

Ideas on the design of earth mounds and dams to protect highways against snow avalanches

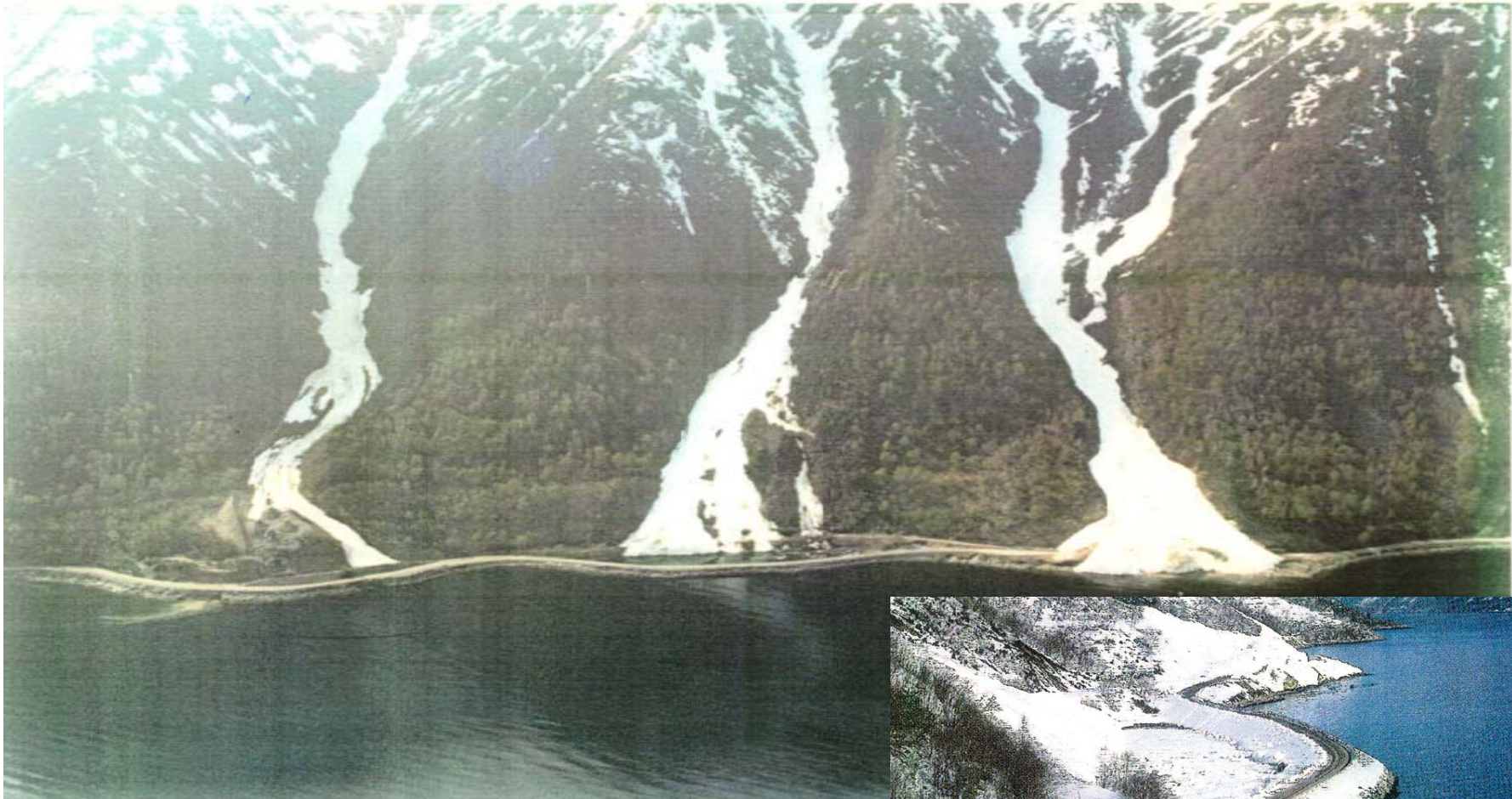
Harald Norem, NTNU
 Linda Brateng, PRA Norway
 Arnold Hustad, PRA, Norway



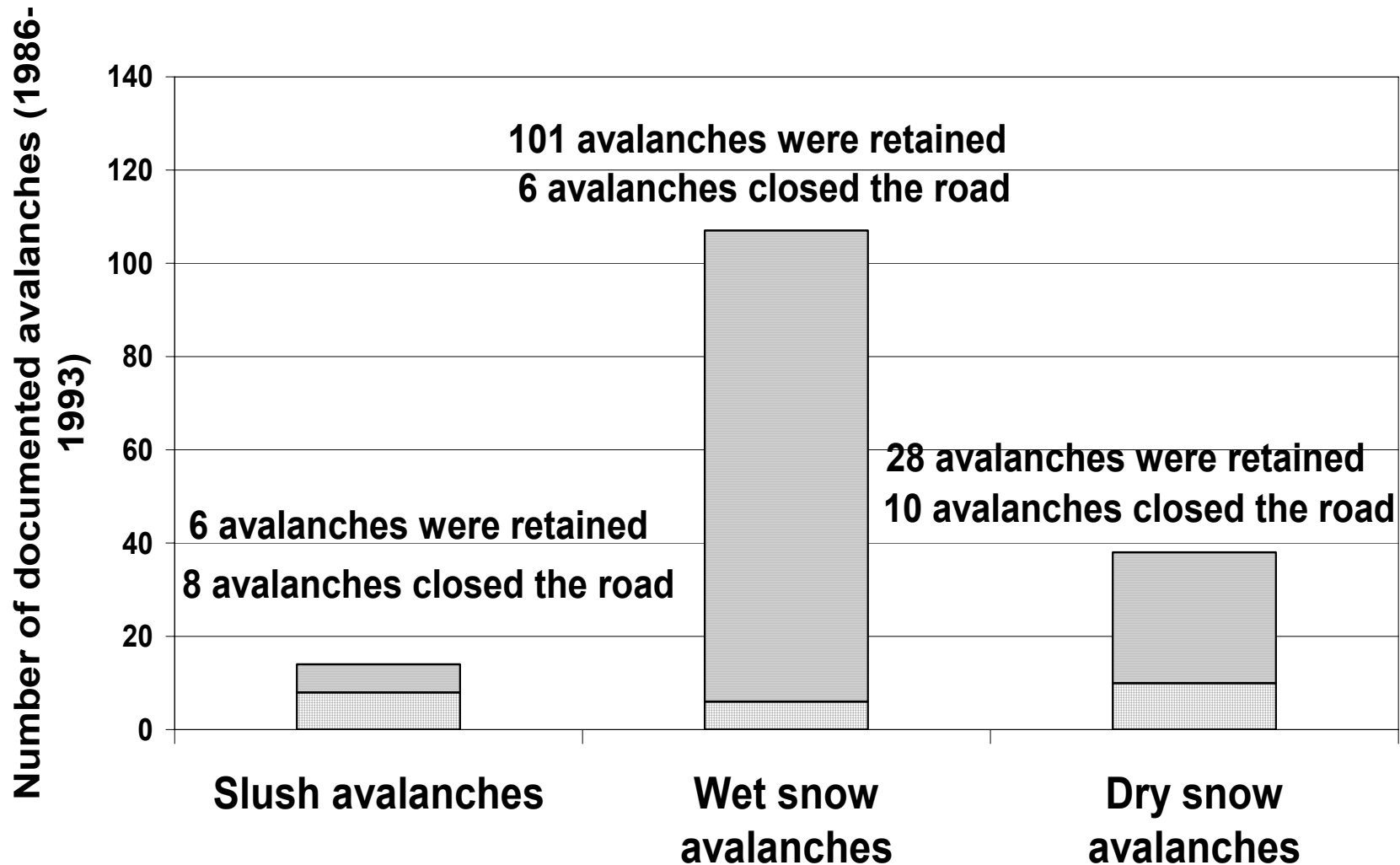
Content of the presentation

- Norwegian experiences with retaining structures like mounds and dams
- Results of model experiments
- Transferring the results of the model experiments to the nature

Protective measures on road 065

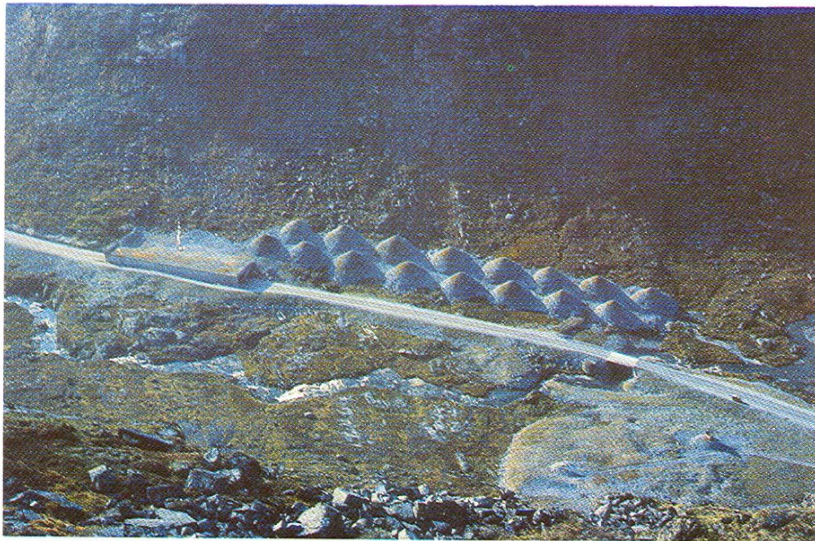
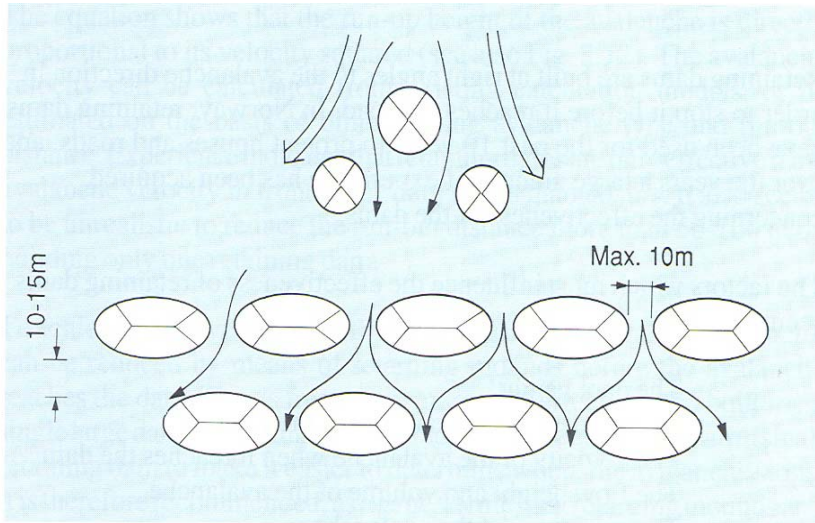


Effect of protective earth works on county road 065, grouped for different types of avalanches,.



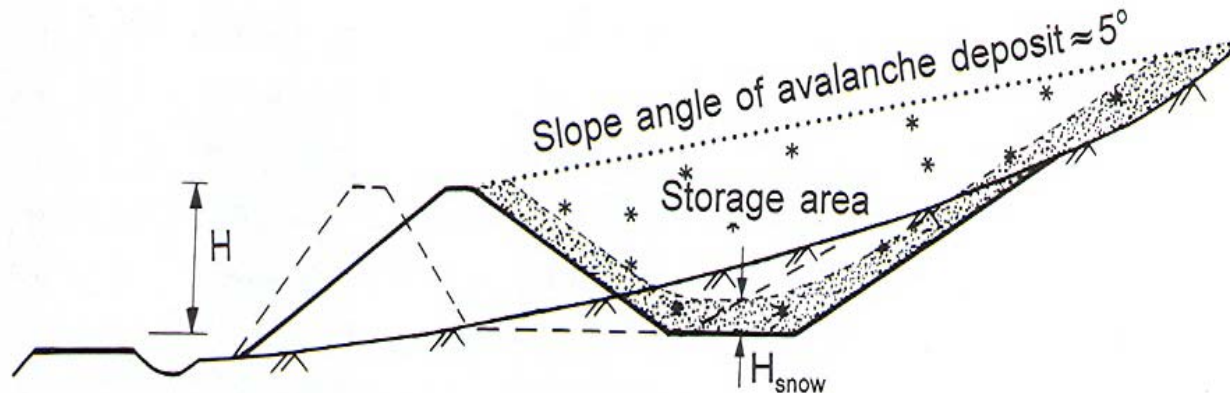
Present use of earth mounds

Earth mounds



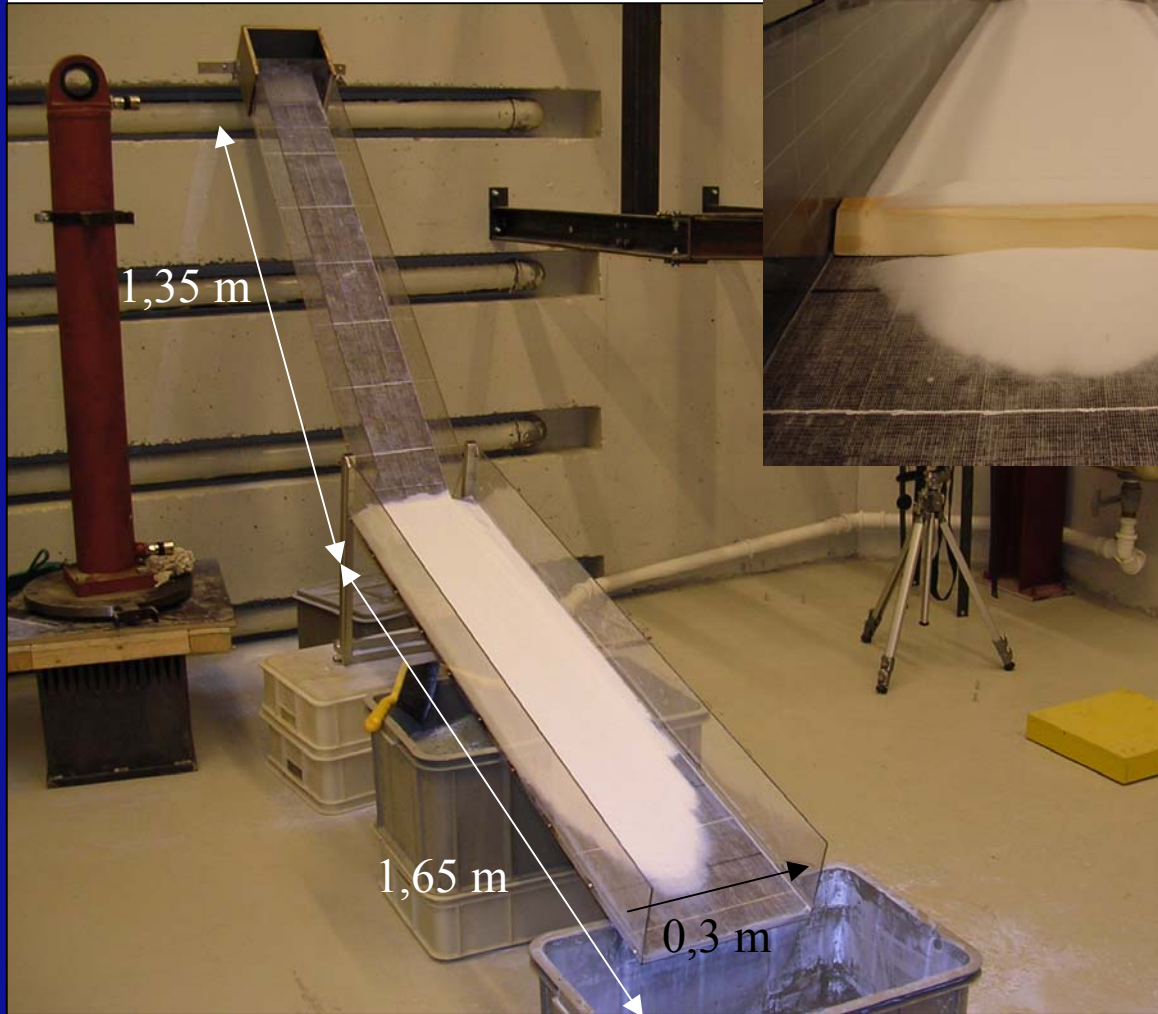
- The height varies within 4 and 8 m
- The mounds are generally made of soil and have slope angles of 1:1,5 (34 degree)
- The mounds should be located in at least two rows in chess-board pattern
- The length/height ratio is recommended to 1
- Preferably, one to three mounds should be located higher up in the run-out zone

Present use of collecting dams



- The height of the collecting dams should be close to the kinetic energy height of the avalanche, $H=kv^2/2g$
- There should be sufficient storage area in front of the dam
- The dam should be located close to the road where the avalanche velocity is at minimum and the dam may offer protection for the powder part of the avalanche

Experimental set-ups



Test procedures

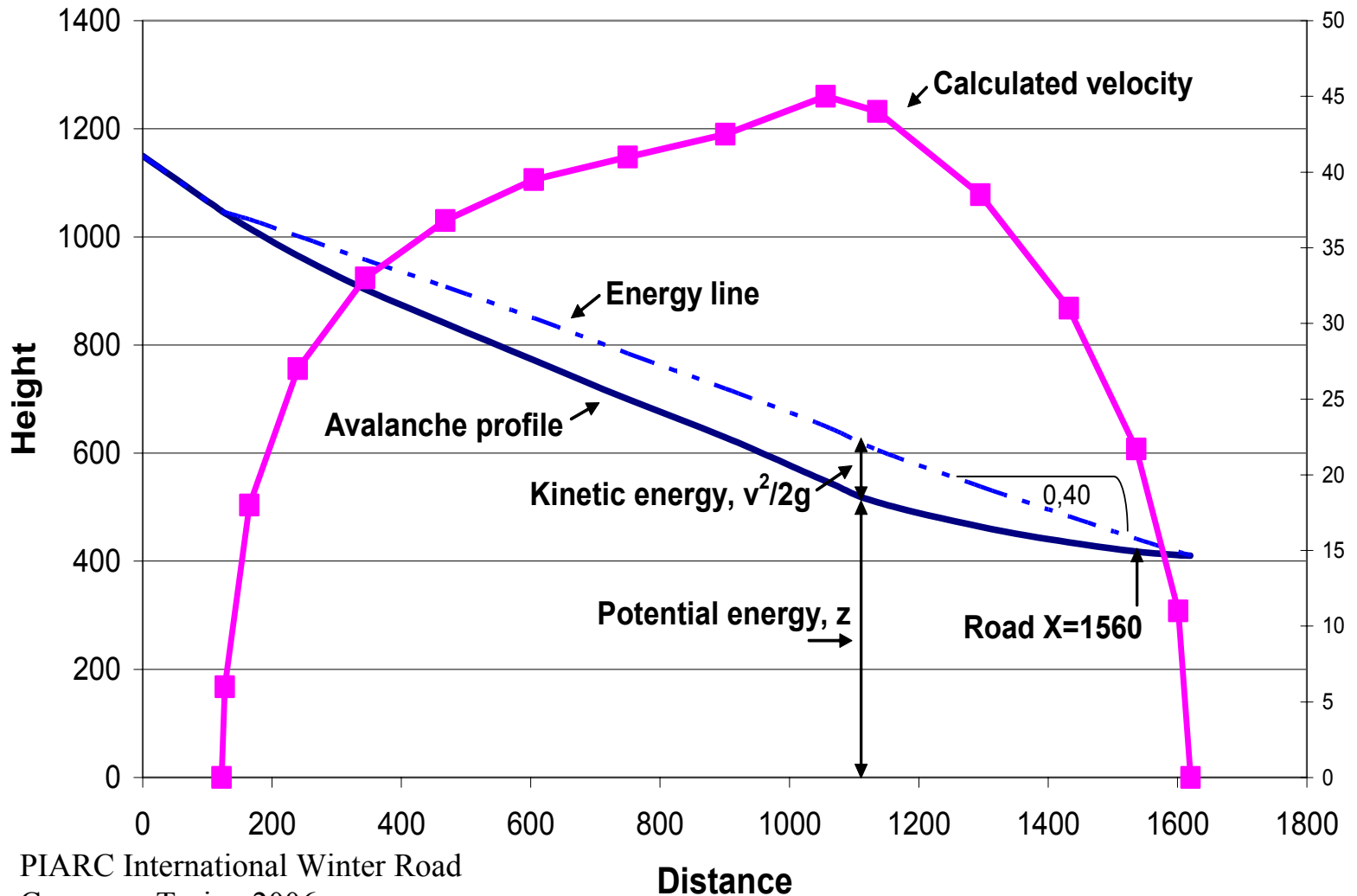
Recorded the retaining effect due to:

- Location in the run-out zone
- Height of the structures
- Steepness in front of the structures
- Combinations of dams and mounds

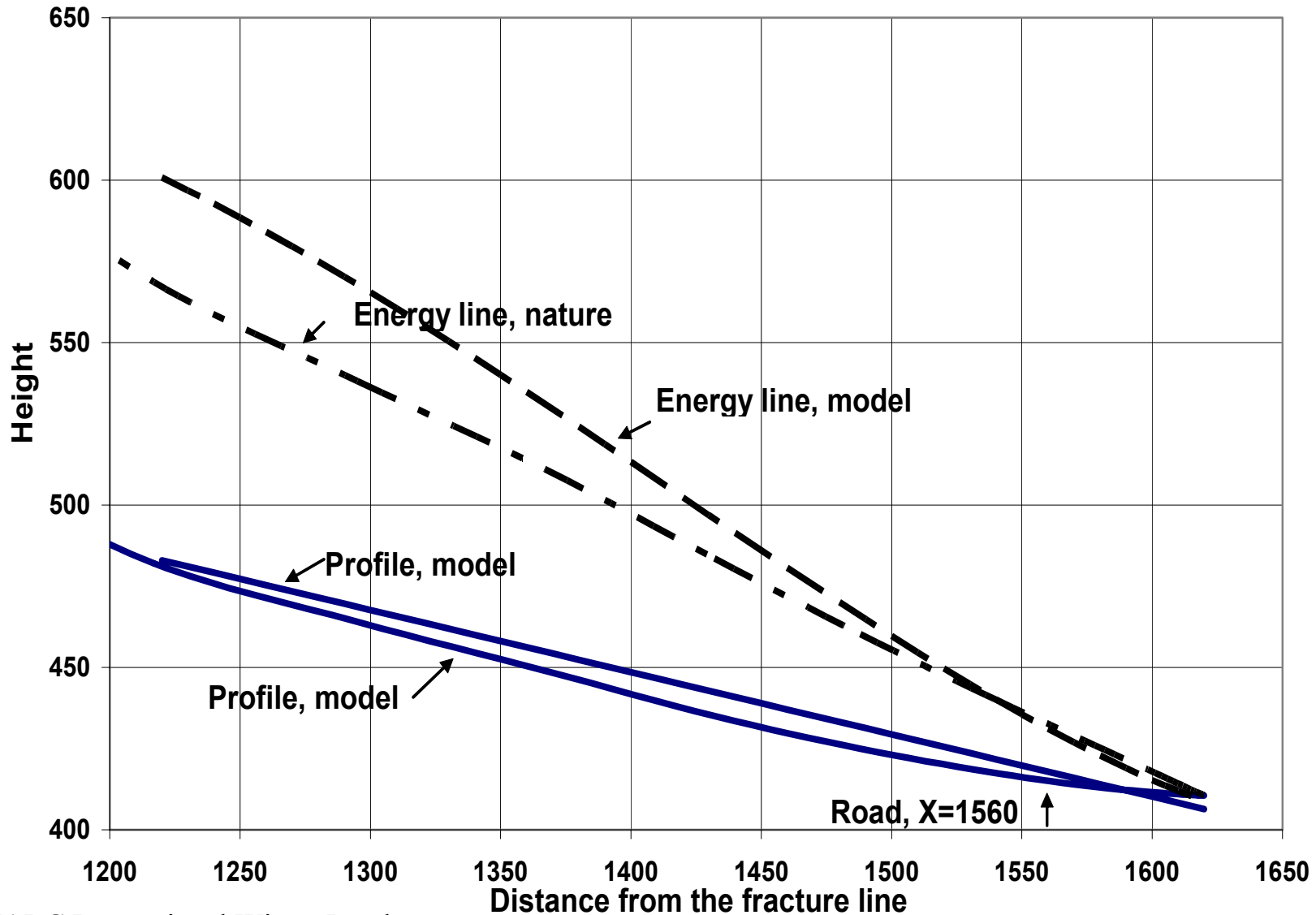


Analyses of the experimental results

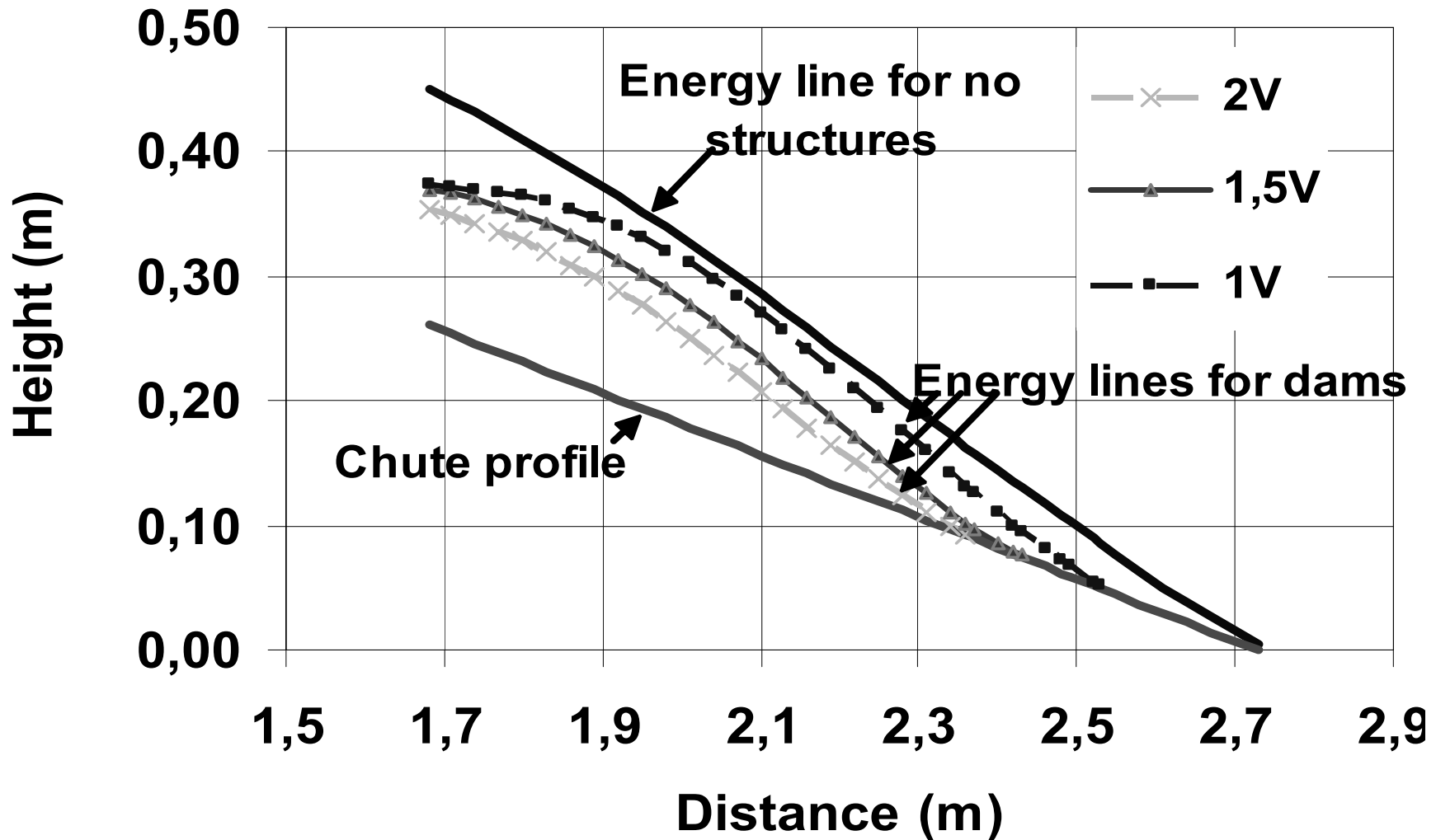
Graphical presentation of the Bernoulli equation



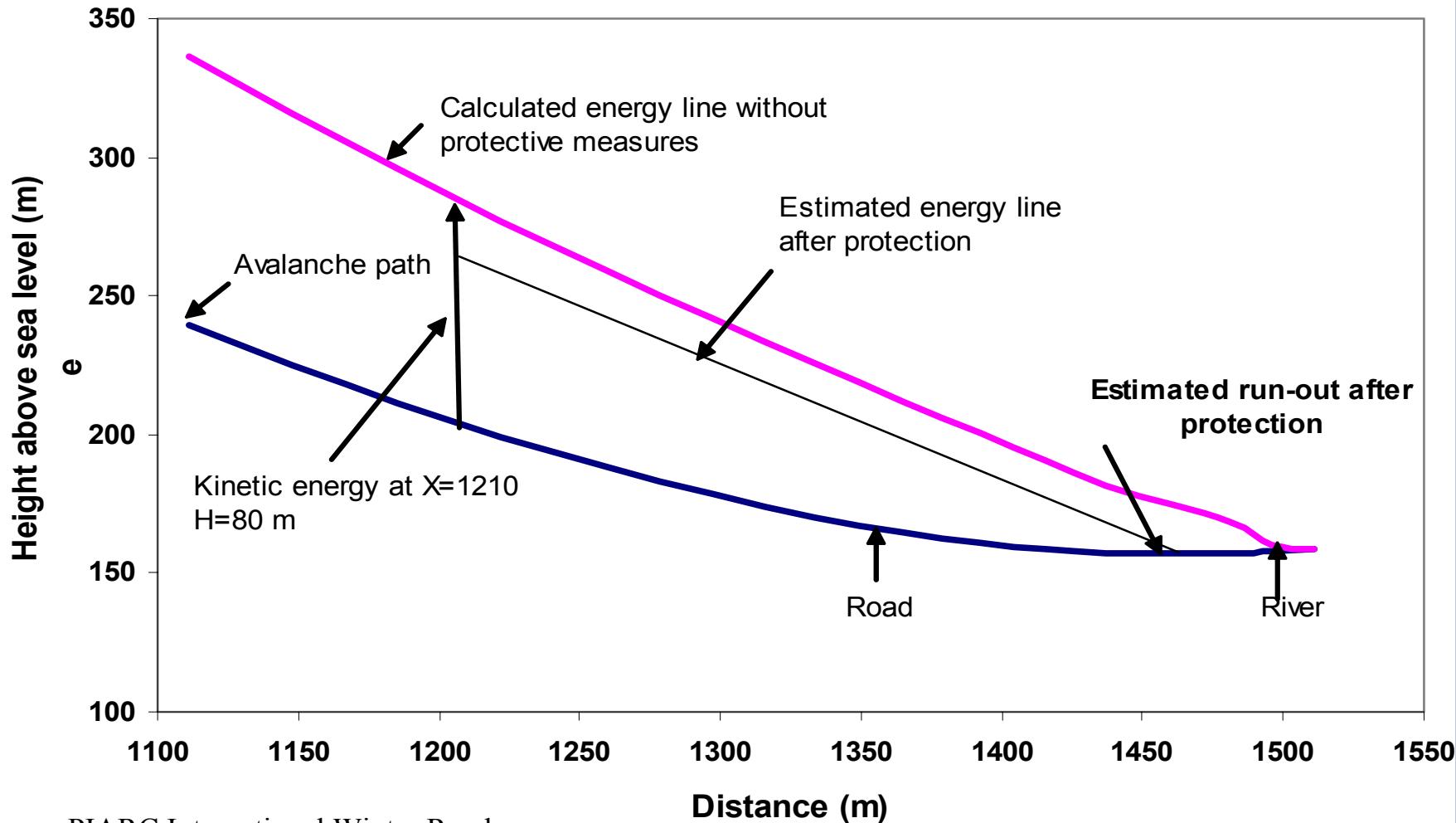
Comparing model and nature



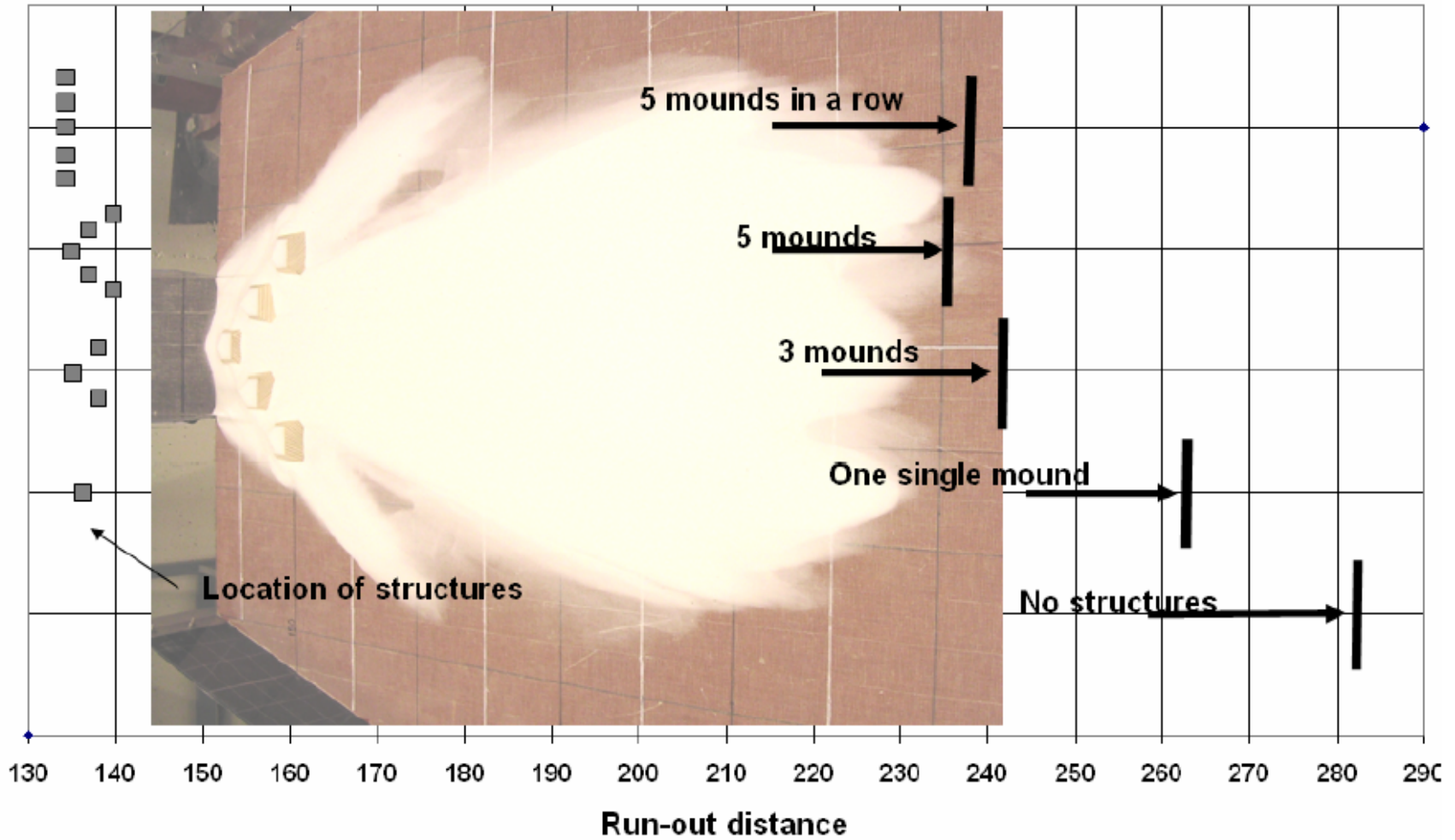
Energy lines for different dam heights



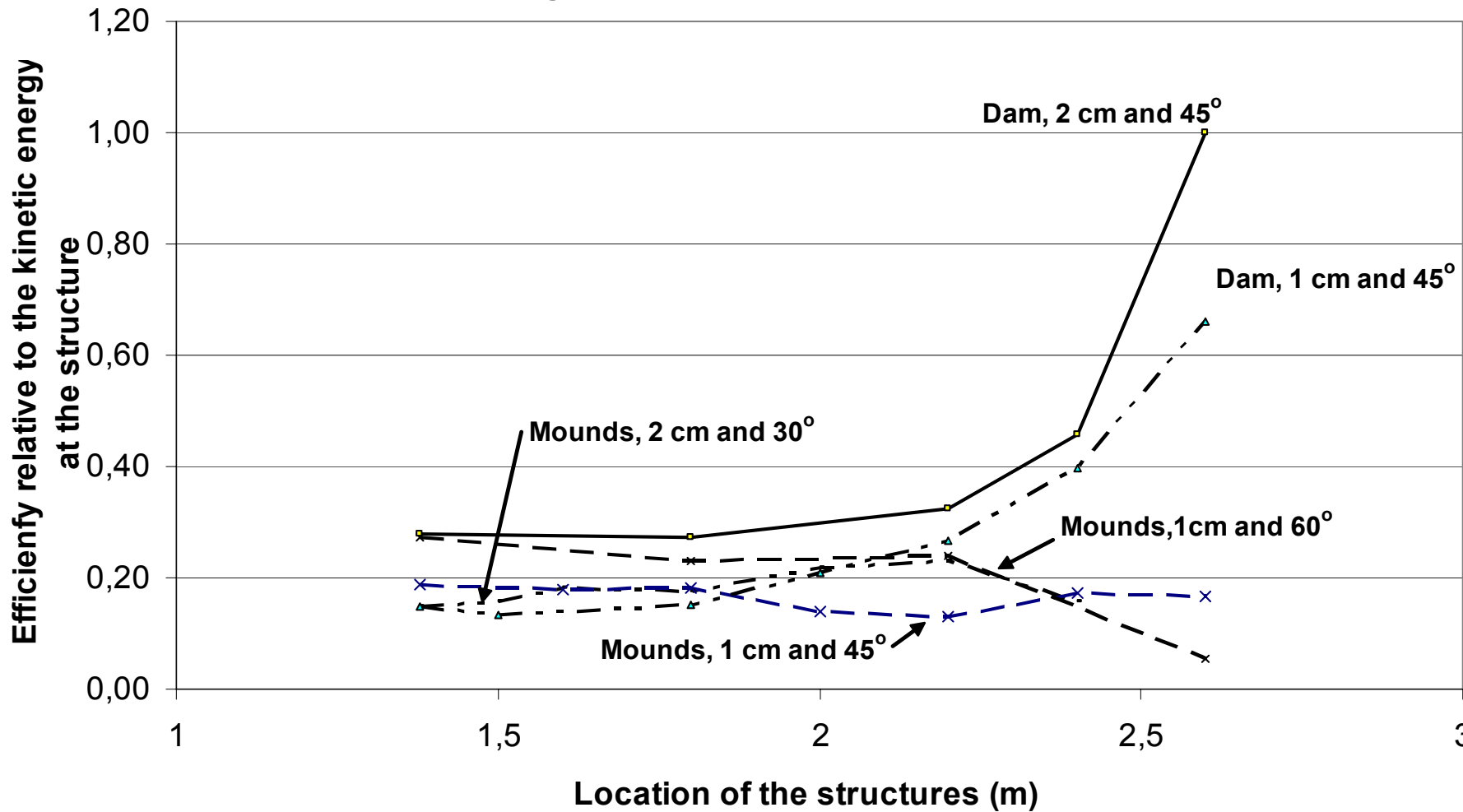
Singular energy loss due to mounds and dams



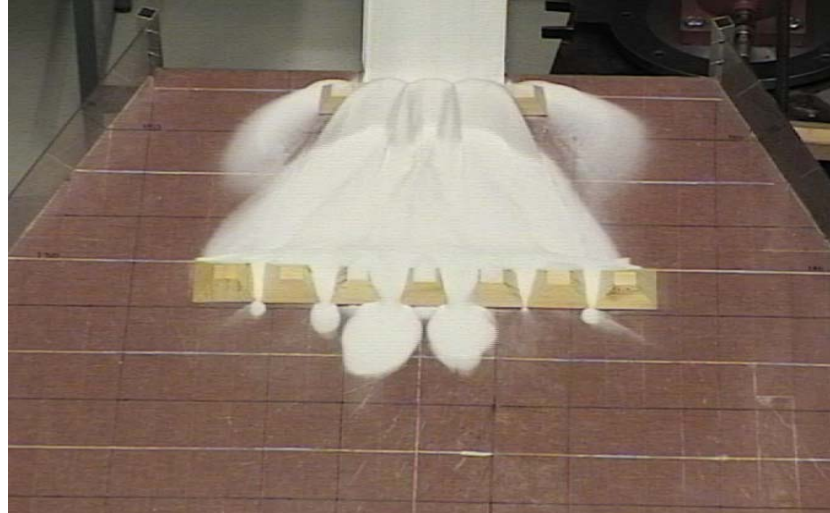
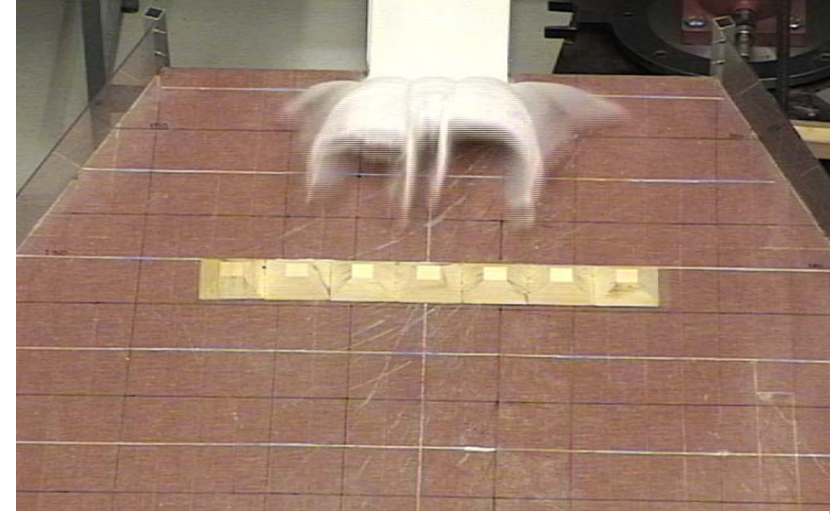
Run-out distances for mounds located in a plow shaped pattern



Energy dissipation of mounds and dams

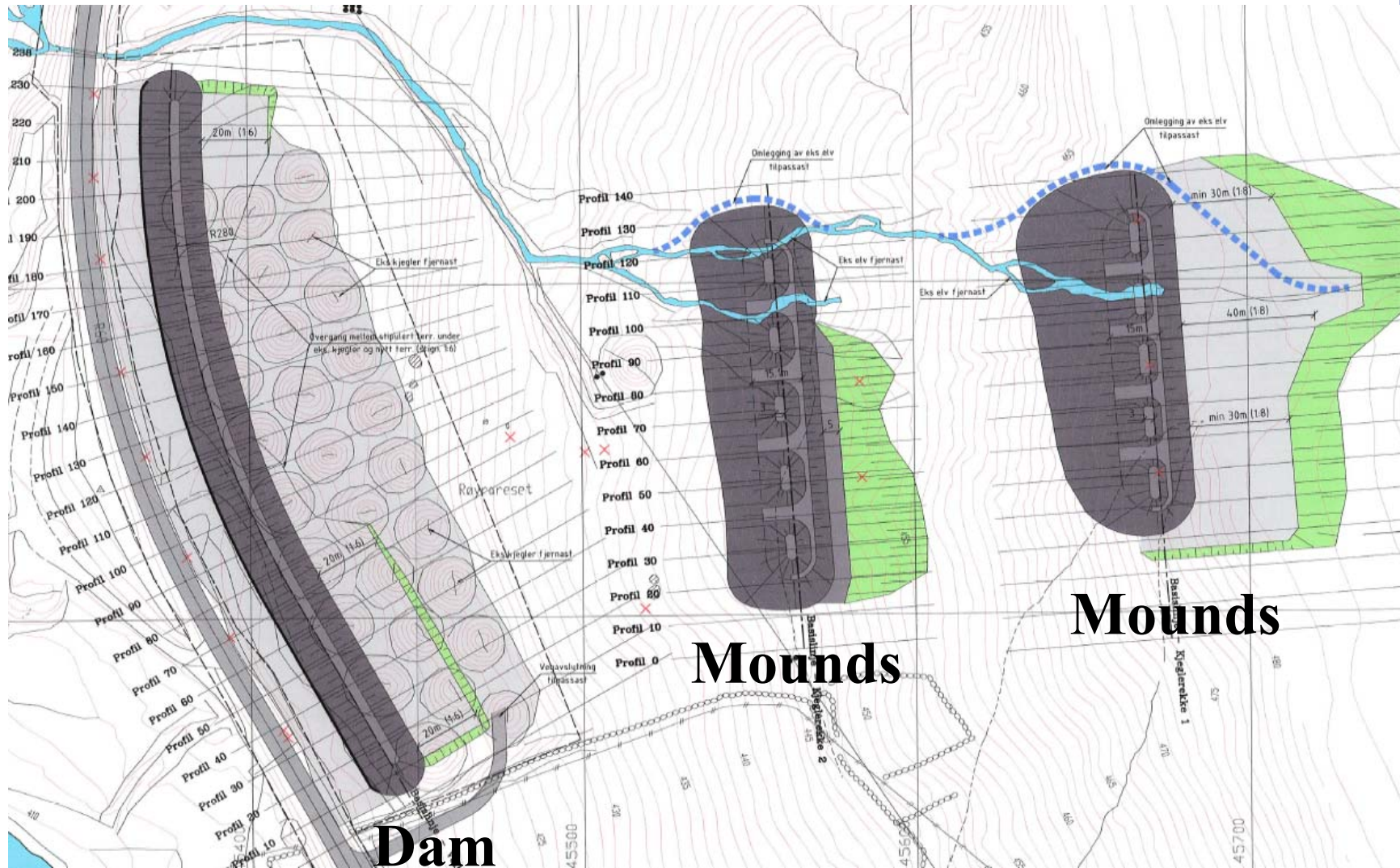


Energy dissipation of mounds

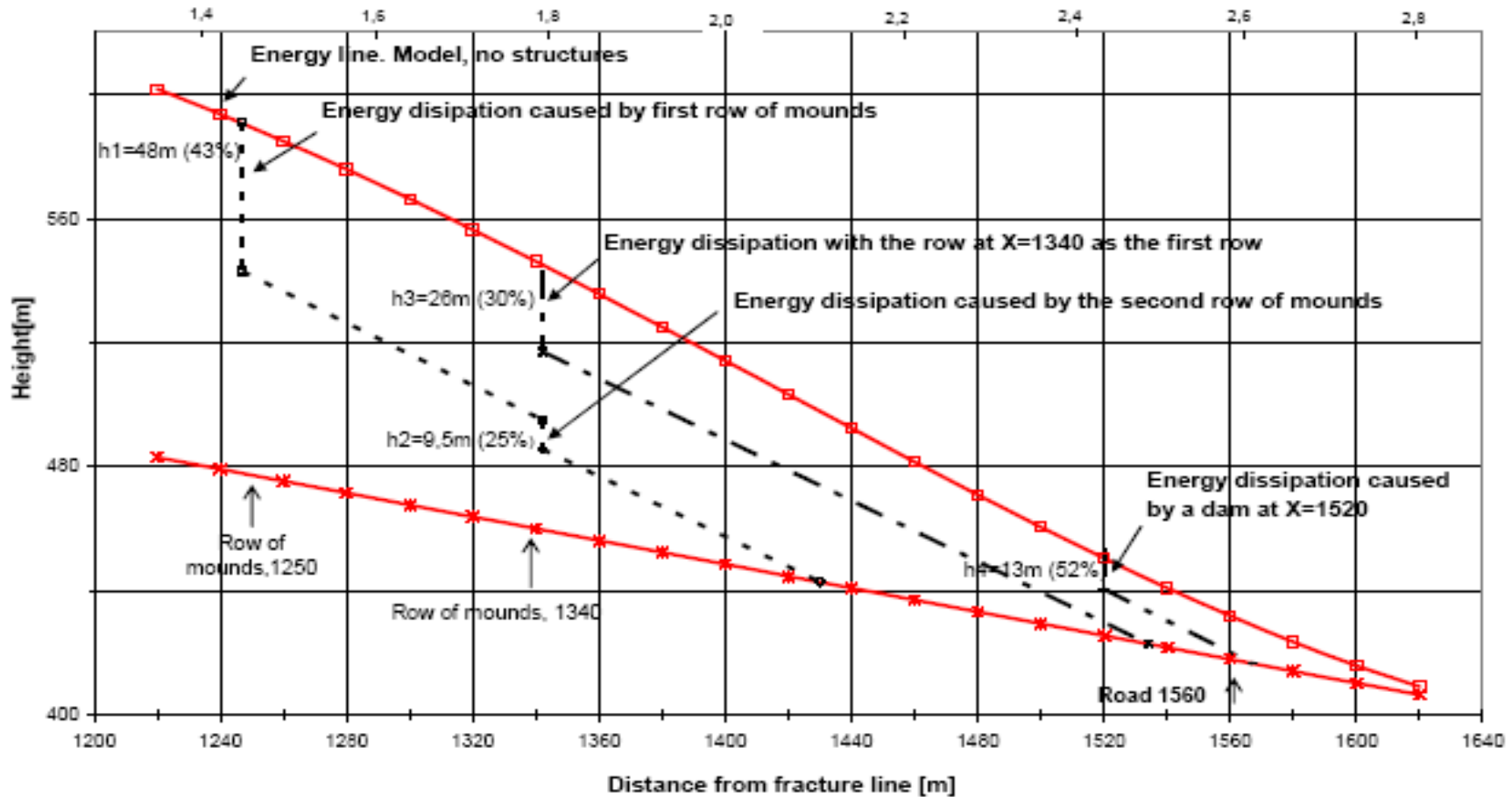


PIARC International Winter Road
Congress, Torino 2006

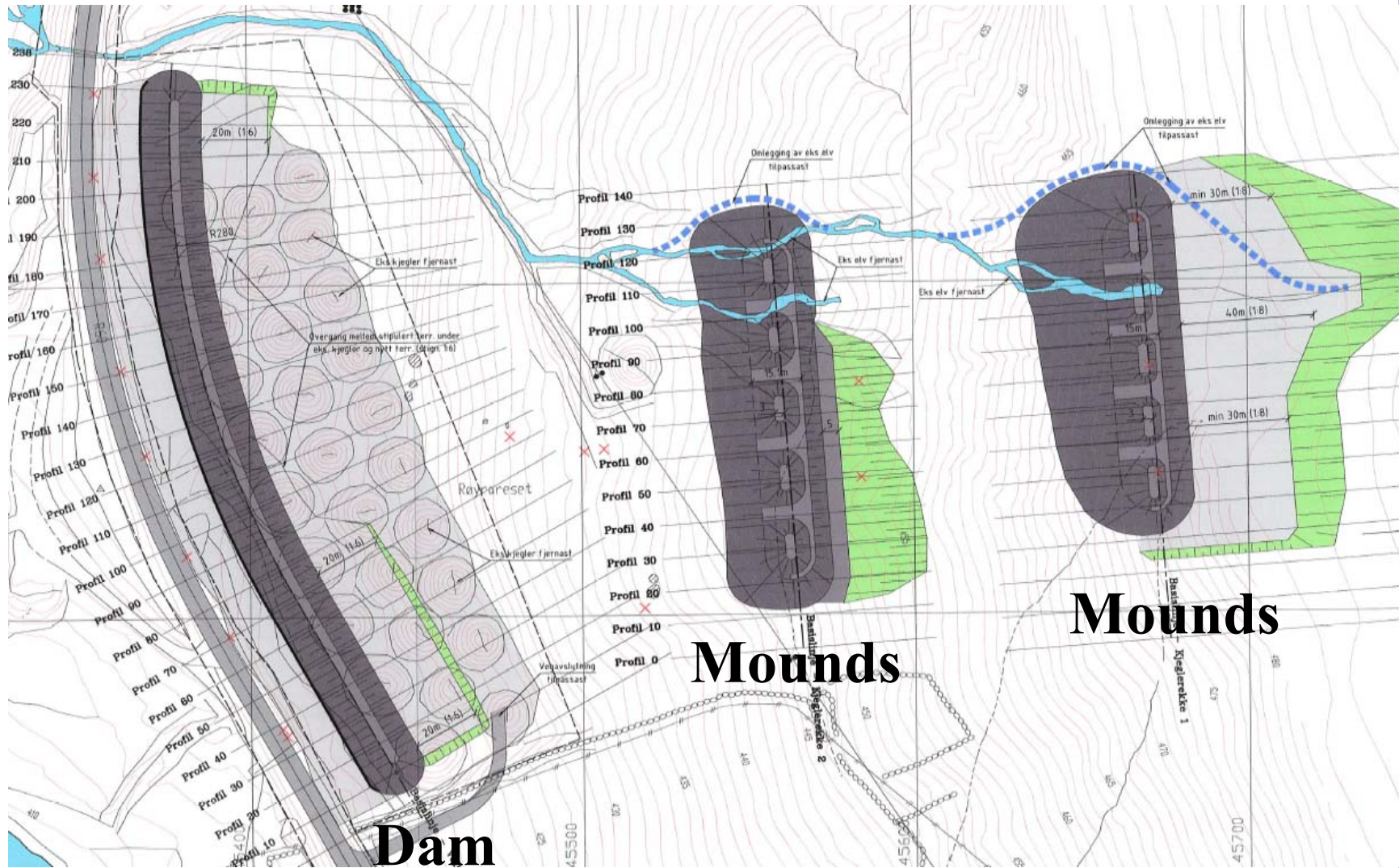
Recommended protective structures



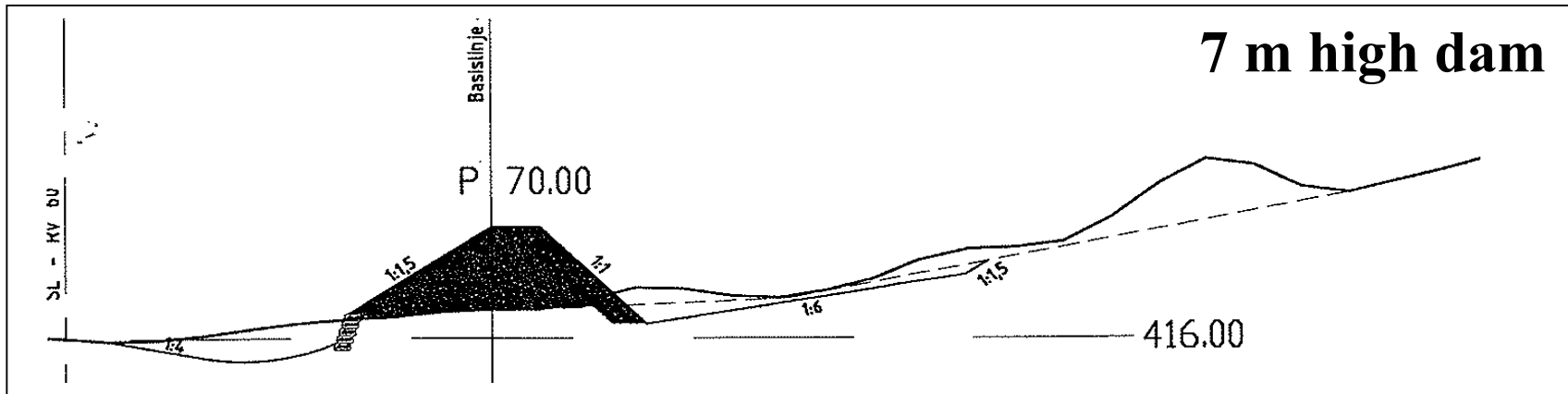
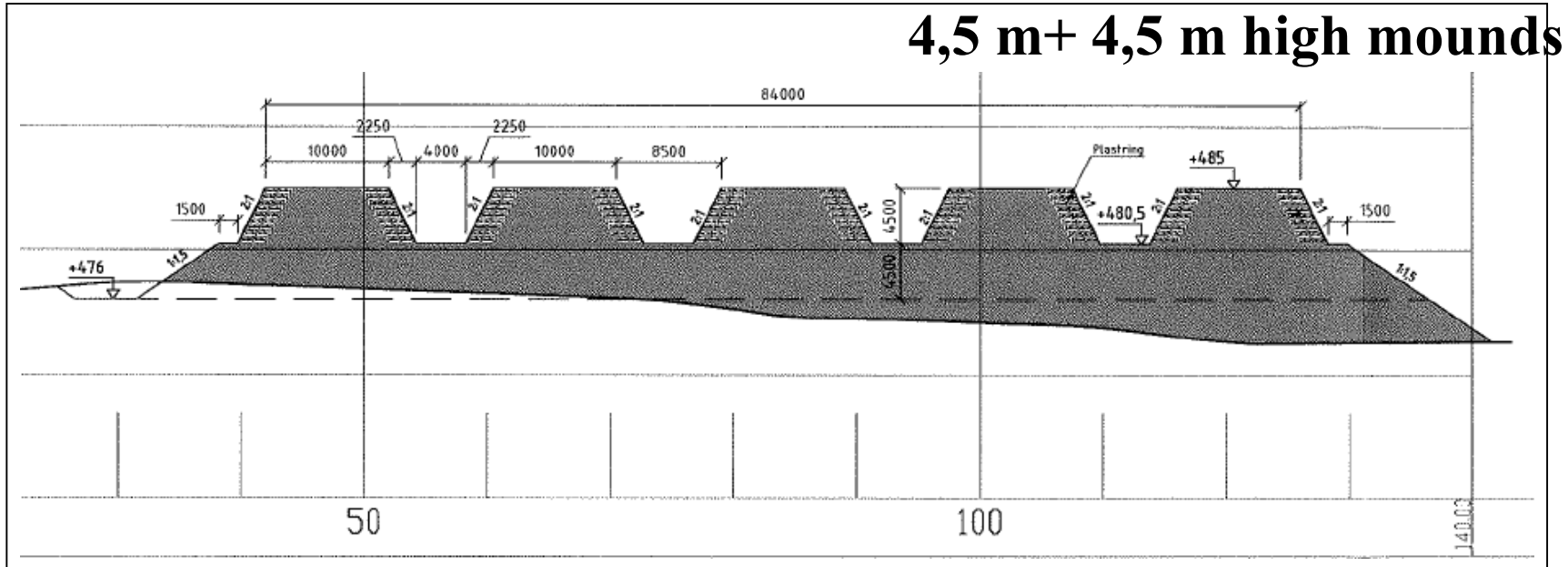
Estimated effect of constructing two rows of mounds and one dam close to the road



Recommended protective structures



Cross section profiles



Conclusions

- The maximum energy dissipation by use of mounds and dams is 30-40 % of the kinetic energy at the site of the first row
- Earth mounds should preferably be used high up in the run-out zone, and should be combined with dams close to the road
- Structures should have steep slopes in the front, especially in the upper part, where the kinetic energy is high
- The jumping distance may be calculated by simple theories for throwing. The second row should be located below the landing area of the masses
- Dams are recommended to be used close to the road where the kinetic energy is at the lowest and, to take benefit of the effect to reduce the impact of the powder part of the avalanche at the road level