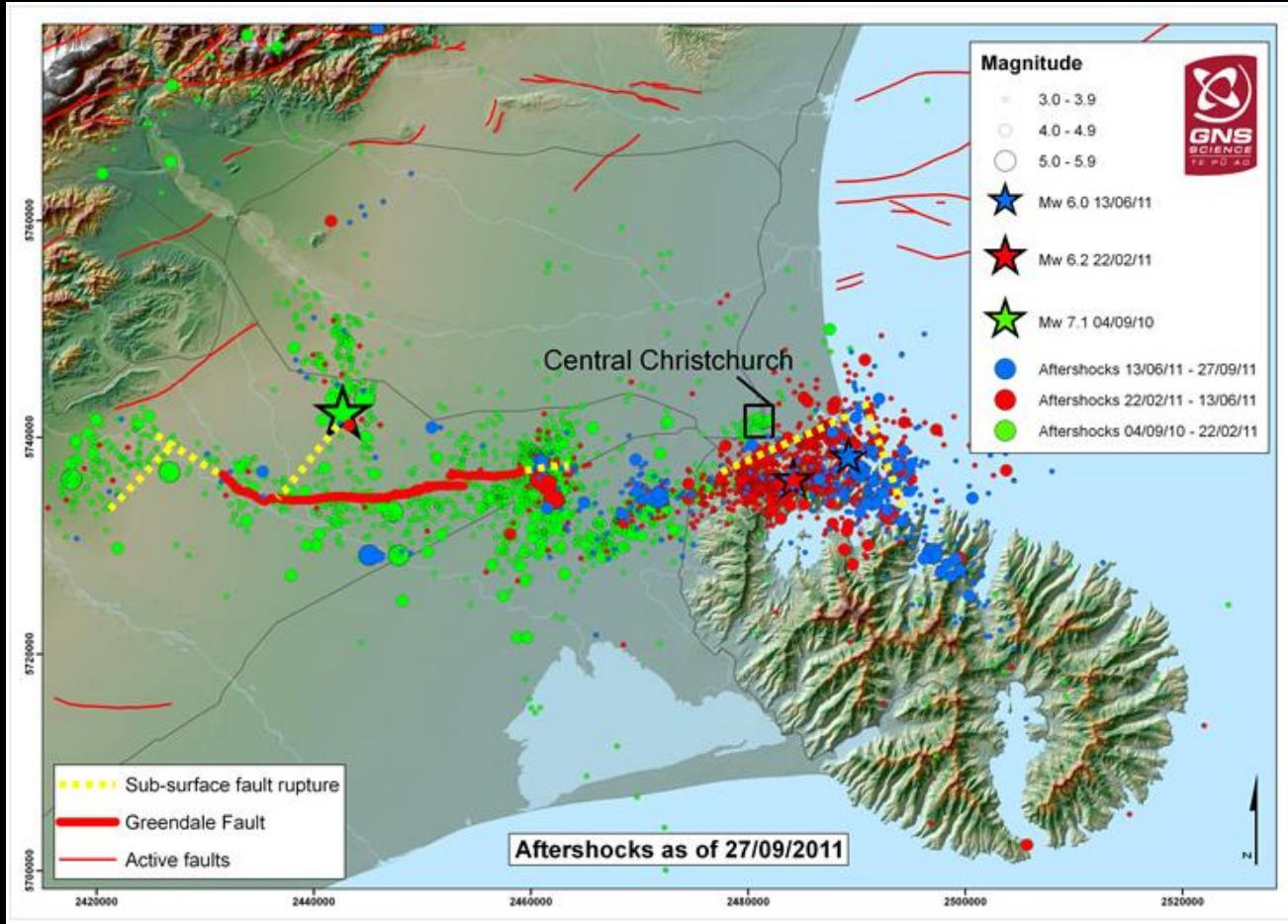
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3. alternative rockfall protection structures overview
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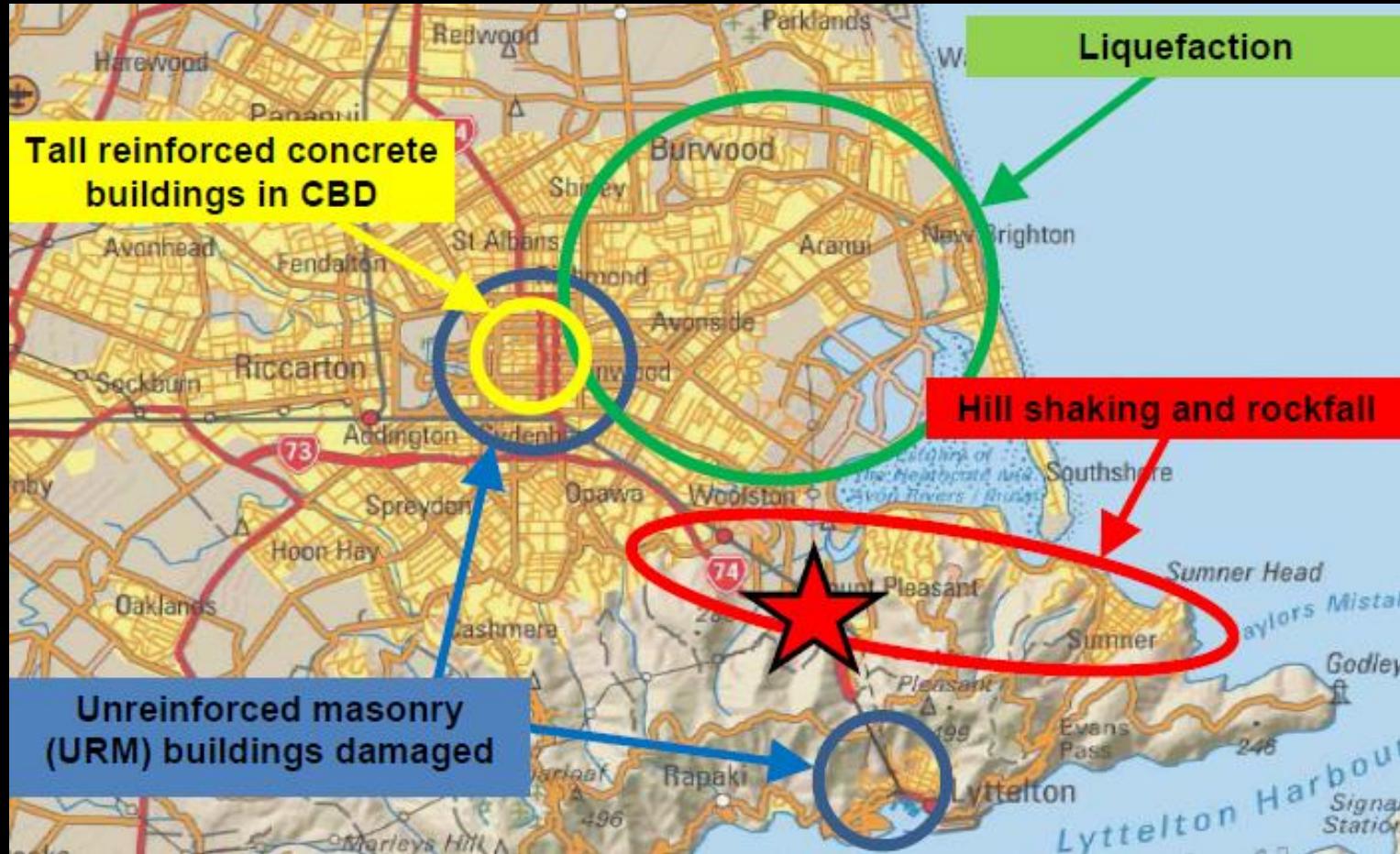
1. Context and background information



Earthquake damage



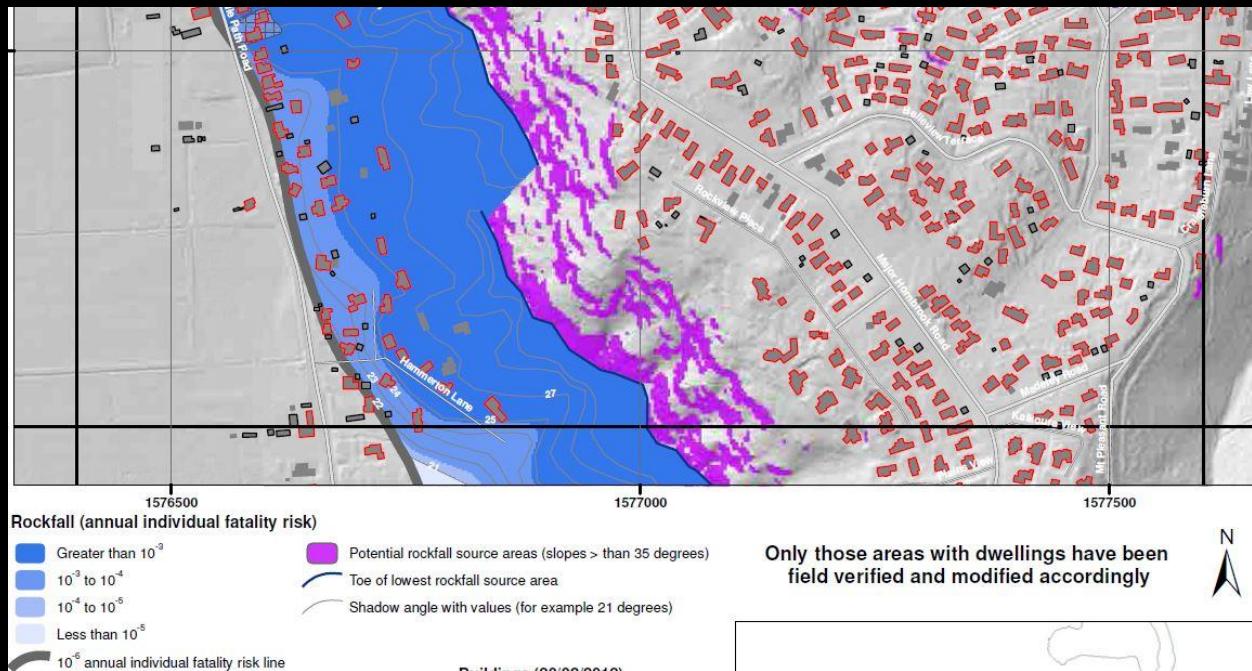
Earthquake damage



2. Property Zoning

Following the Canterbury earthquake of 2011, properties were categorised as ‘red zoned’ or ‘green zoned’.

Canterbury Earthquake Recovery Authority (CERA) defines properties that are ‘red zoned’ as “*Properties affected by rock roll have been zoned red where they face an unacceptable risk to life (greater than 1 in 10,000 at 2016 risk levels)*”, A total of 714 properties were classified as within the ‘red zone’



3. Alternative rockfall protection structures

Prevention of rockfall (primary measure)

- **Benefits**
- reduces likelihood of rockfall occurring and/or reduces the boulder size at the rockfall source
- **Methods**
- rock anchors, rock breaking, installation of mesh
- **Limitations**
- costly, high risk construction and maintenance, heavily dependent on identification of rock masses likely to dislodge



Source: www.gabionsupplier.com



Source: www.can.ltd.uk

3. Alternative rockfall protection structures

Barriers or attenuation fences (secondary measure)

- **Benefits**
- typically installed with small footprint
- **Methods**
- Chain link fence
- **Limitations**
- upon impact, chain link can deform several meters,
- not considered appropriate where rockfall energy $>1500\text{kJ}$, and
- requires regular maintenance following rockfall events.

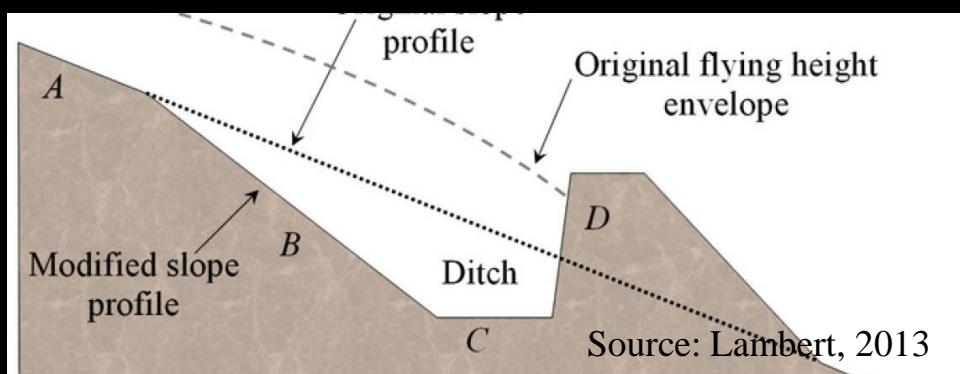


4. Rock fall protection embankments

- secondary mitigation measures
- **Benefits**
 - can resist high kinetic energy rock fall events,
 - embankments have been constructed to resist up to +10,000kJ of energy,
 - geometry and fill materials can vary
- **Methods**
 - embankment facing can vary
 - rockfall ditch
- **Limitations**
 - installation footprint
 - Potential to act as a dam



Source: Maccafferri



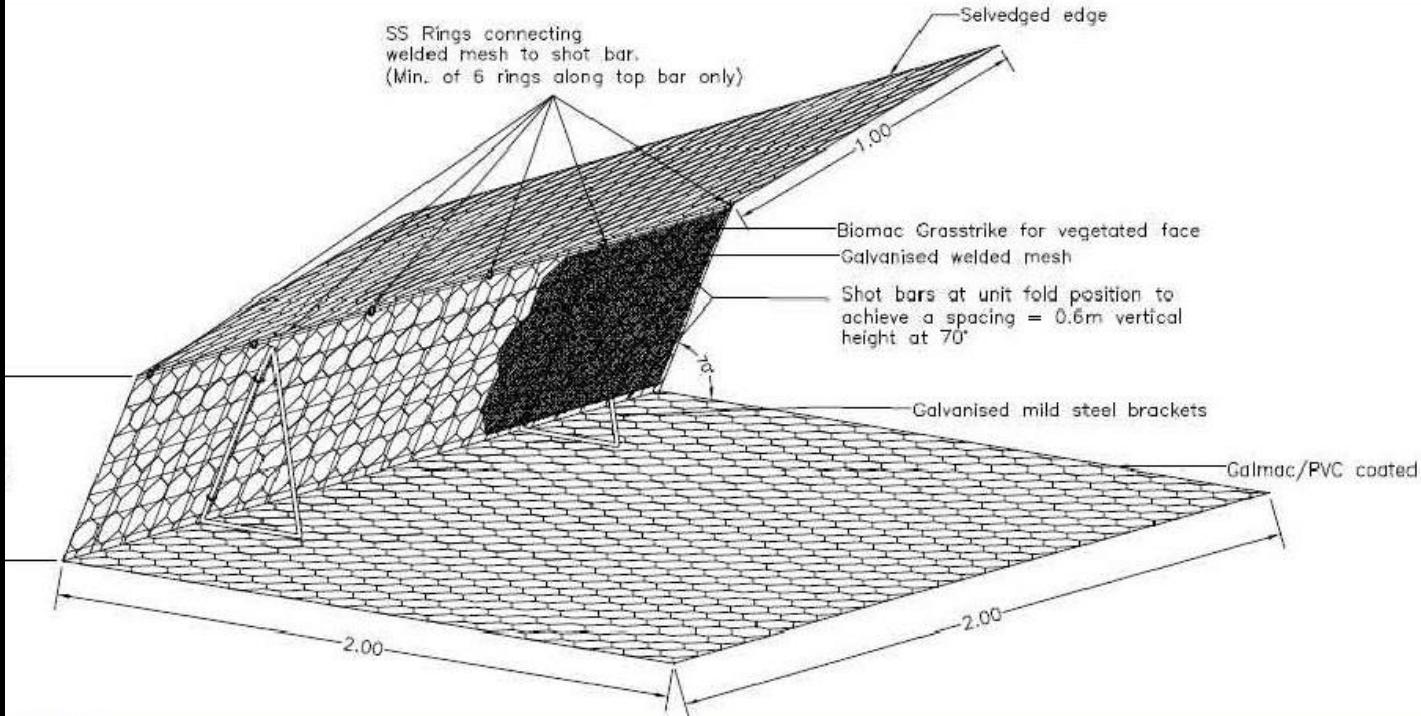
Source: Lambert, 2013



<https://www.youtube.com/watch?v=TMGwVrXmh-o>

Rock fall protection embankment variations

CAFERRI



mesh Unit

Rock fall protection embankment variations



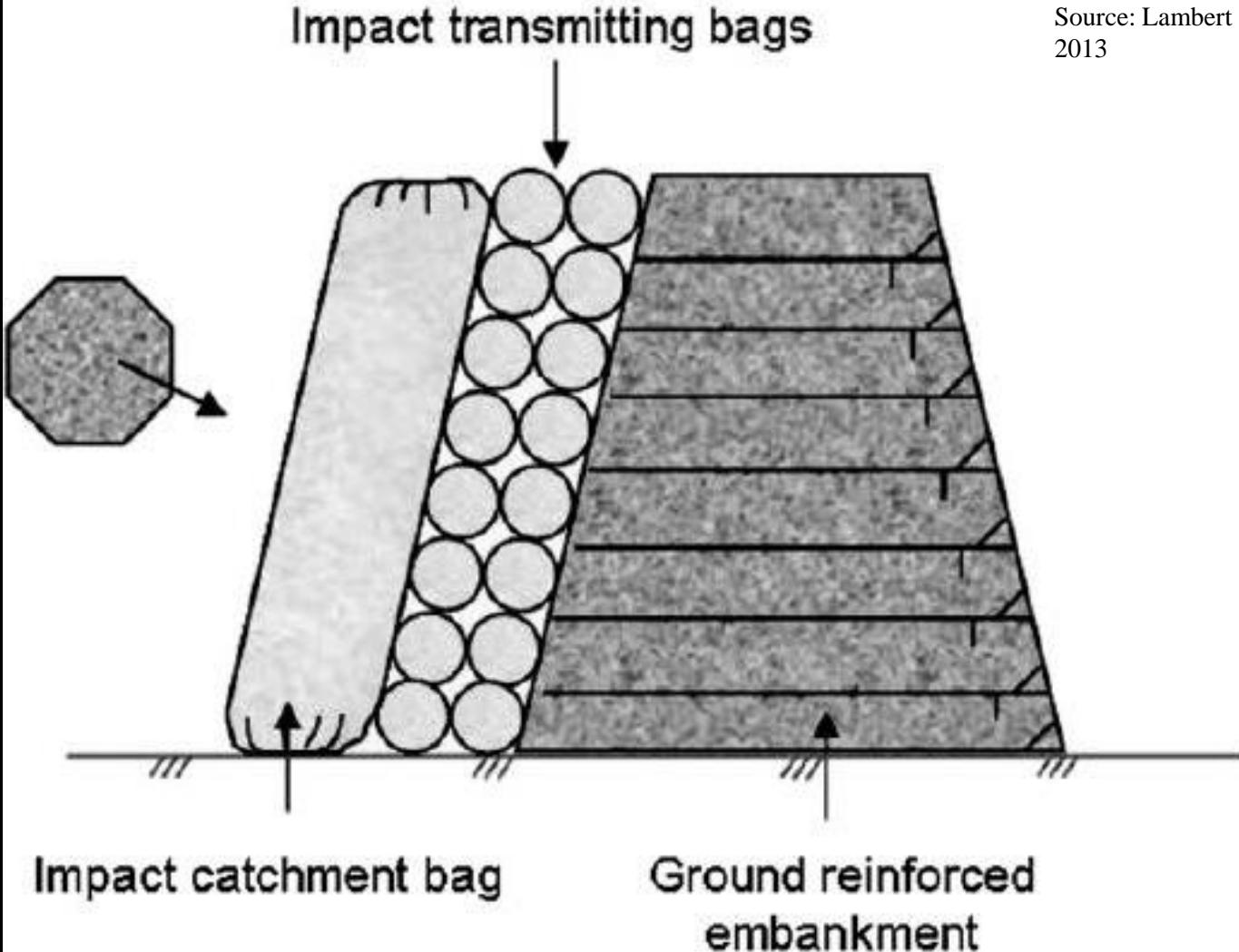
Rock fall protection embankment variations

6

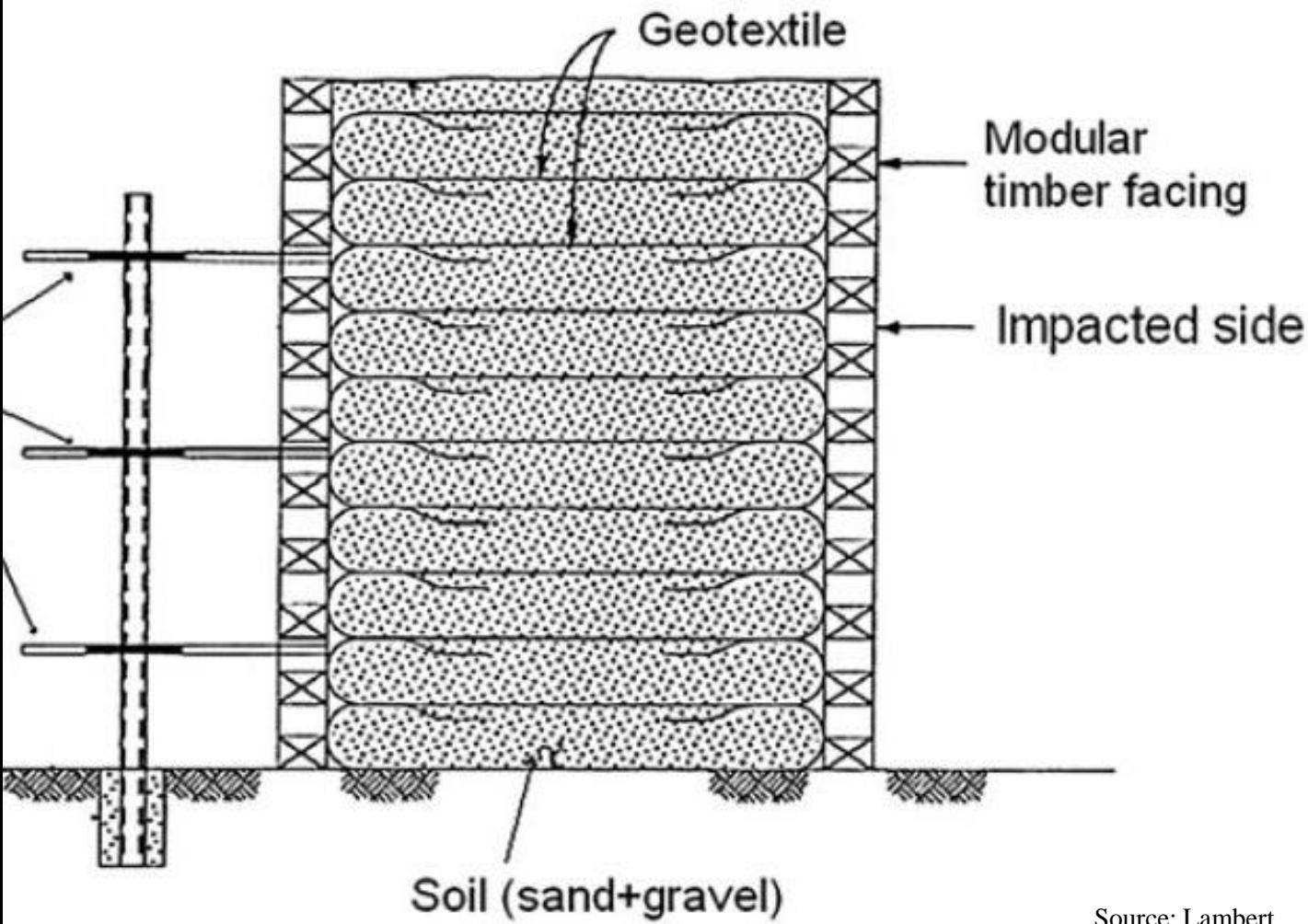


Source: Lambert
2013

Rock fall protection
embankment
variations



Rock fall protection embankment variations



Rock fall protection embankment variations

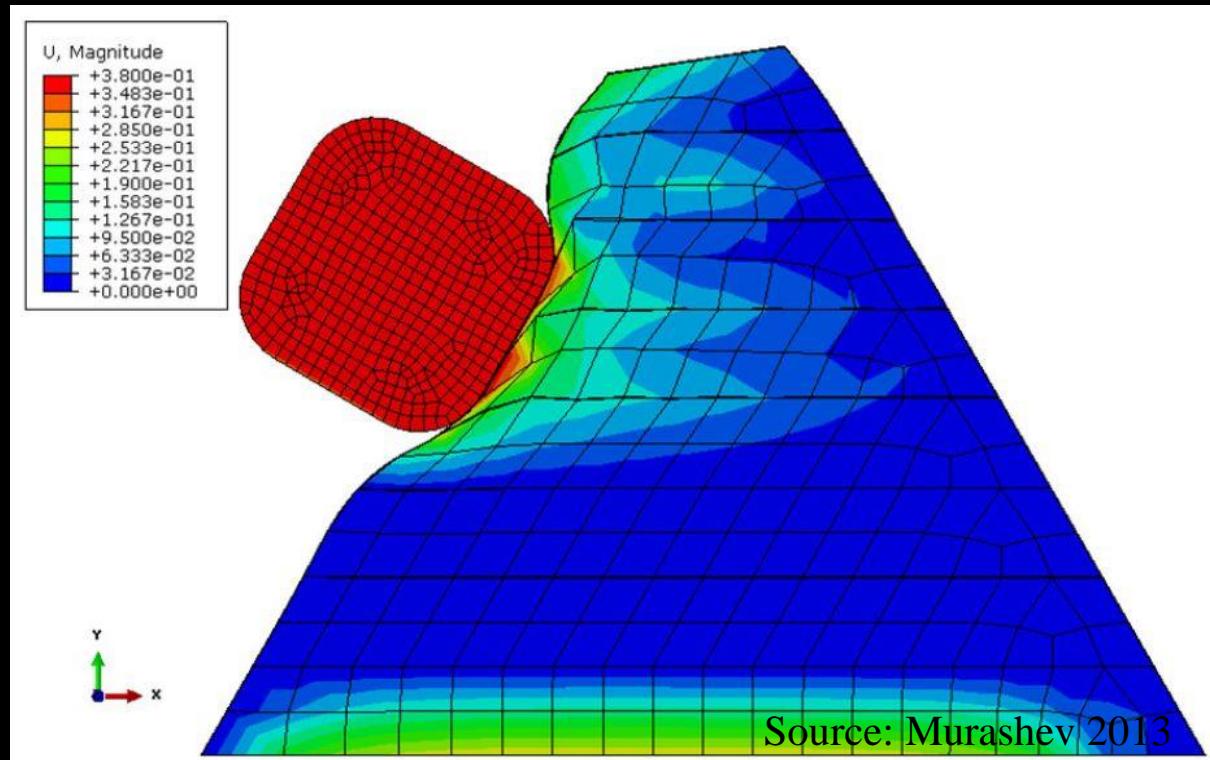


Rock fall embankment design approaches

Multiple design approaches exist for the design of rock fall protection embankments, which vary in complexity:

- Mass balance,
- Factor of Safety,
- Pseudo-static,
- **Energy balance**, or
- Numerical modelling

Arup's adopted method for projects in the Port Hills was an energy balance approach



Rock fall embankment design approach adopted

Multiple variables prevent standardised design procedure in Australia/NZ for rockfall protection embankments, including:

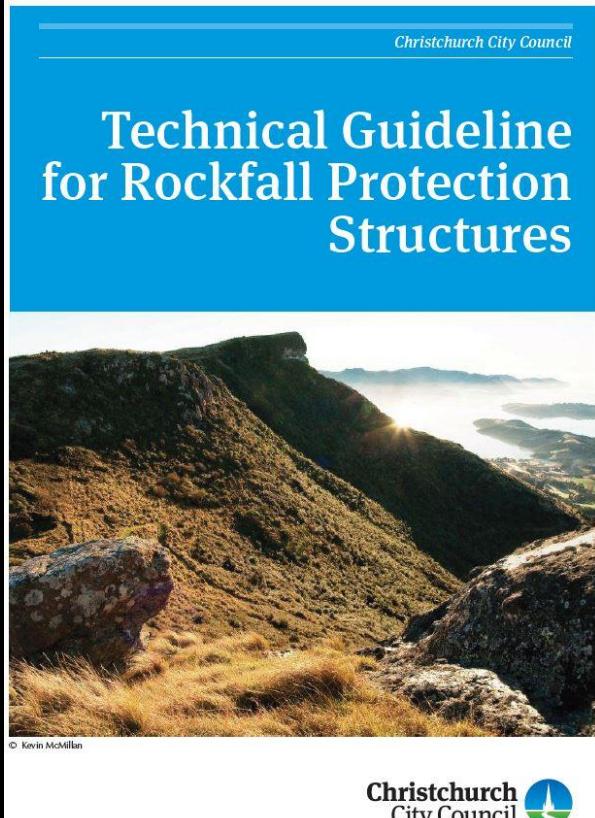
- geometry,
- fill material,
- construction methods,
- reinforcement option (geogrid, steel mesh, spacing), and
- dynamic behaviour of soil.

This design approach is outlined in detail in Ronco, 2009

Modifications were made to meet the requirements of the Christchurch City Council (CCC) technical guidelines for rock fall protection

Design procedure involves two stages:

1. Assessment of rockfall energy levels, and
2. Design of the rock fall protection embankment.



Assessment of rockfall energy levels

Rockfall analysis at specific sites found:

- energy levels often in excess of 6000kJ,
- boulder size in the order of 1.2m³, and
- velocity in excess of 25m/s.



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Physical and topographic survey findings are input into rockfall simulation

Outputs

- anticipated trajectory,
- nominal design energy (DEL) energy levels,
- bounce height, and
- Velocity.

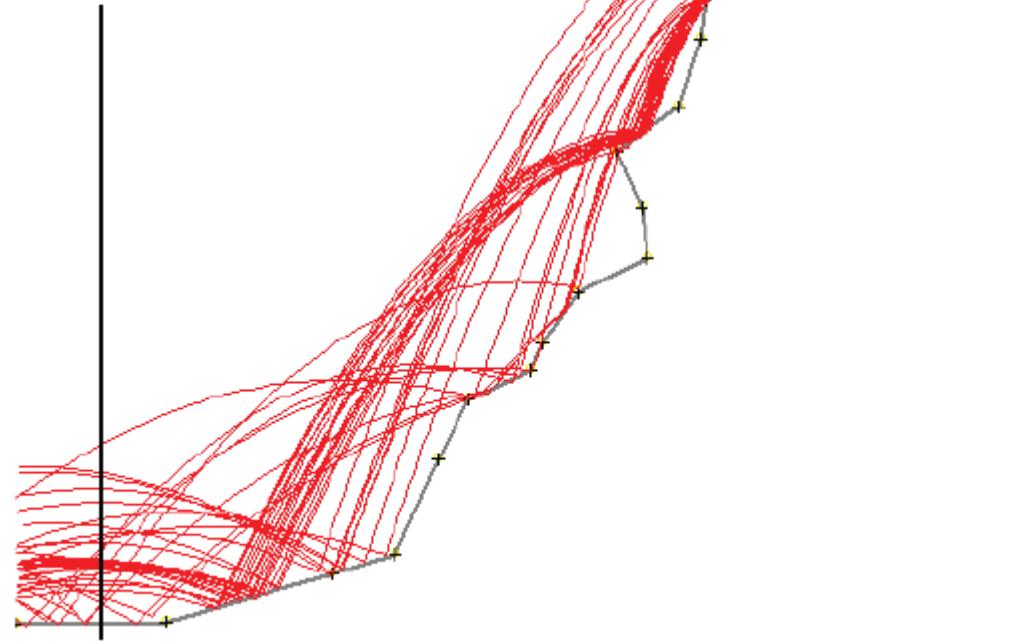
Used to decide the type and location of RPS

DEL parameters obtained from rockfall analysis are factored based on ETAG 27 requirements

Rockfall modelling is a strong tool in deciding on the location of the embankment

Source: Maccaferri

Position of the barrier



Maximum Energy Level, MEL

in the order or 1.3 times DEL; for assessing low frequency rockfall events

Service Energy Level, SEL

in the order of 0.3 times DEL; for assessing multiple impacts

Geometry and Deformation

Up Slope deformation

- The penetration due to plasticisation/ compression,
- Maximum sliding of the soil layers

Down slope deformation

- only the ‘maximum sliding of soil layers’

The geometry of the RPE is determined by multiple elements, including:

1. Impact bounce height;
2. Tolerable deformation from boulder impact and construction requirements;
3. Global slope stability;
4. Global embankment stability due to accelerations from earthquakes; and
5. Effects of the embankment acting as a dam should also be considered.

Source: Ronco 2009

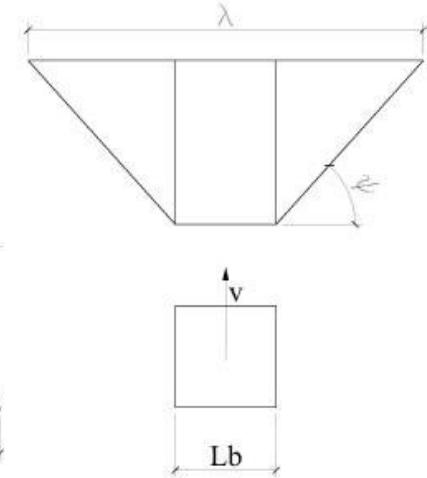
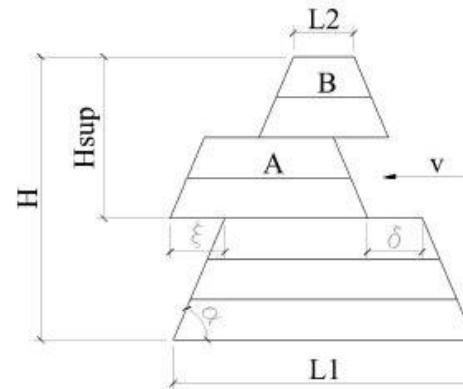
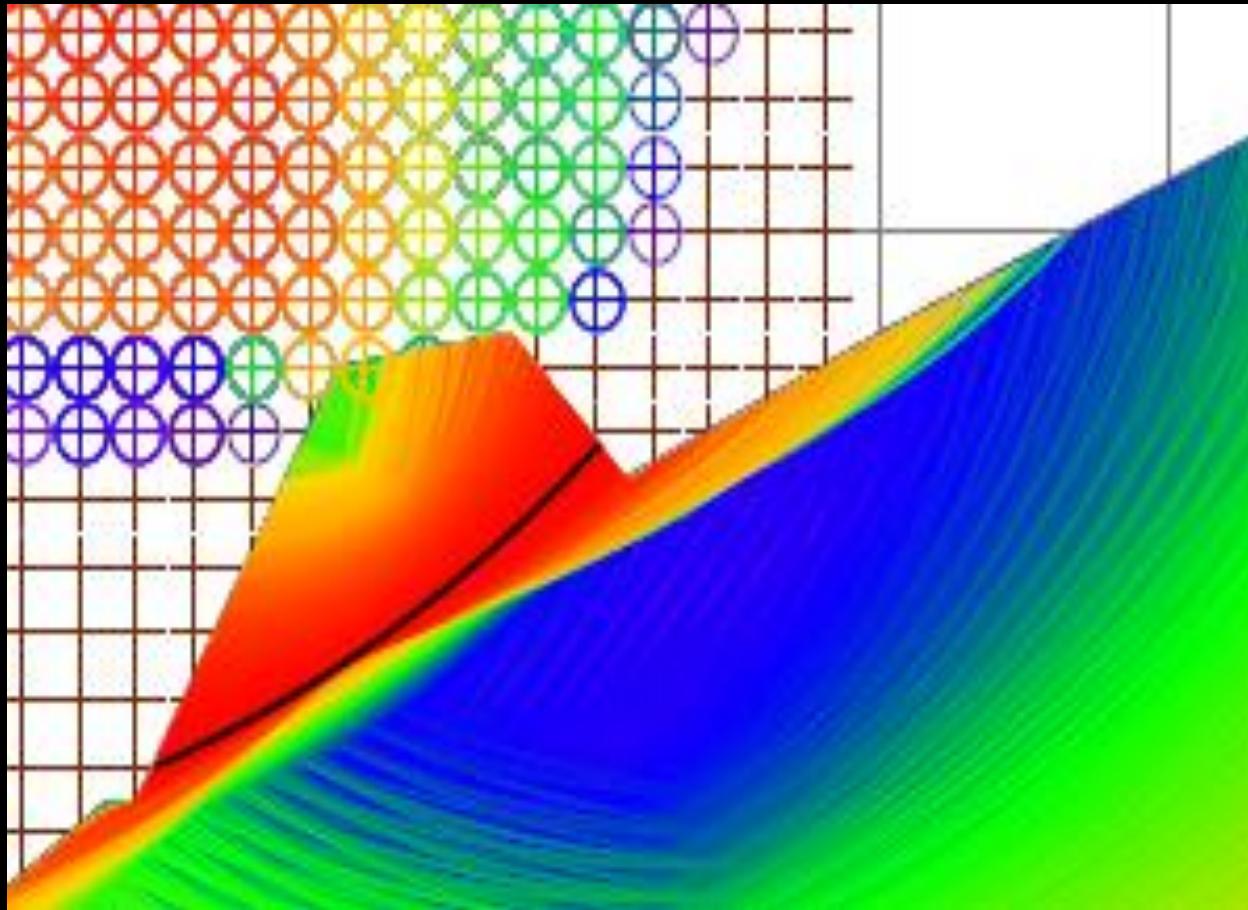


Fig. 6. Deformed shape of the theoretical reinforced embankment after the impact.



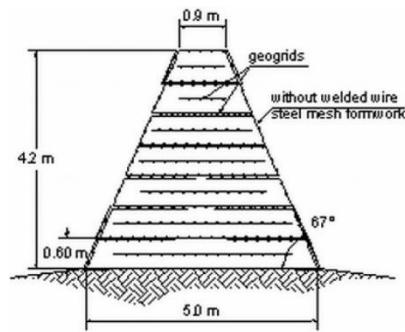
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Global Stability

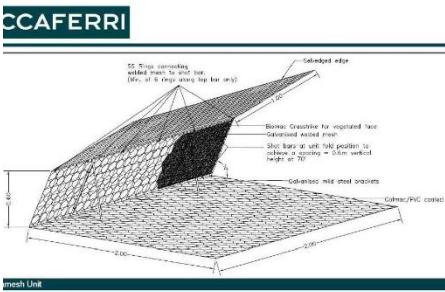




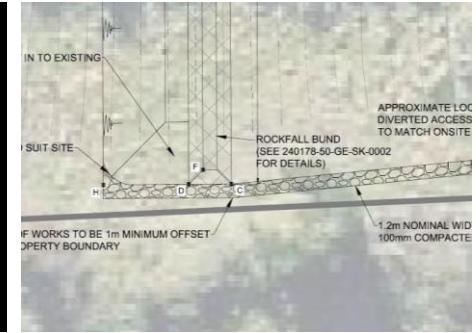
Natural terrain



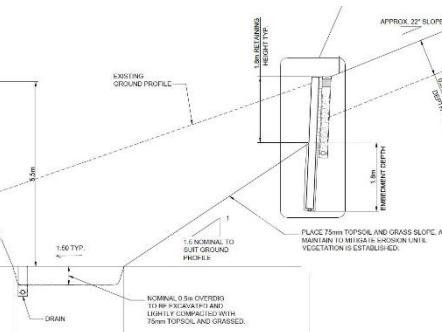
Geometry of embankment



Access Tracks



Embankment fill



Drainage

6. Case study A

MEL in the order of 7000kJ

Embankment was considered most suitable mitigation measure

Visual surveys carried out by Arup

Embankment position options were considered with contractor and client

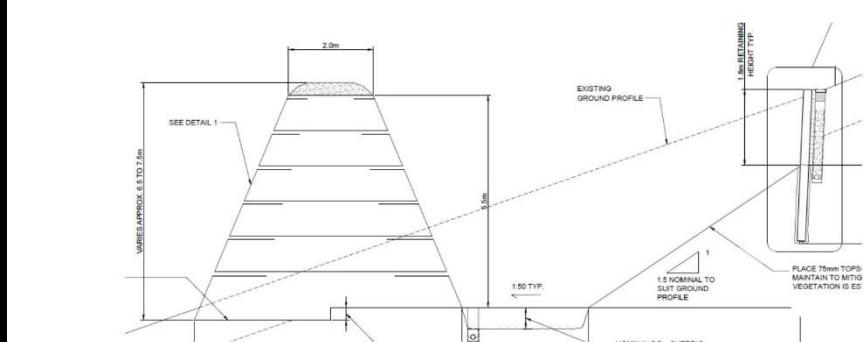
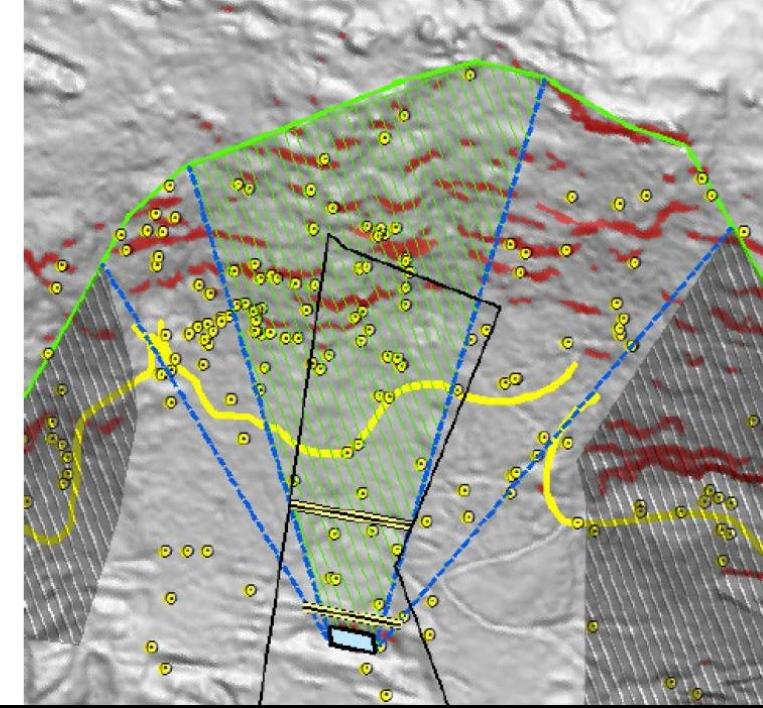
Design allowed balance of cut to fill, minimising construction cost

Excavated rock was proposed to fill embankment

Down slope maximum height 7.5m

Retaining wall utilised up slope

Commercial product proposed



6. Case study B



Conclusions

- Effective, sustainable rebuild strategy,
- Low cost, low maintenance,
- Site and construction constraints should be considered early in design
- No guidelines for the design of embankments exist in Australia, however large amounts of literature and international guidance exists,



Thank you

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24th November 2015

