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Field trip to the western part of Norway around Bergen in September 2007

This field trip was supported by the following companies:

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From the editor

In 1979 a close relation between experts in avalanche control of Austria and Norway started when Josef Hopf and Karstein Lied met at a conference in Colorado for the first time.

During the years several exchanges of experts have been made and knowledge on both sides grew rapidly.

During the field trip in 2007 a young generation of experts in the field of avalanche control from the Austrian Service for Torrent and Avalanche Control and from the BFW cultivated and intensified the friendship with their Norwegian colleagues.

Even if the difficulties on avalanches in both countries are nearly the same the methods applied vary widely based on frame conditions in both countries like density of population, frequency on endangered roads, etc.

This issue of Wildbach- und Lawinenverbau should help to carry out the different approaches in avalanche hazard mapping, on avalanche control measures and in the field of torrent and flood control.

A journey in pictures at the end of this issue will help to round off the picture of a scenic and competent technical trip in the western part of the fascinating country of Norway.

Thank you Karstein, Ulrik and Krister for guiding us during this week.

Josef Hopf

A friend's foreword

When two future friends, Karsten Lied from Norway and Josef Hopf from Austria, met for the first time at the IGS-Symposium 1979 in Colorado/USA they did not know that this was to be the beginning of an outstanding bilateral contact in the field of avalanches and other natural hazards.

Shortly afterwards representatives of the Norwegian Geotechnical Institut (NGI) and the Austrian Torrent and Avalanche Control Service (WLV) started contacts with mutual visits to both countries to exchange and improve knowledge and experience.

The application of the Norwegian Topographic Model for avalanche run-out distances was tested in a joint project in 1995. At that time the contact was extended from both sides to Iceland after two catastrophic avalanche events in that country. This allowed Nordic and alpine snow and avalanche conditions to be compared on a broad basis.

In the last decade, Austrians assisted in cooperation with local companies in the implementation of supporting structures in the starting zones of avalanches in northern Norway as part of projects by NGI, for example in Honnigsvag, Hammerfest, Öksfjord and Tromsö. Snow bridges made in Austria were used in these projects, sometimes galvanized and as such well adapted to the Nordic environment.

Joint activities were even extended to Svalbard (Spitzbergen), where an avalanche course was held for local people and students.

At research level, contacts were developed in the last decade between NGI and the Department for Natural Hazards in Innsbruck, especially concerning the full scale experiment site Ryggfonn in Western Norway.

The Norwegian National Hazard Commission – responsible for public financing of mitigation measures – visited Western Austria in September 2004, and was followed one year later by the Avalanche and Engineering Geology Division of NGI. This field trip (including a short workshop) had an unexpected character due to heavy floods in late summer 2005 in western Austria, the consequences of which became evident shortly afterwards in the Paznaun Valley in the Tyrol.

Undoubtedly this year's return visit by the Austrian delegation to Norway can be considered a highlight in the relationship between NGI and WLV, both dealing in the same scope of work:

NGI as a private foundation in a Scandinavian country, partly supported by the government, with a need to raise money at national level and worldwide.

WLV as a governmental institution in an alpine country, using public funds for all activities (expert opinions, advice and mitigation measures) at national level.

Considering the pros and cons of these two systems and probably as a result of long mutual contacts, ideas for future development may be suggested by a colleague closely connected to both institutions:

Public awareness of natural hazards and financing of mitigation measures could be extended in Norway.

In the long term, WLV should open up and extend its activities, based on experience over more than one century to international consulting and engineering, determined by the principle of "watershed management".

On the basis of these ideas, the contact between NGI und WLV could lead to a new level of cooperation for the benefit of both institutions in an increasingly globalised world with serious climate change.

Good luck!

Josef Hopf
Former Employee of WLV
Honorary Member of the Avalanche
Division of NGI

FLORIAN RUDOLF-MIKLAU

Avalanche protection in Norway: Organisational structure and tasks of NGI in comparison to the Austrian Avalanche Control Service

Lawinenschutz in Norwegen: Organisationsstruktur und Aufgaben von NGI im Vergleich zur Lawinenverbauung in Österreich

Summary:
NGI is a privately owned foundation offering research and consulting services in the field of natural hazards, and in particular avalanche protection in Norway. Its organisational structure and business fields are slightly different to the institutions in avalanche protection in Austria (WLV, BFW) but technical standards and protection strategies are quite similar. The paper gives an overview of the similarities and peculiarities of avalanche protection systems in Norway and Austria and is focused on the reasons for these specific situations in both countries.

Zusammenfassung:
NGI ist eine private Stiftung, die Forschungs- und Consulting-Leistungen im Bereich des Schutzes vor Naturgefahren, insbesondere im Lawinenschutz, in Norwegen anbietet. Ihre Organisationsstruktur und Geschäftsfelder sind teilweise unterschiedlich zu den Institutionen des Lawinenschutzes in Österreich (WLV, BFW), allerdings sind die technischen Standards und Schutzkonzepte vergleichbar. Der Beitrag gibt einen Überblick über die Ähnlichkeiten und Eigenheiten der Lawinenschutzsysteme in Norwegen und Österreich und beleuchtet die Gründe für die spezifische Situation in den beiden Ländern.

Avalanche protection in Norway and Austria: Natural, social and political boundary conditions

Norway ranks among the European countries most affected by avalanche risk. The Alpine areas in the western and northern part of the country in particular and the Fjordland region are subject to heavy snowfall in winter. The narrow valleys formed by the glaciers during the ice age are bordered by steep slopes with differences in altitude of more than 1000m in places. These framework conditions lead to a high risk of avalanches from November to April. Avalanches and so-called „slush-flows“[1] mainly endanger traffic routes (roads, rail-roads) and farm houses while only a few settlements are regularly subject to avalanche activity. The reason for this situation is simply that Norwegian mountain areas are sparsely populated as settlements are concentrated along the coast line. On the other hand the mountains appear to be a major obstacle for traffic leaving only few passes during winter. The economy (e.g. fish industry) along the coast line between Stavanger and Ålesund is dependant on open roads to Oslo all year round. Consequently, although traffic is low in general, the responsibility for road administration in terms of avalanche protection is important. The same holds true for the only railway line between Oslo and Bergen.

In Norway each local council is responsible for protecting property in its area from avalanches, while the Public Road Administration and the Railway Administration are responsible for protecting traffic on roads and railways, respectively. Other organisations with avalanche-related tasks are for instance the Norwegian Water Resources and Energy Administration or the Geological Survey of Norway. Hence the competence of avalanche protection is shared by several stakeholders and information on avalanche events is acquired in a number of forms and kept in different archives. A total of seven Ministries and their subordinate agencies deal with avalanches and

[1] *Wet-snow avalanches that occur on extremely steep slopes develop from a snow cover saturated with water and show a process dynamic similar to mud flows.*

INFO BOX NORWAY	
Size:	364,000 km2
Population:	4.2 mill.
Highest altitude	Galdhopiggen 2649ma.s.l.
Precipitation:	2500 mm west coast 750 mm continental
Temperature:	
Frequent above freezing in winter season along coast	
Long periods of cold and stable conditions	
Wind:	
Strong wind with precipitation from SW-NW along coast , SE-NE inland	

Fig. 1: Map showing an overview of Norway

avalanche protection in Norway. Such a spread of responsibility has resulted in rather poor overall co-ordination in the past. In 2001, to improve the availability of information on avalanche risk, the Ministry of Industry and Trade and the Ministry of Environment gave the Geological Survey of Norway the task of setting up a national avalanche database, mainly to be used in municipal planning and hazard evaluation. This database contains important information on the avalanche pathways affecting roads and railways, major avalanche disasters and maps showing the risks of avalanches.[2] The Norwegian Geotechnical Institute (NGI) contributes to this database by drafting avalanche risk maps.

The main target group of the database, particularly the risk maps, are municipal and regional planners. Each local authority is responsible for ensuring that its inhabitants are safe from avalanches and that expert evaluations are delivered in connection with the granting of building permits. The national avalanche database also provides useful information for consultancy companies which give technical advice on avalanches and undertake investigation in connection with developing projects. The need for information on avalanche risk on the part of insurance companies is primarily related to the desire to reduce the scale of damage in future disasters. One major goal of the database is also to raise public awareness of avalanche risks in endangered areas.

In spite of the public availability of avalanche risk maps and data, the protection system in Norway is predominantly based on the responsibility of the authority or agency in its specific field of competence. As far as we know there are no legal regulations in Norway that force municipal planning authorities to implement avalanche risk maps or to carry out specific measures for avalanche protection. Avalanche protection in general seems to be a matter of voluntariness so that the decisions on protection-need are taken according to the individual responsibility and liability. As a result of the low settlement density and less frequent avalanche disasters with human losses in comparison to Alpine countries, public pressure for counter-measures seems to be low. Most of the protection works are carried out along traffic routes financed by the relevant authority. Public funds for technical protection measures to protect settlement areas are essentially available but few projects are carried out. This is probably due to the fact that there is reluctance on the part of the municipalities or private land owners to undertake major investments in such measures.

A specific feature of the Norwegian situation is also the rather short history of avalanche protection as the economic development of the country only started with the oil boom in the late 60ies. Prior to this, Norway was a rather poor and underdeveloped country with little or no public funds for investment in protection measures. Nevertheless today Norway ranks among the wealthiest countries in the world and can afford a high level of protection and has an extraordinary standard of safety when it comes to natural hazards.

In terms of standards of safety, Norway can in fact be compared to Austria where avalanche protection is also highly developed. The major difference between the two countries lies in public awareness of avalanche risk and the long tradition of this issue in Austria. Alpine areas have been densely populated for ages and avalanche disasters with high human losses have always played a major role in social life. The adaptation of the people to snow hazards in the Austrian mountains was always particularly developed. Land use and settlement were carried out with a focus on avalanche risk. Nevertheless a lot of people have lost their lives in the Alps as a result of avalanche disasters and the opening up of Alpine regions to traffic and tourism was always a fight against the „white death“. Public safety in the Alpine regions depends so much on avalanche protection (as well as torrent protection) that this was laid down as a major task of the federation in the Austrian constitution in 1910. Special legal regulations are included in several Federal and Provincial Acts making avalanche protection an obligatory matter. In particular the regulation of hazard maps in the Austrian Forest Act as an expert opinion authorized by the minister is unique in the world and supports the significance and public acceptance of this planning instrument. Although in Austria hazard maps, which have to be provided nation-wide are not legally binding as such, they have a major influence on land use planning and the building trade. The power of a „red zone“ is comparable to a building ban and municipal authorities are obliged to take these outlines into account in development planning. In connection with a well developed funding system for avalanche protection works based on the Federal Water Construction Assistance Act, the hazard map is a well implemented tool for guiding avalanche protection in Austria. The efficiency of this system is supported by the fact that all these instruments lie in the competence of a single organisation, the Austrian Service for Torrent and Avalanche Control (WLV), which was founded back in 1884 and is a subordinate agency of the Federal Ministry of Agriculture, Forestry, Environment and Water Management.

Widespread competences in avalanche protection also exist in Austria due to the federal structure of the state. Avalanche warning is a competence of the Provinces and the avalanche commissions are a task of the communities in their own domain. Of course the protection of railway is the responsibility of the Federal Railway Company and the roads have to be secured by the service company in charge. The responsibility for protecting people and property from avalanche hazards is, as in Norway, the responsibility of the municipality or the people themselves but the Federal funding system and the work of the WLV supports protection concepts that include all institutions seeking protection in the domain of an avalanche. The efficiency of the Austrian system promotes joint projects and makes public funds accessible to all beneficiaries including public traffic and infrastructure agencies or private companies.

During the last decades Austria has developed a close-knit network of avalanche protection works in the Alpine valleys. These constructions are well maintained and regularly inspected. Additionally, great efforts were made to improve the protection function of forest-stands on steep slopes. Today avalanche protection is one of the most important foundations of economic growth in Alpine regions with the result that public awareness of avalanche risk is high and the acceptance of restrictions is generally well developed.

Due to the high pressure in land use and the limited availability of areas not subject to avalanche risk, conflicts in relation to such limitations are on the rise. But due to the predominant public interest the state has always supported extensive protection and compensated damages in private property due to avalanche disasters by means of the Federal Disaster Relief Fund. Recently the limits of public support by the state seem to have been reached as the need for more own precautions by the individual is strongly pronounced in the political discussion. In the near future a system of obligatory natural hazard insurances will be introduced in Austria to take pressure from public funds in case of a disaster. Although the boundary conditions for avalanche protection in Norway and Austria are quite different in parts,

[2] Clay slides, earth and rock avalanches are also enclosed in the data base.

the problems and protection strategies are comparable. Maybe in Norway due to the state of the area development and low intensity of land use a lot of challenges will only occur in the future, which already had to be faced in Austria. Maybe Austria can serve as an example for Norway in terms of which strategies are successful and which mistakes have to be avoided. On the other hand Norway has still the chance to improve strategies that failed to be successful in Austria.

Organisational structure and tasks of NGI

The Norwegian Geotechnical Institute (NGI) is a private foundation involved in research and consulting in the geo-sciences. NGI's core competence is related to material (soil, rock and snow) properties and behaviour, modelling and analysis, and instrumentation and monitoring. The services are within geotechnics, engineering geology, hydrogeology and environ-mental geotechnology. NGI's strength lies in the expertise of its personnel working in collaboration with clients and partners. NGI is a centre for the assessment of geo-related risk due to natural disasters, especially those associated with landslides, avalanches and earthquakes. NGI is called upon by local authorities in Norway and from abroad to assist in decision-making with respect to risk to life and damage to property.

In 1950, the Research Council of Norway started a „Geotechnical Office" in Oslo, NGI's predecessor. The Norwegian Geotechnical Institute was officially established on the 1st of January 1953. Today, The Research Council of Norway contributes about 10% of NGI's turnover to project-related research. From the start, NGI's goal was to promote geotechnical research and the implementation of research results in practice. When the oil industry started in Norway around 1970, NGI soon became an important contributor to the development of offshore geotechnical engineering. In 1985, NGI was privatised. Research remained at the centre of NGI's activities. NGI currently employs a staff of 145, 110 of whom are university graduates. In 2001 the turnover was NOK 140 million. Today's technological challenges include offshore innovations, environmental protection and risk assessment associated with natural hazards.

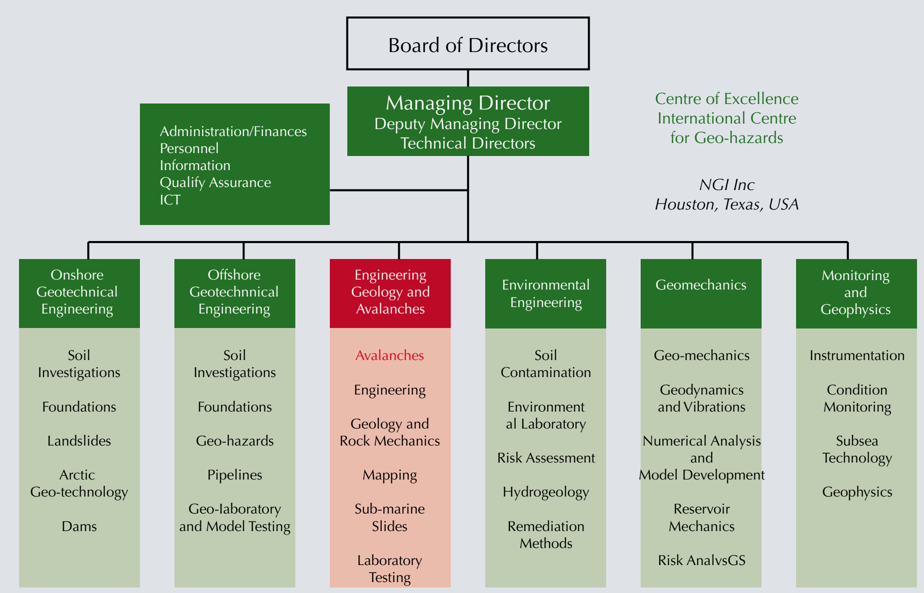

Fig. 2: Organisational structure and business fields of NGI

The most important geotechnical natural hazards in Norway are:

- Snow avalanches and slush flows
- Rock falls/slides
  Debris slides/flows
  Submarine slides
- Tsunamis generated by slides

NGI works on all of these hazards. The most frequent natural disasters in Norway are associated with snow avalanches. During some winters, several hundred people need to be evacuated from their homes. Statistically, seven people die each year in Norway as a result of avalanches.

A major field of activity is traditionally the avalanche section. NGI is the only research and consulting organization in Norway dealing with snow avalanches. In this field about 10 people work on about 100 projects per year. Typical activities of the NGI avalanche group are:

- Hazard evaluation, planning of safety measures
  Avalanche hazard forecasting
  Avalanche hazard mapping
- Research and development

The following organisations are regular clients of NGI: Public and local authorities Norwegian Research Council

- Road and railroad authorities
- Private construction companies Industry Private

Differences and similarities between NGI and WLV (BFW)

Avalanche control in Austria is traditionally a task of the Federal state. Avalanche engineering and research always used to be separate tasks of the Austrian Service for Torrent and Avalanche (WLV) and the Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)[3].

[3] *Historically: FBVA*

In addition research and academic teaching are performed by an own chair and institute at the University of Natural Resources and Applied Life Sciences in Vienna. All of these institutions were more or less subordinate services of the state. The reason for this situation in Austria is the high level of public interest in natural hazard protection in connection with the demand from the people that the state has to provide protection and safety. This attitude lies in the tradition of an administration derived from the ancient monarchy and is only changing very slowly.

Compared to this situation in Austria, a public engineering service for avalanche control is totally missing in Norway. Consulting, planning and project management are in general carried out by private companies in the field of avalanche protection.[4] Also NGI is a privately owned (foundation) but has well-established customer services to municipal planners and public traffic authorities. In a way NGI holds virtually a monopoly as an avalanche expert and research centre but has to face the challenge of business success.

The services in Austria (WLV, BFW) are at present not so much exposed to private competition but due to the growing importance of natural hazard protection a market is developing giving also free space for private companies in engineering, consulting and even research (e.g. AlpS - Center for Natural Hazard Management LTD.) There is no longer a monopoly on avalanche competence in Austria, as many scientific branches contribute to this important topic.

A monopoly still exists in Austria concerning the drafting of avalanche hazard maps which, due to the Forest Act, is a privilege of the Austrian Service for Torrent and Avalanche Control. Hazard maps for avalanches comparable to the Austrian kind have not existed in Norway to

[4] *The situation is different in the field of flood protection where Norwegian Water Resources and Energy Directorate have an organisation similar to Austrian Flood Protection Authorities.*

date while large scale risk maps (1:50.000) are drafted by the NGI. The institute also has a monopoly in this task.

Additionally in Austria, the WLV can offer all the functions of avalanche engineering including hazard mapping, consulting, advice, planning, building (realization of projects) and financing. The major customers are communities, water cooperatives and sometimes other beneficiaries. Although the annual investments for avalanche protection works are on average € 15 million in Austria, no market exists for private building companies as most of the works are carried out by the building operation of the WLV. At least building and financing of projects are not included among the tasks of NGI.

Business Field	NGI	WLV	BFW
Hazard (Risk) Mapping	×	☑	×
Consulting	☑	☑	☑
Advice	×	☑	×
Planning (Engineering)	☑	☑	×
Building (Protection works)	×	☑	×
Financing	×	☑	×
Avalanche modelling	☑	☑	☑
Research	☑	×	☑

Tab. 1: Comparison of the major business fields of NGI (Norway), WLV and BFW (Austria).

Avalanche modelling and simulation, an important instrument of avalanche consulting, is one of the major tasks of NGI. Numerical models were developed since the 80ies of the last century and always in close relation to other research activities. In Austria the development of avalanche simulation models was always related to the demands of the engineering branch. Today software licences of highly developed models are the property of the Federal Ministry for Agriculture, Forestry, Environment and Water Management and the WLV runs a special staff office that carries out avalanche modelling and simulation works for the whole service. The BFW is involved in the development of the models at a scientific level.

As the state provides most of the services of avalanche protection in Austria, the benefits of the WLV activities are mostly free of charge for the beneficiaries (customers). They only have to contribute to the protection measures but also in this field they get most of the budget from public funds (subsidies). This situation makes avalanche protection affordable for most people seeking protection and provides easy access to public information (hazard maps, historical event data base, avalanche warning).

In Norway the private structure of avalanche protection and research entails relatively high costs for people or institutions seeking protection or asking for advice. For this reason the financial inhibition threshold for private persons might be too high to take the decision for extensive investments into avalanche protection but on the other hand the services of NGI and other institutions are offered at a realistic value. Customers might thoroughly check the economic consequences of investments in endangered areas and not simply rely so much on the state as is the case in Austria.

A major difference finally lies in the fact that natural hazards are only one of the business fields of NGI which is very much involved in oil engineering. On the contrary in Austria the WLV specializes in natural hazard protection and only as such is its existence justified by a „complete solution" for natural hazard protection with the appropriate high efficiency. On the other hand the avalanche research of BFW is part of the field of forest research in Austria which is related to the importance of forests for avalanche processes in the country.

Notwithstanding which system - private or public operated services - succeeds in the future, avalanche protection will always remain a very specific field reserved to a small group of experts throughout the world. This is the reason why international cooperation and transfer of knowledge is the most important challenge for the future no matter what organisational structure or ownership exists. The long and fruitful cooperation of WLV, BFW and NGI serves as a model for this task.

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SIEGFRIED SAUERMOSER, THOMAS HUBER, MARTIN JENNI, ULRIK DOMAAS

Hazard mapping in Norway and Austria – A comparison

1. INTRODUCTION

Hazard mapping is an important tool in the prevention of gravity natural hazards in both Norway and Austria.
During our study trip we were able to study some detail hazard maps and some overview maps and discuss different legal and technical approaches to delineating hazard zones with our Norwegian colleagues.
In our paper we give a short description of both systems and try to compare the different approaches with particular emphasis on snow avalanches.
Finally we try to analyse the pros and cons of both systems as far as possible

2. Hazard Mapping In Norway

2.1 Legal Basic

The Building and Planning Act in Norway has been under development since 1924 and the act came into effect for the whole country in 1966. The last review was carried out in 1997.
The building council of the municipalities has to follow the rules set out in the Act and advice in relation to hazard zones and protective measures is given by NGI (as consultant) in each case. In cases where the avalanche-endangered houses date before 1966, the National Fund for Natural Disaster Prevention can give economic support to allow rebuilding with protective measures or towards moving the houses.
The estimation of natural hazards is associated with the Norwegian Planning and Building Act. According to the Technical regulations in the law, three Security classes of avalanche and slide frequencies are usually considered.

Security class	Maximum nominal avalanche annual probability	Avalanche return period (years)	Type of construction
1	10^{-2}	100	Garages, smaller storage rooms of one floor, boat houses
2	10^{-3}	1000	Dwelling houses up to two floors, operational buildings in agriculture
3	$<10^{-3}$	>1000	Hospital, schools, public halls etc.

Tab. 1: Nominal avalanche annual probability with corresponding return periods related to security classes and types of constructions.

In addition, the Building regulation states that rebuilding after fires or other kinds of repairs may be done for class two, where the nominal annual frequency is less than 3x10-3, i.e. return period of 333 years.
The use of the word «nominal», as opposed to «real», demonstrates that exact calculation of avalanche run-out distance for the given frequencies is not possible, and the use of one's subjective judgement is therefore necessary.

Fig. 1: Avalanche hazard situation in Östra.

2.2 Hazard Map Content

Based on map contents and methods used in data collection and data processing, NGI found it appropriate to distinguish between three types of hazard maps:

Hazard registration maps:

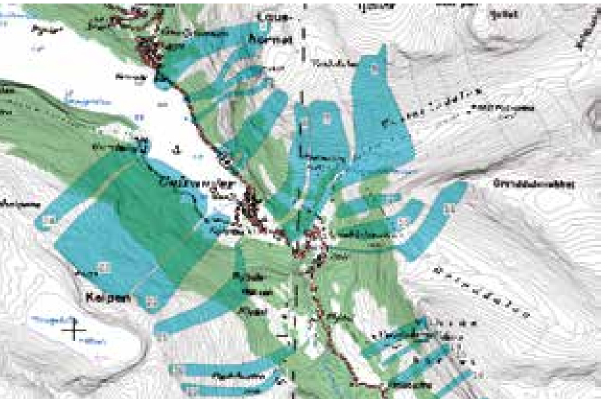

Fig. 2: Map showing historic avalanches close to the Geiranger village.

These are maps containing historically known slides and avalanches, compiled from literature, historical documents, interviews and field work.

Geomorphic hazard maps:

These are maps containing information on hazard-prone areas identified by geomorphologic investigations in the field, and by the use of topographic maps and aerial photos.

Hazard zoning maps:

These are maps that define hazardous areas compiled on the basis of known historic events, geomorphologic investigations and the use of frequency/ run-out calculation models. The hazard zones should correspond to the safety requirements in the national building regulations.

Fig. 3: Avalanche hazard map with historic events estimated return periods corresponding to the Norwegian legislation for Geiranger village. The red line marks the security class one, the blue line, security class two and the green line, security class three.

2.3 Hazard Zones

The three security classes defined can also be described as three different hazard zones. The difference between the three classes is made only by the return period. There are no further differentiation criteria such as avalanche pressure or others.

2.4 Hazard Zoning Procedure

a) Survey Maps

Ongoing hazard mapping on survey maps has been operative since 1979 and to date approximately 110 maps have been finished. It is still necessary to prepare 100 maps and it will take NGI another 15 years to accomplish this work.

So far these maps have no legal liability, but will be used as a support for the municipalities in land use planning. The work is carried out jointly with the client the Statens Kartverk (The Norwegian Mapping Authorities).

The maps used are standard topographic maps of a scale of 1:50.000, with a contour line interval of 20 m. Since 1982 the 1:50.000 maps have been available in digital format in Norway, and since then the hazard zoning process has been computerized.

Survey maps are meant to give general information on hazards. The production covers a fairly large area in a short time at low costs. It is estimated that each map sheet covering an area of approximately 600 km², should be evaluated in 4 weeks.

At present, this method of hazard zoning is performed by a commercial GIS system (PS GIS), and by the commercial digital terrain modelling system SURFER, for the computation of avalanche runout, storage of avalanche data in a relation database and for the graphical presentation of hazard zones.

As a first step, all potential hazard zones are identified regardless of the frequency of avalanches and rock falls. The hazard zones are divided into two areas:

- Starting zones
- Runout zones

The starting zones include all areas on the map, which are steeper than 30°. For snow avalanches, areas covered with dense forest are not considered.

The identification of the starting zones is done automatically by the computer using vector information. On a map sheet with a surface area of 600 km², this process is completed within a few hours.

Using the terrain profile in each slide and avalanche path identifies the run-out zones. Each profile is drawn as a line on the computer screen, from the top of the starting zone, along the path to the valley floor. Based on the information from this terrain profile, the run-out distance is calculated by the computer in a few seconds by the topographical/statistical model for snow avalanches and rock falls according to the empirical model developed by DOMAAS (1994).

After completion of the hazard map on the computer, the map is checked and corrected by inspection in the field.

Zoning of debris flow hazard has been tried out following the procedures used for snow avalanches and rock falls. For the time being, NGI´s experience is that debris flow hazard is too complicated to be solved in a survey hazard zoning procedure, as the investigation of this type of hazard needs more basic field work than potential snow avalanche- and rock fall areas. Hazard zoning of debris slides is therefore carried out by detailed zoning procedures only.

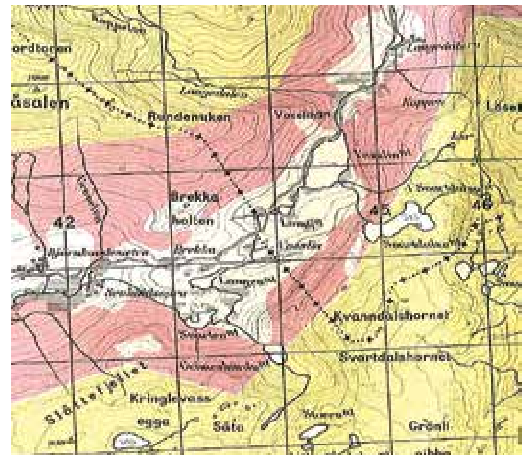

Fig. 4: Survey map scale 1:50 000; the red area indicates potential hazardous areas..

b) Detailed Maps

These maps should have a high degree of accuracy and therefore demand comprehensive field - and computational work and they are time-consuming to produce. In Norway such maps are based on the Norwegian economic map series at a scale of 1:5000, with a 5 m contour line interval, or for certain areas at a scale of 1:1000, with a 1 m contour line interval. In this zoning process, each avalanche path is examined in detail; both, rupture area, track and run-out zone are evaluated carefully, first of all to identify the magnitude, frequency, and runout distance of slides and avalanches.

Detailed hazard mapping starts on the order of the municipality. The municipality gives the order to delimitate hazard zones for a certain area that is under topical interest or for all of the housing areas. Because the municipality has to pay for this map, the area that has to be mapped in detail is mostly chosen small.

Three different sources of information are used to complete a detailed hazard map:

- historic records of avalanches
- geomorphic analysis of the avalanche path
- computational models for run-out calculation

All information of known avalanches and slides, their run-out distance, damage, weather conditions connected to the release etc., are collected. Both oral information and written records are used.

Geomorphologic evidence of avalanche frequency and runout is studied in the field. First of all how vegetation is influenced by avalanche activity, and how loose deposits are eroded, transported and accumulated in the avalanche track.
Bedrock type and quality is investigated, along with the distribution and type of loose deposits.
Debris flow hazard is identified mainly in terrain formations at, and nearby river fans. Soil profiles from test pits are also used to identify and date the type and frequency of slides.
Runout models for avalanches and slides are an important tool when it comes to establishing the hazard zones. Each avalanche and slide path is modelled in detail by using digital maps and terrain models. The runout models are used to calculate the hazard zones corresponding to the national safety requirements for natural hazards.
Calculation of the runout distance of debris flows has to date been done manually. A new Graphical User Interface has been developed at NGI to support practical work. It is an assembly for practical use of avalanche computational models based on more than 20 years of research.
It contains

- Statistical and dynamic computational models for consulting work (a/b-, PCM-, PLK-, NIS1- & NIS2-, comparative- and deflecting dam models)
- Use of terrain profiles from digital maps (GIS)
- Model descriptions
- Database on extreme avalanches
- Link to Norwegian legislation internet pages.

3. Hazard Mapping In Austria

3.1 Legal Basis

Hazard zoning was started in Austria around 1970 by the Austrian Forest Technical Service for Torrent and Avalanche Control and after a few years of practical experience regulated officially in the new Forest Law 1975. The details concerning Hazard Zone Plans were settled in a decree by the Federal Minister of Agriculture and Forestry in 1976.
Beyond these federal regulations, executive rules concerning hazard zones are held in provincial laws for land use planning. These laws generally state that areas at risk from natural hazards like floods, avalanches, debris flows, rock falls or landslides cannot be defined as development areas. The hazard zone maps have to be observed by local authorities (municipalities and rural communities) in the relevant decisions.
In addition, the Ministry of Agriculture and Forestry has decided that failure to follow the Hazard Zone Maps shall lead to public funds for flood and avalanche control works not being available or where relevant money already used having to be reimbursed.

3.2 Hazard Map Content

Under the 1976 decree, the Hazard Zone Plans for avalanches and torrents have to be prepared by the Federal Forest Technical Service for Torrent and Avalanches Control and are available free of charge to the communities.
A Hazard Zone Plan is worked out normally for an area of one community and consists of a cartographic and a textual part.

The cartographic part includes

a) Hazard maps

(scale 1:10.000 – 1:50.000) with all relevant catchments and an overview of the whole community area.

b) Hazard Zone Maps (scale 1:1000 –

Fig. 5: Section of a Hazard map.

1:500 at least), showing the results of investigated and evaluated data for each hazard in the form of "Hazard Zones" on the basis of a return period of approximately 150 years for torrential floods and avalanches and 100 years for floods of rivers. The map shall include the land register.

The textual part consists of description of the

a) Basic data
b) Arguments of valuation and
c) Arguments for the hazard zoning.

3.3 Hazard Zones

The Red Hazard Zone
Includes areas at risk from torrential floods or avalanches to such an extent that their permanent use for settlements, infrastructures or traffic facilities is not possible. The Red Hazard Zones also include less, but frequently endangered areas. The criterion for the delimitation of a Red Avalanche Hazard Zone is a pressure criterion. When an avalanche pressure of over 10 kN/m² is to be expected from an avalanche with a return period of approx. 150 years and less, the criteria for a Red Avalanche Hazard Zone is reached.

The Yellow Hazard Zone
Covers areas with reduced danger between the Red Zone and the boundaries, where the damaging effects of the design event with a return period of approx. 150 or 100 years come to an end. This means an Avalanche pressure between 10 kN/m² and 1 kN/m². Buildings and infrastructures are allowed to be built in the Yellow Zone but they must be protected by reinforcements and special architectural design. People within new buildings should be safe, but outside they are still at risk. In areas which are already settled, an expert opinion has to be followed by public authorities for

the permission of buildings and infrastructural installations. Limiting terms are: reinforced walls and windows, no doors and windows towards the avalanche site, anchoring of the roof construction and so on.

In non-settled areas natural dangers normally have to be eliminated by technical defence works before they are dedicated as developing areas, but public funds are not available for this purpose.

Red and yellow zones are delineated for debris flow and avalanches and in the case of rock fall or landslide hazard, a Brown area is delineated. This only gives an indication of a possible hazard and further investigation by a geologist is recommended.

Protection woods that need special treatment to sustain the protection function are coloured blue as areas that are needed for future protection work.

Violet areas have special morphological protective effects, for example a natural earth dam above a settlement. This type of area therefore has to be kept free from any kind of development or alteration.

3.4 Hazard Zoning Procedure

Historical method

When avalanche hazard mapping started in the seventies, the use of avalanche runout models was limited to the analytical VOELLMY-SALM model. This model was widely used in alpine countries but the use was restricted to the flowing part of avalanches. The possibilities of investigating different scenarios were limited and therefore the preference was for the so-called "historical method". "Historical method" means that all data of historical events has to be collected and evaluated.

This would be written reports in old newspapers, or historical archives as well as "silent witnesses" along an avalanche path or the experiences of old people in the locality like hunters, foresters or farmers.

Hazard indicators also known as "silent witnesses" are for example the pattern of vegetation, distribution of debris, former damage to houses and so on.

Run out calculation:

Run-out models for avalanches and rockfall are an increasingly important tool when it comes to establishing hazard zones. Each avalanche path is modelled in detail by using at least the a/b model and one physical model.

Computational models in use:

Topographical landscape model (LIED, BAKKEHOI, WEILER, HOPF 1995)

The a/b model is based on the Norwegian model developed by LIED, BAKKEHOI (1980). It is adapted to an Austrian dataset consisting of well-documented maximum run out distances in 80 avalanche paths.

One-dimensional numerical dense snow avalanche dynamic model AVAL-1D (CHRISTEN, BARTELT, GRUBER, ISSLER 1999)

The model was developed in Switzerland and it follows the classical analytical Voellmy-Salm model which has been applied in the setting Salm, Burkhard, Gubler (1990) for several years in Austria. Flow velocity and height are calculated for every point on the path of the avalanche. The choice of two friction parameters (dry friction μ and turbulent friction z) and the estimation of the fracture height and fracture area (avalanche mass) require some experience in using the model. The authors recommended using both models (the analytical and the numerical) for a comprehensive consideration. It should be borne in mind that the numerical model delivers higher – more realistic – velocities and unlike the analytical model a non-linear decrease of avalanche velocity and pressure in the run out area.

Two-dimensional numerical dense-snow avalanche dynamic model ELBA (VOLK, KLEEMAYR 1999)

The avalanche simulation model ELBA was developed at the University of Natural Resources and Applied Life Sciences in Vienna and it is mainly designed for application in risk analysis. The basic constitutive equations have been derived from the Voellmy approach and modified for 2-dimensional implementation. The program is stand-alone software with standard interfaces to ARC/Info and ArcView GIS software. The choice of the avalanche mass and a dry friction parameter μ is necessary. The turbulent friction normally used in the Voellmy model is integrated into the model and derived from the roughness in the landscape model. The model is calibrated to approx.150 avalanches (VOLK, KLEEMAYR 1999). Because of its two dimensional design, the simulation of lateral spreading is possible. The experience with this model in practical application is good, the computer programme is easy to handle and the display of the results is very good due to the combination with ARC View GIS Software. First of all the model is applied to determine run out directions and run out distances.

Three-dimensional powder snow – dense snow model SAMOS (Snow Avalanche Modelling and Simulation, (SAMPL, ZWINGER, KLUWICK 1999, HAGEN, HEUMADER 2000)

The computer program SAMOS was developed by AVL in cooperation with the Austrian Service for Torrent and Avalanche Control, the Austrian Institute for Avalanche and Torrent Research and the University of Technology in Vienna. The model is able to describe the formation of powder snow avalanches from the dense flow part of dry avalanches and hence is able to capture the whole range of mixed dry avalanches from pure dense flow to pure powder snow avalanches. Because of the complexity of the model, handling is much more expensive than with the previously mentioned models. It is the most advanced model and SAMOS is the only model able to simulate the behaviour of both the powder and the dense flow part of an avalanche. Therefore it is applied to solve special issues such as the height of the powder avalanche cloud or the direction and the impact of a powder avalanche, which is separated from the dense flow due to morphological conditions in the avalanche track or the run out area. The model is the most important one because big disastrous avalanches are usually dry snow avalanches with a powder part and a dense flow part.

The determination of runout distances and forces of debris flows is presently done by subjective judgement based on historical data and personal experience. Because of the complexity of the process, no fitting models are available yet.

Rockfall runout is estimated by personal experience and subjective judgement because brown areas do not have as high a demand for accuracy as hazard zones.

4. Comparison Of The Different Hazard Zoning Approaches

The practical hazard zoning process is quite similar. In both countries the attempt is to find out certain runout distances based on historical events and model calculation. While in Norway only the run out distance with a certain return period has to be found, the criteria for the hazard zones in Austria is the Avalanche pressure. Finally, and this is an experience from a common project in Iceland along with all the theoretical background, the hazard lines to a high degree are the expression of personal experience.

The legal basis is quite different. In Austria the Forest law states, that all municipalities must have a hazard map. According to the Forest Law, hazard mapping for avalanches and debris flow is the task of the Forest technical Service and therefore no costs for the municipalities accrue.

The administrative procedure is strictly regulated in Austria. Two internal checks are necessary before a public opening of at least four weeks is obligatory. During this opening, the inhabitants have the chance to give their written opinion on the maps. Finally the so-called Hazard zoning commission consisting of four members (Representatives of the Federal Ministry, the Forest technical Service, the county authorities and the major) makes the final decision. Every hazard map has to be approved by the Minister of Forestry and is the basis for

- Land using maps
- Planning permission for houses within the hazard zones
- further crisis management tools (evacuation maps…)
- management of public money

The Forest law stipulates that a hazard map has to be revised, when new facts (knowledge, methods) come to light or when the surroundings have changed (e.g. protective measures).

There is a strong link between public money for protective measures and hazard maps. If a community does not consider the map in land use planning, no public money will be spent for protection.

In Norway no public organisation is responsible for hazard mapping, planning or implementing of protection constructions or administration of the National Fund for disaster prevention. Basically the communities are responsible for all these tasks. There are no strict legal regulations governing land use with responsibility for safety ultimately residing with the major.

The client of a detailed hazard map would be for example a community or the road authority and contractor would be a civil engineer. The community is free to follow the hazard map and it is a part of their responsibility. The hazard maps obviously are not a basis for the distribution of public money for protection measures. A review of the maps with the advent of new knowledge or change in circumstances is not compulsory.

A remarkable difference in the avalanche hazard zoning process is the use of pressure criteria in Austria. The Norwegian system distinguishes between safety classes only on the basis of different return probabilities.

The view to return periods seems to be different. In Austria the 150 year design event is regarded in a way that one event per 150 years happens. This does not mean that all buildings within the hazard zones will be affected by this event. The return period in the Norwegian approach means that every building within the zone will be affected with a certain probability.

5. Conclusion

Both systems are developed based on the geomorphologic situation and the settlement history in each country.

In Austria there is a very high settlement density and intensity of land use combined with high relief energy in narrow valleys. This situation requires strict land use regulations. The settlement density in Norway is much lower and the affected municipalities are far more remote.

6. Literature:

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Methods of avalanche defence in Norway

Summary:
During this year's study trip to Norway we inspected a lot of avalanche defence works. Technical avalanche protection in Norway has a comparatively young tradition and – unlike in Austria – mainly avalanche dams are constructed. Avalanche galleries and defence works are only used very rarely. The reasons for this are, on the one hand, the good geotechnical conditions for the erection of avalanche dams, and on the other hand, the fact that compared to dams these can be built faster and more cheaply.

Preamble

In the course of this year's study trip throughout the southwest of Norway, we viewed numerous avalanche defence works. Avalanche defence has quite a young history in Norway – apart from very few single protective measures, for example roof terraces. Unlike the Alpine region, mainly avalanche dams in the form of deflecting dams, catching dams, retarding mounds and deflectors were built. The reasons for this are various. Dams are usually much cheaper than other avalanche defence methods (defence works in the starting zone, avalanche galleries) and can be built in a relatively short time. Moreover, the planning of deflecting dams benefits from the dispersed housing pattern in Norway, as there is adequate free space.
The topography of the southwest of Norway does not lend itself either to building defences in the starting zones.

Unlike Austria, Norway does not have a state-run defence system. The defence measures are usually planned by the NGI or other private engineers and carried out by local construction firms. The commissioning of both the planning and the implementation is primarily organised by the community concerned. As they have to bear the biggest part of the costs, the aspect of cost is the main focus. High labour costs in Norway make the construction of avalanche defences expensive and this is the reason why snowpack-stabilizing works are only opted for in exceptional cases.

Another reason for concentrating on avalanche protection dams is the nature of the bedrock in Norway: the absence to a large extent of glacial clay sediments for the base of dams is very favourable and the geological bedrock (Caledonian rock mass), mainly consisting of granite and gneiss, provides very good conditions for the fill and the existing coarse sediment.

In cases where the topography or the extension of the avalanche impact does not support protection dams, there are also galleries built in Norway. As in Austria, however, very often their length is calculated too short and the safety advantage gained is only limited. Nevertheless, galleries do ease the necessary clearance works.

The following describes the individual excursion points in more detail:

1. Avalanche control in Aga

Fig. 1: Hazard zone at Aga

Near the village of Aga some agricultural buildings are an area at risk from a large avalanche. In addition to the danger of avalanches, debris flow und slush flow is expected from the catchment area. Locally people tell of an event in the 13th century when the roof of a hay barn was transported off to the coast located around 1 km below the dam.

After a devastating flow of debris in 1992, a 10–12 m high and 350 m long catching dam was built to protect against avalanches and possible debris flow. The basis for planning was a hazard zone map for the area concerned. The basis for dimensioning the dam was not velocity calculation, but an optimization of the protection based on local conditions.

Fig. 2: Catching dam upon completion

Fig. 3: Wooded catching dam after a period of eleven years

The material was collected locally and the uphill slope was constructed using riprapping at a gradient of 1:1. As the area at risk is also a torrent, the dam had to be constructed consistent with the down-flow of water. This was done with a placed rock fill water outlet in the middle of the dam

The starting zone is very structured. Primarily wet snow avalanches are expected but powder avalanches cannot be excluded. The avalanche mass is estimated at 500,000 m³ for a powder snow avalanche. The established dam was planned by NGI and it was expressly pointed out, that the dam cannot offer 100% protection but rather merely improve the existing hazard situation. Especially in the case of a powder avalanche, it must be expected that the avalanche will overtop the dam. However it must be assumed that the air-borne powder component is influenced via the retarding of the flowing component.

Fig. 4: Outlet in placd fill

In the configuration of the catching dam, the possibilities of the availability of ground had to been considered, as the area of the dam area is used intensively for agriculture. The discussion threw up some weak points:

- Due to the land use it was not possible to extend the forefield of the dam including a running in ramp into the basin, which would be assumed to be advantageous by the excursion members.

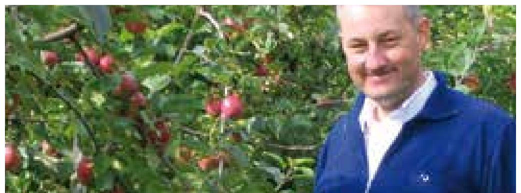

Fig. 5: Intensive agricultural use in form of pomiculture nearby the dam

- The debris-flow cone has a gradient of 15° so that the avalanche track reaches directly to the dam.
- Another problem is the existing drainage of the field, where there is intensive water-logging directly at the foot of the dam on the upward slope.
- The integration of the catching dam shows weaknesses, as it was considered too short for extreme avalanche deposits.

Fig. 6: Too short integration of the dam to the original terrain on the right hand side

- Another problem of the dam could be the rather flat inclination of the dam slope, which was made with 1 :1.
- Also the foundation of the placed rockfill in the water outlet and the steep inclination could be a problem. Small bulges in the wall are already noticeable, although the causes of these could not be clearly detected.

The costs of this dam, which was built in 1996, were 5 Mio NOK (€ 660.000,--).

2. Avalanche wall in Bleie

The avalanche comes from a wide open, flat starting zone. The result of this circumstance is the occurrence of extremely rare, but consequently also very large avalanches, which is also documented in local records.

The settlement of Bleie dates back to the year 1293. Until 1994 no-one was aware of any avalanches having reached the settlement area.

On January 27th 1994 a huge avalanche hit several farmhouses in the Bleie area (municipality of Ullensvang) very hard. In total three houses were completely destroyed and another one was badly damaged. One stable and three barns also serious affected.

Fig. 7: Destruction of three farms at Bleie in 1994

The length of the avalanche path is 3.6 km in total and the starting zone has a gradient of 30° to 35°. In the avalanche track there is only a small concentration possible and the mass of the avalanche from 1994 was estimated at about 1 million m³. The avalanche of 1994 represents a period of return of 800 to 1000 years, based on historical records and climatic information available. So the avalanche concerned can be characterized as a very dry flow avalanche with a very high period

Fig. 8: Catchment area of the avalanche

of return. The new-snow increment recorded at the avalanche event in 1994 was 3.0 m within 6 days, combined with heavy storms leading to huge snow redistribution.

Different means of protection were designed on the basis of the recalculated velocities in the run-out zone and the determined mass of the avalanche. At the end of this planning process an impact wall consisting of 6 semicircular reinforced concrete segments was built. Because of the high velocity of 20 m/s this building has mainly a retarding function, not as much as the wall can stop the avalanche at all. The absorption function of this wall is also reduced by the estimated mass of 1.0 mio m³ compared to the theoretical capacity of the building, which is only 800.000 m³.

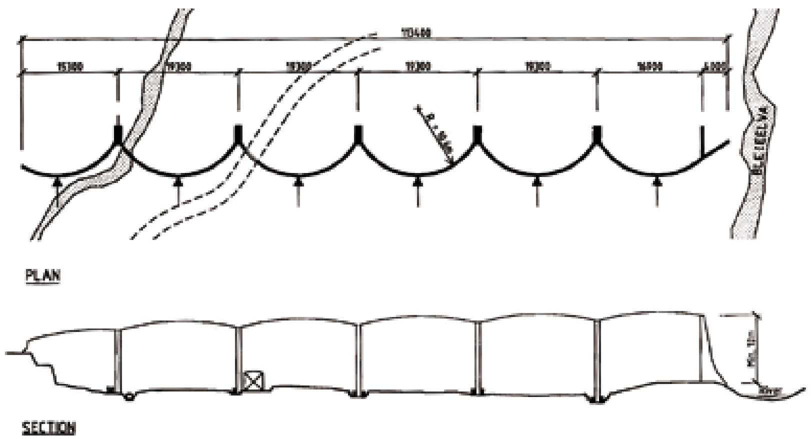

Fig. 9: Design of the avalanche wall

Fig. 10: Avalanche wall with a small opening in the third half-cylindrical shell from left (crossing)

In the planning phase several proposals were developed focusing on establishing catching or deflecting dams.

It was not possible to make retarding dams, as the owners of the properties required for the protection premises were not affected by the avalanche at all and were not willing to provide any sites.

Because of this difficulty an impact wall was created, as this required the least amount of ground. The total length of the 10 m high wall is 113 m. The consulting engineers involved proposed creating semi-circular arched walls to improve the static function.

About 650 m³ of C45 grade concrete with a compressive strength of 45 N/mm² were applied. The wall has a thickness of only 0.35 m and in total 120 tonnes of reinforced steel were needed. To deflect the occurring lateral force into the ground 22 anchors with a capacity of each 2800 kN were installed.

The building works were completed in a period of only 5 months and the costs were 5.6 NOK (€ 740.000,--) including the access road to the building site.

One problem with this protection measure might be a possible pre-filling with an avalanche effecting a force impact mainly in the upper part of the wall.

Another point of consideration is the fact that a torrent must pass the wall and the gap for this is quite small. Also the bonding of the wall in the surrounding area could be longer. Further on the farmers modified the terrain above the wall to improve the agricultural utilization thus reducing the effective height of the dam.

In the completion of this costly measure of protection the issue that a whole settlement was affected by the avalanche and political pressure was high took precedence.

Fig. 11: Design of the five and a half half-cylindrical shells in ferroconcrete

Fig. 12: Stabilized connected design of the half-cylindrical shells from the valley view

Fig. 13: Small ferroconcrete wall with a thickness of 35 cm (crossing)

3. Deflecting dam Eitrheim

To protect the settlement areas of Eitrheim a huge avalanche deflecting dam was built.

The deflecting dam is 350 m long and reaches a height of 8 to 10 m. The slope on the avalanche side has a gradient of 2:1 and the mass of the dam is 55,000 m³. A large torrent flows down directly in front of the dam and so it was necessary to stabilize the torrent bed with reinforcements to make sure that the torrent would not endanger the bedded rock-fill of the dam.

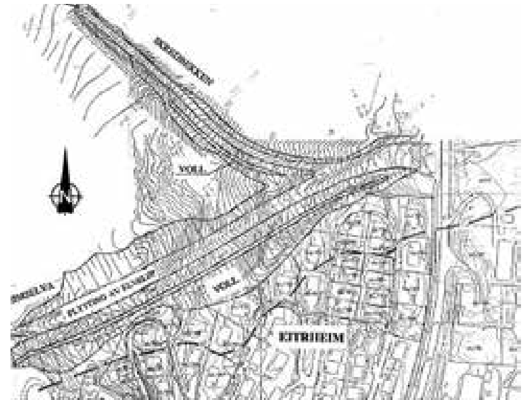

Fig. 14: Design of both deflecting dams for the protection of the houses on the orographic right hand side

Fig. 15: Catchment area with both dams and the protected properties

Downstream from the dam there is a road bridge and above the bridge the bed is getting wider leading to increasing sedimentation. A jamming of the bridge is even possible but not dangerous, because the damming concerns only wasteland. An outburst of the torrent into settlement areas can be precluded.

Fig. 16: River bed with placed fill, taper in the bridge zone shortly before confluenced in the Sørfjorden

A hazard zone map for this area does not exist and it is remarkable that the angle of deflection is greater than 15°. But this fact is not adverse, because flow avalanches are mainly expected und due to the high longitudinal inclination of the dam it is unlikely that the avalanche would overtop the dam.

4. Avalanche galleries

Beside the lot of avalanche dams in Norway also avalanche galleries are implemented mainly to protect roads. On the way to our next stop we were able survey one of these avalanche tunnels opposite Lofthus in Velme. In this passage of the road a very large avalanche, also with an extreme wide deposition area must be expected. The avalanche consists of many separate starting zones,

Fig. 17: Gallery along the Sørfjorden

which are difficult to divide. The length of the gallery was determined on the basis of well-known huge avalanche.

As a result of the huge width of this avalanche it was not possible to ensure the hazard area at all. After completion of the avalanche gallery, a large avalanche occurred and unfortunately also the unsecured part of the road was affected.

In the avalanche track there are also numerous torrents, which have to be lead over the gallery. These crossovers are completed in a very simple way directly over the ceiling of the gallery.

Fig. 18: Huge width of the avalanche with unpredictable hazard areas, riverbed with placed rock-fill heading over the gallery

5. Deflecting dam Egne Hjem:

Nearby the Tokheim River a deflecting dam was built combined with retarding mounds to protect the local housing areas. These protection measures were dimensioned on the basis of calculations of the avalanche velocity and the mass of recorded avalanches in the past.

One problem with these buildings could be the possibility of pre-filling of the dam, especially because during the winter several incidents could occur.

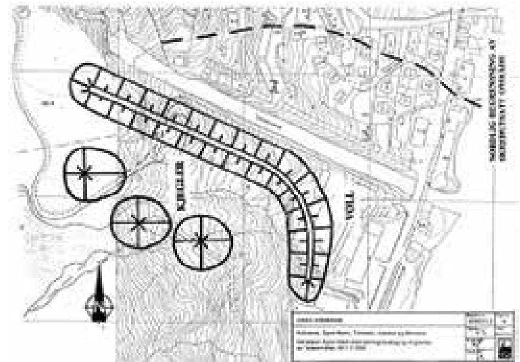

Fig. 19: Design of the deflecting dam

Dating back to 1928 a huge avalanche was documented and after further avalanches in 1993 and 1994 a 7m-high retarding and catching dam was implemented. Due to the limited function of this rather low dam, the local municipality has to contact NGI in the event of critical avalanche conditions to decide when an evacuation is necessary. Defence works in the starting zone are not possible because of the existing conditions of snow and wind.

Fig. 20: Deflecting dam shortly after completion, protection of the properties on the left hand side and the road along the Sørfjorden

6. Avalanche protecting dams Gudvangen

In Gudvangen a small settlement and a hotel are greatly at risk from avalanches. Because of this, two avalanche deflecting dams were built in 1998. An additional purpose of these dams is to deflect possible debris flow and rock-fall. After completion of the works, a design event occurred in 1999 and both dams proved they could rise to the occasion.

The Langageiti dam is 660m long and 7m high, the Nautagrovi dam is 350m long and 15m high. Before implementation it was recommended that the subsoil conditions be surveyed, as the site on its own and also the dam slopes are very steep. In total 4 probes were made by excavator to verify whether the subsoil outcrop would be suitable for such a structure. The geotechnical survey showed that the subsoil ranged from sandy to gravel material, suitable for filling. The portion of fine material (grain size under 0.075 mm) is at some spots up to 25 percent. The exact layer of solid rock could

Fig. 21: Langageiti dam on the orographic left hand side with light-shade effect along the dam crest

not be determined, but it was assumed that the superficial deposits are rather shallow. After dimensioning the geotechnical parameters, both dams were planned in detail. Costs for both dams were around 12.1 million NOK (€ 1.6 million).

Fig. 22: Depositional area of snow avalanche along the Langageiti deflecting dam in winter 1998/99

The Langageiti dam was hit this year also by a great rock-fall, where altogether 3 boulders with a volume up to 120 m³ were deposited but without damaging the dam.

On both avalanches in general, wet snow avalanches are expected but in extraordinary climatic conditions of snow and wind, powder ava-

Fig. 23: Permanent high risk of rock-fall in the area of the Langageiti dam

lanches are also possible, due to the great height of descent and the steepness of the avalanche track. The filling slopes of the dams have a gradient of 39°. This gradient is very steep and is testament to good, solid technical work.

In 1999 the Nautagrovi dam was hit by an avalanche. The starting zone has an extent of 0.15 km² and due to the lee side the crown depth was up to 2 m. In total 60 – 100.000 m³ avalanche snow were deposited and the dam was practically tested showing its outstanding function.

Fig. 24: Two big avalanches would be defected by the Nautagrovi dam (foreground), Langageiti dam in the background

In the hazard zone of this avalanche there is also a load station for anhydrite, which is very important for the local economy. Hazard mapping is currently underway for the settlement area, and in light of possible restrictions, a conflict with the local tourist business is expected.

Fig. 25: Nautagrovi dam on the orographic right hand side, heading to the top forms a shallowing crest, loading place for anhydrite in the confluence area of Næroyfjorden

Fig. 26: Nautagrovi dam on the orographic right hand side with light-shade effect along the dam crest, regulated river bed with placed rock-fill of the torrent heading to the Næroyfjorden

7. Frudalen Avalanche dam

Since 1992 there has been a new road (RV5) that is of huge importance to the traffic in this part of Norway. In the planning phase NGI evaluated the situation of avalanche hazard. In this section of the road 3 avalanche paths are known and to protect the road a avalanche catching dam was built.

Fig. 27: Design of the avalanche paths, previous run-out areas and location of the avalanche dam

Fig. 28: Catchment areas of the avalanches

The dam has a height of 15m and is 300m long. The cost was 13.5 million NOK (€ 1.8 million). In an extreme avalanche event the dam would be of limited effect, but does substantially improve safety. The avalanche-sided filling slope of the dam has a gradient of 31°, whereas the other side of the dam slope is a little flatter. The avalanche side of the dam was not replanted with greenery and some drainage works were also carried out.

On the part of the road authority it is accepted that the dam will overtop once every 20 years. In the event of an acute avalanche hazard, the road is closed and the situation is assessed by local experts.

Fig. 29: Avalanche dam during construction

Fig. 30: Finished avalanche dam, construction with local material, important new road RV5 in the background

8. Avalanche Protection RV5

In the region of Kjosnesfjorden the road is threatened in a big way by a total of 7 avalanches. For this reason it is proposed to create an avalanche tunnel at a length of 2.6km and create 4 protection dams. The material excavated from the tunnel should be used for filling the dams.

Fig. 31: Location of seven avalanche paths and the line of the prospective tunnel (red)

9. Hogrendefonna deflecting dams

In this extreme steep terrain 2 deflecting dams were established to protect the road below. Settlements are not threatened. In general wet snow avalanches must be assumed, but powder avalanches cannot be ruled out either.

The fundamental idea of these dams is to retard the wet snow avalanche massively and bring it to deposition. In the event of powder avalanches the dams are useless. Unfortunately it is not possible to deflect the avalanches out from the road and so the measure does not work if the avalanche does not stop and deposit at the dams.

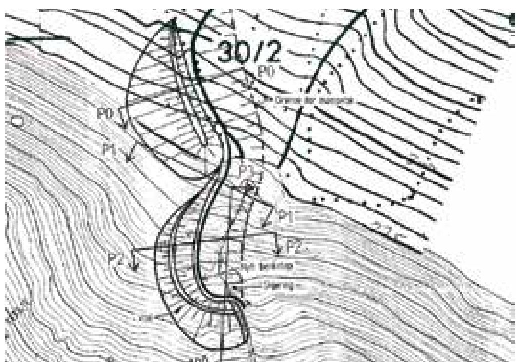

Fig. 32: Design of both dams

In 2000 a very wet avalanche (slush-flow) occurred and the mixture of snow and water progressed across the road, showing the limited function of these dams. But it is worth mentioning that due to the difficult terrain a catching dam cannot be built and other methods of avalanche protection with the exception of an avalanche gallery would be no good.

Fig. 33: First deflecting dam with tapering design to the river bed with placed rock-fill, higher closing-off of the second deflecting dam in the background

Neither are temporary measures (avalanche prediction, temporary road blockage) promising in this case, because the starting zone is very complex and strongly divided. Wet snow avalanches in particular are difficult to predict.

Fig. 34: First deflecting dam, protected road and the Kjosnesfjorden in the background

Fig. 35: Deflecting dam, protected with placed rock-fill and smooth connection to the origin terrain (background)

Fig. 36: Drain with placed rock-fill to the Kjosnesfjorden

10. Orsta Avalanche dam

On February 11th 1979 a disastrous avalanche occurred in the area of Engeset in the municipality of Orsta. This event must be classified as an extreme avalanche with an extraordinary long period of return. The avalanche killed 3 people and 11 buildings were completely destroyed. The run-out zone of the avalanche was longer than 2km with an average gradient of only 14 %.

Fig. 37: Destruction of eleven houses, finger-shaped deposition

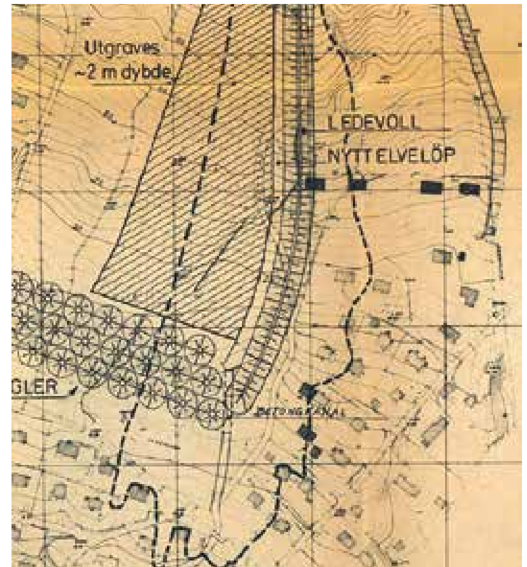

Fig. 38: Design of the dam with the depositional line of the large avalanche, the retarding mounds would be replaced by a catching dam

The avalanche was very dry and the total starting zone broke away at the same time. The length of the fracture line was over 3km and this enormous extent was the reason for the catastrophic consequences of this avalanche.

To protect the endangered buildings, a deflecting dam combined with a catching dam situated at the last part of the run-out zone was erected. Since then the dams have been covered with trees and shrubs and so the protection measures are difficult to recognize.

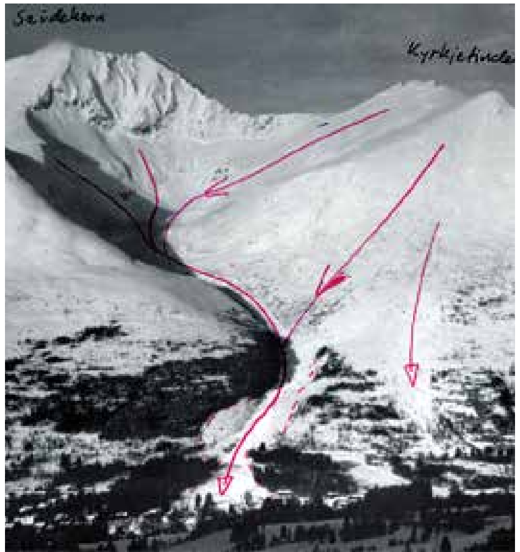

Fig. 39: Catchment area between the peaks Saudehorn on the orographic right hand side and Kyrkjtinden on the orographic left hand side with a three km long starting zone

Fig. 40: Densely wooded catchment area with deflecting and catching dam no longer visible, protected houses in the foreground

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The Godtifonn avalanche

The group also had the chance to visit the Godtifonn avalanche track located about 25 km west of Stryn. 1 ½ years previously, a huge avalanche event released and impacted one of the most important transnational roads connecting eastern and western Norway. The name "Godtifonn" indicates an avalanche breaking during "good times" in the sense of bright weather conditions. In this region, blue sky weather conditions are often related to easterly winds leading to snow redistribution into the huge release area (Fig.2). The avalanche has a frequency of 5-10 years but normally smaller than the last event.

The Event

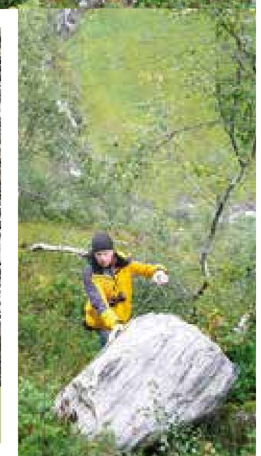
On the 16th of February 2005 at about 10:30h a huge avalanche was triggered. The night before there had been strong easterly winds. It was cold, clear weather with an east wind at the summits at the time of the avalanche. Records speak of an event of comparable size in the late 1970s.

The dust cloud and flying debris affected the RV15 road. Several cars were caught up in the cloud, but only one was seriously damaged. This car was turned over several times on the road and the bodywork was dented by flying debris.

No people were injured. The other cars were left standing in 20-30 cm of avalanche deposit and the road was blocked by trees and rocks. The telephone line near the road was broken. On the counter slope the whole forest in the main direction was broken.

Fig. 1: Location of the Godtifonn avalanche

Seeing the run out area of the Godtifonn avalanche for the first time normally causes disbelief that an avalanche would be able to distribute the rocks over the whole area as can be observed. But two observations make it quite clear, that only the avalanche can be the reason for this phenomenon. First, in the area of the distributed rocks, a birch forest was also destroyed. The main impact direction of the avalanche is cleared witnessed by the forest and is in very good congruence with the area in which the distributed rock particles can be observed. Secondly, the translocated rock is clearly different from all other rocks which can be found in the counter slope in terms of surface condition and shape. All transported rocks have a perfectly clean surface, with no moss or grass and they have a perfectly smooth and rounded surface as typically found in river or torrent beds. Fig.2 shows the group during the field survey.



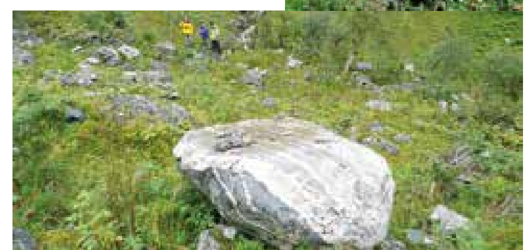


Fig. 2: Distribution of rock particles with impressing size on the counter slope. The particles are either fully rounded or partly broken. The shape and surface properties rise the assumption that the avalanche translocated the single objects from the torrent bed.

The release area

Fig. 3: Godtifonn release area. The arrow indicates the easterly wind direction leading to additional snow by redistribution.

Figure 3 was taken a few days after the event, but now the clear fracture line or Stauchwall can be observed and delineated. The release area therefore has been determined by using the information of Krister Kristensen who was flying by helicopter over the area a few days after the event and by analyzing the inclination map derived from the Dem. Fig.4 outlines the spatial distribution of the inclination classes. The area is very flat thus leading to a very low frequent release behavior. The very upper and lower part has steepness even less than 25 ° which is a generally accepted as a criterion. In the middle the steepness has values between 25° and 35°. For the simulations the release area has been determined as outlined in Figure 4.

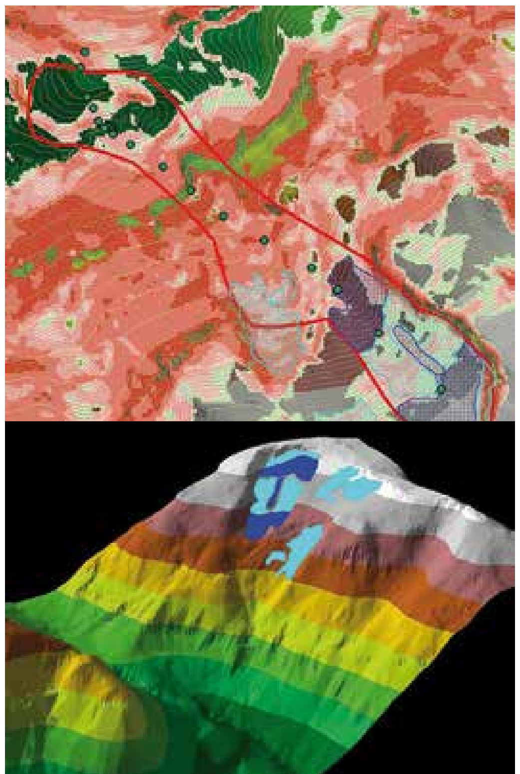


Fig. 4: Inclination classes in the release area. Right: the blue boundaries show the release areas determined for the dynamic simulations. Left: 3D overview of the release area.

The track

The Godtifonn avalanche track, with an inclination of 31.3°, is medium steep but parts of it are nearly vertical as can be seen in Fig.5 and Fig. 6. The channeling effect (horizontal curvature) is not very pronounced but given for the whole track. In the lowest part, the track flattens leading to a "rounded" longitudinal profile enabling the avalanche to rise on the counter slope with full energy.

Fig. 5: Track of the Godtifonn avalanche

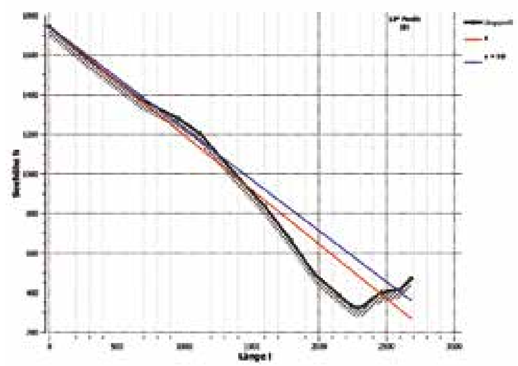


Fig. 6: Godtifonn release area. The arrow indicates the easterly wind direction leading to additional snow by redistribution.

Simulations with the dynamic models

The dynamic calculations have been carried out with ELBA+ and SamosAT. The calculations have the character of a first attempt. In order to facilitate the comparison of the results, the same initial conditions have been used. The release height was set at 1.71 [m] giving a release volume of 239213 m³ with a density of 300 kg/m³. For the friction parameter standard values were applied. Many interesting comparisons between ELBA and SAMOS and sensitivity analyses could be worked out on this event, but for this report the "standard" calculations should meet the demand. Fig. 7 outlines the distribution of the calculated avalanche. The results have satisfying congruence both in the spatial extension and the calculated velocity. The quality of the simulations also slightly limited by the DEM, which has a high generalized character.

Velocity profiles

The avalanche front speed calculated with Samos AT and ELBA+ develops differently along the track.

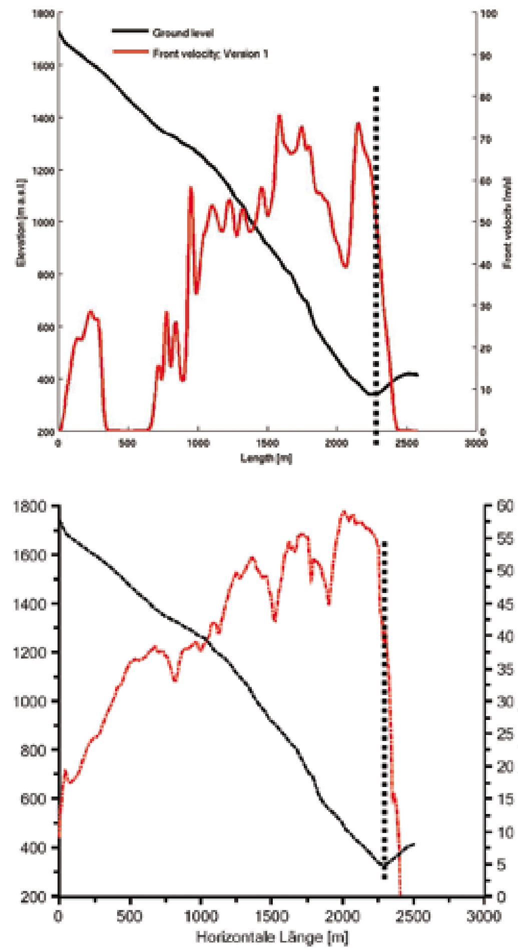


Fig. 7: Velocity profiles of Samos simulation (top) and ELBA+ simulation (bottom)

Preliminary interpretations

Basically there are two methods of interpreting the distribution of the stones in a physical way. One method would be to compare the driving forces F_f with all withholding forces F_w. F_w has to be broken down into three components:

i) F_a: the force to accelerate the particle,

ii) F_h: to hoist the mass particle against gravity,

iii) F_r: Friction forces due to gliding or other collisions.

Yet, for the sake of simplicity, the choice was for the more straightforward approach of comparing the turbulent drag forces F_d with the driving forces F_f. The driving forces can easily be derived by m*a of the single rock particles with m: mass and a: acceleration. The drag of obstacles in a turbulent fluid again can easily be achieved by F_d= A v² /2 C_w with A: cross sectional area of the single particle, density, v: velocity (of the current) and Cw: empirical resistance factor.

The driving forces have to meet the drag forces if the particles are starting to move. In this way of "back calculation" low drag forces would indicate that the avalanche has not enough power to move the block. The interesting feature of this simple threshold approach is that it enables rough analyses on the relation between deposition, fluid velocity, density and particle size.

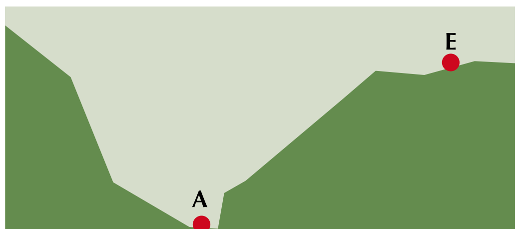


Fig. 8: Schematic outline of the track

The avalanche calculations with the numerical models delivered front velocities between 40 -50 m/s. The initial avalanche speed at the beginning of the counter slope was therefore determined at 45 m/s for the analyses (A in Fig. 7). At a height of 90 m above ground (deepest point of the valley) the last block has been observed and also the influences to forest disappear. Therefore the maximum height of the event on the counter slope has been fixed at 90 m (E in Fig. 8).

During the field inspection, there was a discussion as to whether this impressive event follows the behavior of an explosion or the stones have been moved by the "avalanche fluid". Despite the "explosion impression" in the field, the distribution of the single rocks clearly indicates the translocation of the particles being caused by a viscous transport medium. With increasing block size, drag force must increase and subsequently the deposition has to start earlier in relation to smaller particles. When passing the valley the avalanche added new rocks from the torrent bed (in addition to the particles already entrained in the track). It will be hard to determine the velocity of the various single particles at point [A], but nevertheless the sorting effect can be clearly observed.

The velocity distribution of the avalanche from [A] to [E] differs in the two dynamic models and should be tested in detail for further applications. Therefore again a simplification has been made by assuming a linear velocity decrease between 45 m/s in point [A] and 0 m/s in point [E]. With this assumption a first estimation of F_f and F_d can be made by using the values:

A: cross sectional area of the observed block,

 : 50 kg/m³ (assuming that this very fast current should have low density),

C_w: 0.7 (typically from 0.4 to 1),

v: velocity of the avalanche calculated for every deposition point.

It is worth mentioning that F_f only depends on the mass and acceleration (in fact deceleration) whereas Fd depends on much more uncertain parameters like density or even the C_w value (which is uncertain especially in relation to the fluid type „avalanche", not following a Newtonian behavior).

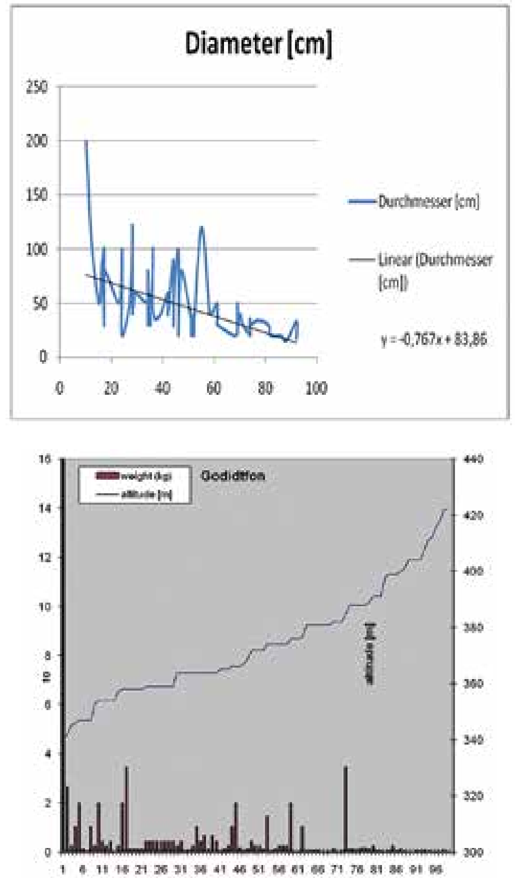


Fig. 9: Distribution of the transported rock particles over the counter slope. Top: clear decrease of rock size with increasing altitude. Bottom: frequency of deposited particles; a single block with a mass of 3.5 to has been moved 70m up.

The first tests with an avalanche density of 50 kg/m³ resulted in drag forces which have been much too low in relation to the driving forces. Values varying between 5-20% of the need drag. By increasing the density to 250 or 400 kg/m³ and also increasing the Cw value to 0.8 the results become more valuable. With a density of 250 kg/m³ the drag forces for all observed blocks increased to in average 60% of all Ff values. But by increasing the average density of the avalanche up to 400 kg/m³ the difference decreases to only +6%. Thus an avalanche with the supposed velocity and a density of 400 kg/m³ would be able to move the blocks as observed. Fig. 9 outlines also that there are obviously single blocks which do not follow this positive general trend. As indicated by the peaks in Fig. 9 the biggest blocks of the various levels still would not be impacted by sufficient forces to be moved. Further studies on this point would be very interesting. As a first interpretation the similarity with e.g. debris flow would attempt to explain this phenomenon by interacting and collisional forces of the smaller particles.

Further analyses using also RADAR and other particle velocity information will be carried out for this very interesting avalanche event.

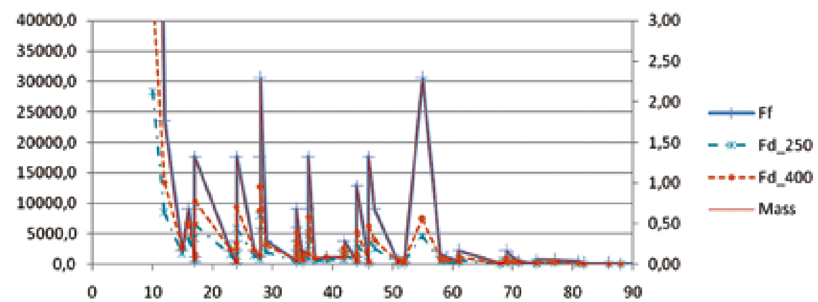


Fig. 10: Derived drag forces for all deposited blocks assuming a linear velocity decrease. Left axis - Ff: driving force; Fd: drag forces with varied density. Right axis: weight of the single blocks [to].

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The Norwegian avalanche test site - RYGGFONN

In 1981, NGI established the full scale avalanche test site at Ryggfonn. Since then the site has been fitted with an increasing number of sensors and instruments.

The Ryggfonn avalanche is one of the most interesting full scale test sites worldwide due to the avalanche catching dam with an effective height of 16 m. Characteristics of the track are summarized in table 1. A total of about 100 avalanches have been observed over the last 20 years. Both natural and artificial avalanches are observed. For artificial release, explosives are placed before the winter near the upper ridge of the release zone in order to enable 3-5 controlled releases of the cornice.

Internationally the test site of Ryggfonn has become increasingly important due to the numerous avalanche dams that have been established and relied upon as protection measures in the past. However, most have never been subject to the test of a real avalanche because they are normally placed in low frequency avalanche run out zones. Many questions about the interaction between dams and avalanches with different characteristics like flow type, density, avalanche size, flow height and velocity still need to be investigated and this can be done at the Ryggfonn site on a more or less regular basis.

Tab. 1: Characteristics of the Ryggfonn avalanche	
Vertical drop:	900 m
Horizontal distance:	2000 m
Mean slope angle:	30°
Volume:	5.000 - 540.000 m^3
Velocity:	max. observed ~ 60 m s^{-1}
Frequency:	2 -10 avalanches per year
Types:	dry dense, dry mixed and wet dense

Fig. 1: Release area of the Ryggfonn avalanche test site

Fig. 2: Avalanche dam (height: 16m) in the Ryggfonn run out area

Fig. 3: Deposition of big avalanche in 2000

Numerous measurements are carried out by NGI: weather and snow cover observations, front velocity with FMCV Radar, photo and video, velocity distribution with 2 ground radars and ground vibration with geophones. The impact forces are measured at three sites. Two 0.7 m2 load cells are placed on a steel tube and three similar ones on a concrete-steel construction in the track. Three additional load cells are also embedded in the uphill dam slope.

In the winter of 2000 a huge avalanche destroyed the two upper constructions. These were rebuilt a year later and NGI will now install two additional towers with load sensors and LED-indicators. The data acquisitions systems will also be greatly upgraded. In the winter 2008/09, the new measurements will be carried out. Figure 5 shows the existing installations.

Steal tower Pressure gauges

Armed concrete constr. Pressure gauges

Shear and pressure Load cells

Fig. 4: Load cells at the Ryggfonn test site

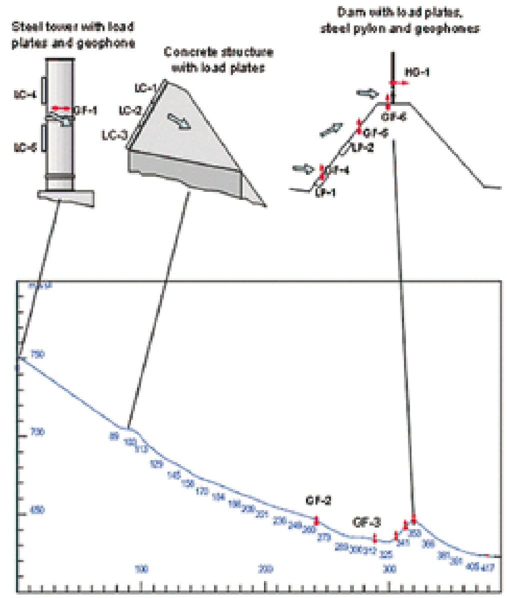

Fig. 5: Overview of the new measurement installations in the Ryggfonn track

Research activities on avalanche dynamics in Ryggfonn are carried out by NGI with strong international cooperation. In particular the NGI cooperates with the BFW (Innsbruck) in relation to the development of load cells, radar measurements and laser scanning measurements.

In order to facilitate the numerous field research activities, NGI established a wood cabin which burned down in 2004. The new research centre at Fonnby (Fig.6) is a highly practical building with interesting architectural features. The new centre fully meets all practical and "atmospheric" requirements.

Fig. 6: New field research centre at Fonnby

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Flood management in Norway

Summary

Norway has a long tradition of managing floods due to its wet climate, many rivers and mountainous terrain. The hydrological regime in Norway is influenced by the northern position of the country with long winters having low runoff and snowfall accumulation and high spring flows due to snowmelt. High autumn and winter flows are also experienced in the milder coastal climate in the west of the country. Runoff times are generally short due to small catchments and shallow soils. Many rivers in Norway have steep and short courses and the topography is in many parts, similar to that of the Alpine region of Central Europe. Problems associated with erosion, sediment transport and deposition are therefore also of major concern in terms of damage mitigation along rivers. There is also risk of severe accidents caused by quick clay slides in Norway. The country is sparsely populated, with a density of on average 14 people per km2. The population in the inland is usually concentrated along the valley floors. Good farmland was found on the flood plains and formed the basis for early settlement. Further development and infrastructure such as roads and railways consequently follow the valley floor, and are subject to flooding. Until 1995 flood risk management was very much dominated by traditional physical flood protection works such as flood levees and erosion protection consisting of stone rip rap. The major actor at a national level dealing with flood risk management, The Norwegian Water Resources and Energy Directorate (NVE), dates back to 1804.

Water resources management in Norway

The responsibility for water resources management in Norway is divided across national, regional and local levels. At local level, municipalities prepare water resource plans concerning water supply and quality, land use, sewage, water pollution and fishing as part of their ordinary planning work. At regional level, county planning is used as a tool for management of rivers and lakes. Both long-term and corporate plans are statutory and represent important management tools for both municipalities and counties.

An overview of national institutions and their responsibilities is given below.

Ministry of Petroleum and Energy (OED)

The Ministry of Petroleum and Energy has a key legislative and policy responsibility for the management of water resources in Norway. One of the most important tasks of the water resource authorities (OED and NVE) is the processing of licence applications for projects subject to legislation on water resources. The Ministry is responsible for the following legislation regarding water resources management: The Watercourse Regulation Act, The Industrial Concession Act and the Water Resources Act. The Ministry is furthermore responsible for the licensing of hydropower projects, which is an essential part of the utilisation of the water resources, with some authority delegated to NVE. OED is responsible along with the Ministry of Environment for administration of the Norwegian Watercourse Protection Plan, and the Master Plan for Water Resources.

OED, along with the Ministry of Environment, also has a main role in the implementation of the European Union's Water Framework Directive in Norway.

Water Resources and Energy Directorate (NVE)

NVE is a directorate subordinate to OED, and has the main responsibility for managing Norwegian water and energy resources according to the policies laid down for the energy and water resources sector. NVE's mandate is to ensure integrated and environmentally friendly management of watercourses. NVE plays a central role in flood prevention work, to prevent accidents in watercourses, and has the overall responsibility for maintaining national power supplies, to promote an efficient power market and cost-effective energy systems and to work to achieve a more efficient use of energy. NVE aims to prevent damage and improve safety within river basins by implementing safety measures against flooding, erosion and landslides along watercourses and by mapping of flood prone areas.

NVE is responsible for weighing up conflicting interests when plans for developments in watercourses are presented. NVE assesses whether new developments have impacts that make licensing mandatory. NVE administers the protected watercourses, proposes restoration in connection with former developments, and co-ordinates management duties in accordance with the Planning and Building Act.

As the national institution responsible for hydrology, NVE collects and disseminates information about surface water and ground water. This work also includes studies and providing advice about glaciers, ice and snow conditions, and sediment in watercourses. NVE is responsible for the national flood forecasting service.

NVE has five regional offices responsible for planning and carrying out work related to water resources management, hydrology, watercourse safety and licensing conditions.

Ministry of the Environment (MD)

MD has responsibility for overall environmental policy in Norway.

MD is also the Ministry responsible for relevant Acts in this field, e.g. the Pollution Control Act, the Nature Conservation Act, the Act relating to Salmonids and Freshwater Fish, and the Planning and Building Act. MD is the Ministry responsible for handling the EIA process in Norway. MD is partly responsible for administration of the Norwegian Watercourse Protection Plan, and the Master Plan for Water Resources.

Directorate for Nature Management (DN)

DN is a directorate of MD, and is the national authority for key aspects of biodiversity and nature management. Key areas include vegetation (aquatic and terrestrial), wildlife, freshwater fisheries, freshwater ecology, limnology, interactions between terrestrial and aquatic ecosystems, landscape ecology and land use planning and management, including the use of GIS methodology, monitoring of aquatic ecosystems and of alien species, outdoor recreation, and multiple use of river basins. DN has established a database on water information.

Norwegian Pollution Control Authority (SFT)

SFT is a directorate of MD. Its main tasks are to combat pollution, noise and waste, and to regulate the use of environmentally hazardous substances and products. Measures to protect the environment and people's health through legislation and supervision of e.g. waste treatment, sewage and fish farming are central activities. The basis for its work is the Pollution Control Act and the Product Control Act.

The Geological Survey of Norway (NGU)

NGU is a governmental agency of the Ministry of Trade and Industry. NGU is the central national institution for knowledge on the bedrock, mineral resources, superficial deposits, groundwater and marine geology of mainland Norway and its continental shelf.

White paper – 1996-1997
National flood action plan

Norway experienced a major flood in the south-eastern part of the country in 1995. The total economic damage caused by the flood was approx. 230 mill Euros and 7000 people were evacuated. A Commission on Flood Protection Measures was established by Royal Decree after the flood. The Commission produced an Official Norwegian Report (NOU 1996:16) and the report was followed up by a government White Paper (No. 42 1996-1997 – Measures against floods - www.odin.dep.no). The White Paper is regarded as a national action plan for Norway on measures against floods and has an English summary for those interested.

A central message in the Commission's work was that an integrated approach is necessary in planning and carrying out flood protection measures and that the 'most important measure to reduce flood damage in the future is to improve land use planning in flood prone areas'. The report and White Paper led to several improvements in flood risk management. The flood forecasting system was continued and strengthened and extra funding for physical protection works was provided. Most important however was that a flood hazard mapping programme was initiated and a guideline for land use planning in flood risk areas was issued. Six new positions as land use planners were provided to strengthen NVE's role as the national authority responsible for ensuring acceptable land use in areas with a risk of flood damage.

Guideline for land use planning in hazard areas related to rivers

According to the national Planning and Building Act (PBA) the local municipalities are responsible for taking natural hazards into account in land use planning, and could be liable if damage occurs. NVE is a directorate under the Ministry of Petroleum and Energy with responsibility for the management of the nation's water and energy resources, and plays a major role in relation to flood risk management. NVE provides advice to the municipalities, but according to the Planning and Building Act, NVE may also object to land use plans if national interests or regulations are not followed. The Ministry of Environment has the final say if agreement is not reached between the municipality and NVE.

The Planning and Building Act states that development is not allowed, unless safety is at an **"acceptable level"**. NVE has developed a national guideline defining acceptable safety levels with respect to floods and other hazards related to rivers. The safety levels are differentiated related to hazard type and type of asset.

The first guideline for land use planning in flood hazard areas was issued in 1999. It was revised in 2006/2007. The main philosophy behind the first guideline was to quantify and define acceptable hazard levels for different types of assets. This was generally well received and did clarify to local authorities what were the acceptable levels of risk for different assets. The guideline focused however rather unilaterally on building types. It did not encompass planning objectives according to the Planning and Building Act and there was a need for more clarification as to how the guideline could be implemented in land use planning processes. A further reason for revising the guideline was to include the risk of quick clay slides and include advice as how to proceed in areas with a potential risk, i.e. where hazard information is not readily available. Quick clay slides are closely associated with river erosion and areas at risk of such landslides have been mapped since 2000. More information on the programme is available in Endre et al. (2004).

One of the main aims has been to develop a step by step procedure for identifying potentially hazardous areas in order to prevent planning development in hazard areas at an early stage in the planning process. This reduces the need for protection that is often costly and will require maintenance. Furthermore protected hazard areas will always have a residual risk in spite of protection. If development can be avoided in areas with a potential for flooding, this is always a preferred option to physical protection. Besides cost and residual risk a further reason for this is the environmental aspect. Good hazard management in areas close to rivers coincides closely with good environmental management of such areas. Revision of the guideline was part of the Interreg project FLOWS (www.flows.nu) and a description of these in English is given in Berg et al. (2006).

The revised guideline defines safety levels in areas at risk from different hazards connected to rivers such as flooding, ice flows, debris flows and quick clay slides. These are, similar to the first guideline, differentiated according to the function of the building. Table 1 and table 2 show the safety classes related to floods and debris flows respectively.

Safety class	Type of asset	Return period Flooding, erosi-on, ice flow
F 1	Small garages, boa-thouses, sheds	1/20
F 2	Houses, cabins, industry, offices, important infra-structure	1/200
F 3	Hospital, emergency institutions, critical infrastructure	< 1/1000

Tab. 1: Acceptable safety levels related to floods

Safety class	Type of asset	Return period Debris flow/ land slides
S 1	Garages, boathouses	1/100
S 2	Small domestic buil-dings, cabins,	1/1000
S 3	Other buildings	< 1/1000

Tab. 2: Acceptable safety levels related to debris flows and land slides

NVE expects the municipalities to assess the flood risk as part of the land use planning process. Based on a Provision from 2006 on Environment Impact Assessment (EIA), the revised NVE guideline of 2007 aims at clarifying what this includes in terms of the different planning levels.

The planning process in a municipality is typically split into three levels:

1. Municipal plan - giving principal strategies for land use within the municipality,
2. Zoning plans - where specific areas are zoned for different land use with detailed regulations
3. Building case - where the processing of building application is done.

A step by step procedure for assessing the hazards has been designed to fit with these levels.

The following procedure is now recommended:

- Municipal plan: potential hazard should be identified
- Zoning plan: the actual hazard should be described and the risk quantified
- Building case: a satisfactory level of safety must be documented

This procedure ensures that areas with a potential hazard are identified at an early stage. This will give municipalities more reliable and predictable land use plans. Previous experience has been that the flood hazard has been identified at a very late stage in the planning process, when other principal strategies for structural development have already been decided upon. The only practical way of tackling the hazard is then often to proceed with development and include structural protection of some sort.

The revised guideline also offers detailed technical instructions for assessing the risk of flooding and the same for assessing the risk of quick clay landslides.

Hazard categories	Implications for deve-lopment
High hazard: Depth > 1.5m or velocity x depth > 1.5 (m²/s)	No development accepted
Low hazard: Depth < 1.5m or velocity x depth < 1.5 (m²/s)	Development could be accepted provided protection measures will prevent damage to property and people Damage to small garages etc., can be accepted provided the annual probability of damage i less than < 1/20

Tab. 3: Implications for development under design flood level, as function of flow velocity and flood depth

If development is allowed below the design flood level, protective measures must be put in place. These might be levees or special design of the building to prevent damage. A new feature in the revised guideline is a proposal on limiting the possibility of development below design flood level, based on the hazards connected to flow velocity and flood depth. This is inspired by similar restrictions from other countries, and still undergoing evaluation. Similar restrictions would apply behind levees. Table 3 shows the proposal as of February 2007.

Flood hazard mapping

As part of the effort to improve land use planning and as an aid to local authorities a flood hazard mapping programme was started in 1998.

A total of 134 areas covering approximately 1100 km of river length will be mapped by the end of the programme in 2007. The maps are provided digitally to enable users to make their own presentations in combination with other land use and hazard information. The method includes flood frequency analysis, hydraulic simulation based on surveyed cross sections of the river bed, GIS analysis identifying inundated areas based on a digital elevation model with high resolution (5x5m) and vertical accuracy (+/- 30 cm). The maps are presented in a standard format (fig 1) and the modelling is performed for six different flood levels, the 10-, 20-, 50-, 100, 200- and 500-year floods.

The main target groups are municipalities and county officials, who are responsible for land use planning and emergency planning at local and county levels respectively. All maps are presented in meetings with the local authorities and often at

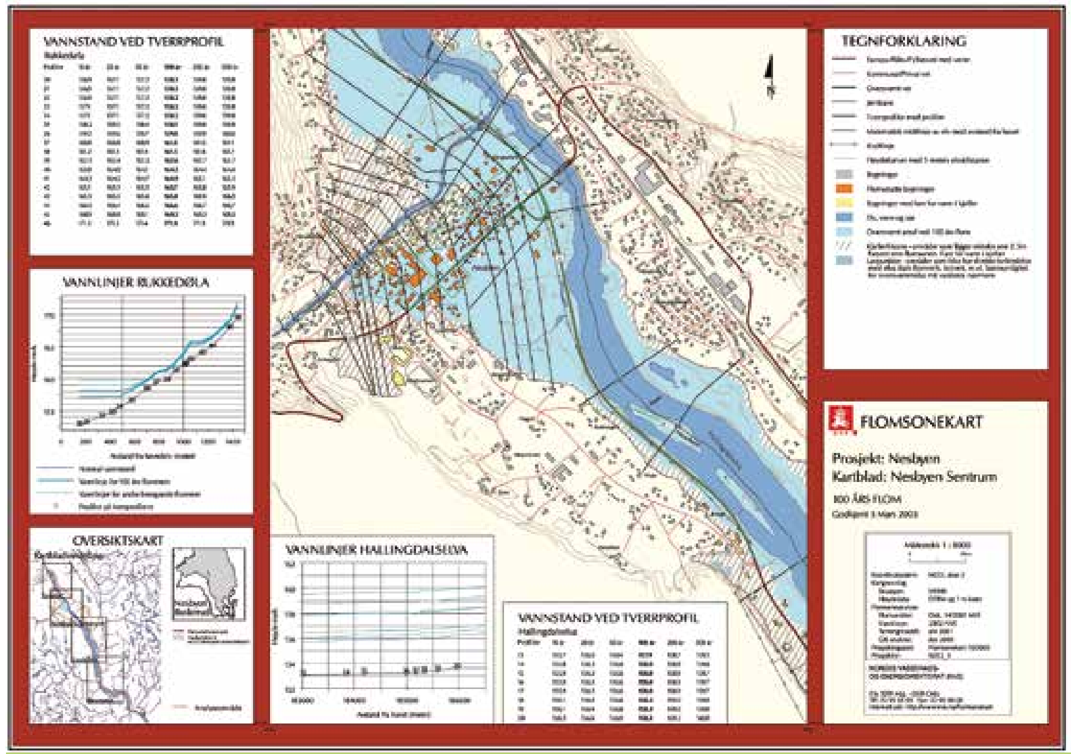

Fig. 1: Flood hazard map for the municipal centre of Nesbyen in the county of Buskerud in South Norway. The map shows the flooded area for a flood with a 100 year return period in the main river and tributary. The tables and graphs give the water levels for floods with different return periods.

meetings with the general public present as well. The press are usually present at such meetings and they are important in increasing the awareness of flood risk among the public. The maps are presented by a representative of the group that has produced the map and a land use planner from NVE. This is to ensure that the maps are to be understood and used as tools in land use planning.

The maps are a useful tool in contingency planning and are used actively in flood situations. During a major flood situation (50 year flood) in 2007 the maps were actively used to manage the situation and give advice to affected municipalities.

The flood hazard mapping programme is to be finalised by the end of 2007. Further reaches with a high flood risk have been identified and the mapping continues as part of a general effort mapping different hazards related to rivers. Included in this is mapping of potential hazard related to floods and debris flows.

Other flood management measures

Flood forecasting and hydrological monitoring

NVE has carried out flood forecasting in Norway since 1967. The prognosis is based on local observations of discharge, snow measurements, precipitation accumulation maps, satellite photos and meteorological prognosis. NVE has a comprehensive network of hydrological observation stations with a large number of these with long term data series. Hydrological models are used along with the qualified evaluation of the duty hydrologist. The forecasts are published on the Internet, Teletext and are sent to the county governor. NVE is currently working on producing quantitative forecasts that will be presented on digital maps for selected river basins.

Physical flood defence

Physical flood defences are inevitably necessary in a number of cases. NVE is responsible for allocating state funding for flood and erosion defence. Approximately 10 million EURO are allocated annually on the state budget for building flood, erosion and landslide protection measures. NVE also assists in planning and carrying out defence measures. An integrated approach is used in evaluating the need for flood and erosion defence measures and the need for defence at one point is weighed against the need for defence in other river sections. Downstream and environmental consequences of defence measures are also evaluated. Cost/ benefit analyses for the measures are carried out and play a role in deciding for or against funding and planning assistance. There are no examples in Norway of permanently removing flood protection works and using the areas behind these as retention basins.

Responsibilities of hydropower companies in flood situations

The responsibilities of hydropower companies in flood management is regulated in the licensing laws, which is the main legislation governing hydropower production in Norway. In all cases hydropower companies may not worsen natural flood conditions through regulation of river flows and can be held liable if found to have done so. NVE can impose restrictions and regulations on hydropower companies in the case of a flood situation. This may be done to alleviate and reduce flood damage.

Insurance - The Norwegian Pool of Natural Perils

In Norway there is a split compensation-system on natural perils. Non-insurable objects are subject to public compensation from the Norwegian National Fund for Natural Damage Assistance, e.g. damage to crop land, forests and roads.

All buildings and chattels with fire insurance are automatically insured for natural damages. The system is administered by the Norwegian Pool of Natural Perils, and it is mandatory for all insurance companies operating in Norway to be members. In the case of a natural disaster, insurance companies pay a share to the Pool according to their share of the market so that costs are spread across all companies equally. It is mandatory for all insurance companies in Norway to be a member of the pool. The system and legislation is well documented on good English internet pages at the site www.naturskade.no.

Municipalities may be liable if damage occurs in areas exposed to natural hazards where development has been permitted. Insurance companies are no longer willing to pay compensation for damage caused by poor land-use-planning. During the last few years the insurance companies have increasingly made appeal actions against municipalities. This means that they claim back compensation provided to owners of damaged buildings from the municipalities, as the municipalities are responsible for approval of construction and development.

The Norwegian Pool of Natural Perils claims that making municipalities economically liable increases risk awareness and promotes better practice in land-use-planning. The pool's impression is that several municipalities have taken this seriously and work with a risk and vulnerability analysis to improve routines.

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MARTIN STREIT, FRANZ ANKER

Torrent and Flood control in the Norwegian Fjord Lands from the Austrian point of view

Zusammenfassung:

Wesentlichen Einfluss auf die Wahl von Schutzmaßnahmen in Norwegen haben die extremen klimatischen und naturräumlichen Bedingungen in den Fjorden:
Die hydrologischen Verhältnisse sind einerseits geprägt von hohen Niederschlagsraten bei Dauerregen und andererseits von geringen Abflussraten während der langen winterlichen Schneebedeckung. Katastrophale Verhältnisse treten immer wieder während der Schneeschmelze bei der Überlagerung mit Niederschlägen aus Warmfronten auf, die auch in der kalten Jahreszeit auftreten können. Die Häufigkeit konvektiver Punktniederschläge ist geringer.
Größere Geschiebequellen sind meist auf Moränenablagerungen begrenzt. Das kristalline Grundgestein mindert die rezente Geschiebebildung.
Besonderheiten stellen Ausbrüche von Gletscherseen und Aufdämmungen von Wildbächen durch Lawinenereignisse und die damit verbundenen Auswirkungen dar. Die Kartierung von möglichen Überflutungs- und Geschiebeablagerungsbereichen wird in Norwegen in den letzten Jahren stark forciert, um Grundlagen für die Raumplanung zu erhalten.
Im Wildbachbereich werden primär Leitwerke, Dämme und Auffangbecken aus lokal vorhandenem Boden- und Steinmaterial errichtet. Beton, Stahl und Holz wird selten eingesetzt.

1. Introduction

Technical Services in Flood and Torrent control are young traditions in Norway. In former days Norway was poor, just with the fish-breeding industry and the oil rush more money came into the country. Living at all was and is still very expensive because of the extreme climate and limited land use possibilities especially in the fiord land.
The country is sparsely populated with a density of on average 14 people per km².
A feature of most Norwegian rivers is their large catchments areas. The hydrological regime is influenced by the northern location of the country, with long winters having low runoff and snowfall accumulation and high spring flows due to snowmelt. High autumn and winter flows are also experienced in the milder coastal climate in the west of the country.

Many rivers in Norway have steep and short courses and the topography is in many places similar to that of the alpine region. This is also linked to the problems associated with erosion, sediment transport and deposition.
There is also a risk of severe accidents caused by quick clay slides in Norway; but they are not considered in this report.

2. Flood management by the NVE

Flood management was developed after a major flood in 1995 and is organised by the NVE (Norwegian Water Resources and Energy Directorate). NVE is a directorate under the Ministry of Petroleum and Energy. But five other ministries define the basic conditions of the organisation.

Water resources management in Norway has historically been strongly linked to flood management and protection and energy management. In addition to the NVE, local municipalities are responsible for water supply and land use management. They are responsible for looking at natural hazards in land use planning, and may be liable if damage occurs.

NVE plays a central role in flood and hazard contingency planning, but also maintains the national power supply. The goal is to ensure an integrated and environmentally sound management of the nation's water resources. They wish to take care of environmental and user interests in water courses and be a Safeguard society from flooding. NVE also manages protected watercourses (389 rivers are protected = about 1/5 of the hydropower potential).

Fig. 1: Autumn flash floods – south west of Norway 2005 – caused by extremely intense precipitation (Photo NVE)

The **Hydrology Department** is entrusted with Studies and consultancy work on erosion and sediment transport and the National flood warning services.
The **Water Resources Department** provides advice and assistance on the planning and implementation of safety measures against floods, erosions and landslides and is divided into five regional offices. The office handles the planning and execution of safety measures against flooding, erosion, and landslides. It provides advice and guidance on technical issues involving watercourses by operating its own constructions on a commercial basis.
NVE construction is organised into independent operating units under the regional offices of NVE. It undertakes measures against erosion and floods, environmental measures in watercourses,

thresholds, and dry walls. It also acts as an emergency response unit against floods, water course accidents and landslides.

3. Land use planning

The Norwegian Planning and Building Act is the main piece of legislation that regulates land use. Local municipalities carry the main responsibility for ensuring that areas at risk from floods or other naturally occuring hazards are not utilized allowing an unacceptable risk to human lives or material damage to arise. The risk must be acceptable in relation to the planned use of the area. Until 1999 the definition of acceptable risk had been left to local decision-makers and sometimes expert views collected from NVE.
In the meantime a new guideline had been developed for land use in flood exposed areas with differentiated safety requirements. It was necessary to differentiate along two dimensions:

- The type of flood hazards, grouped into two classes
  1. High risk fatalities
  2. Risk of material damage (lower risk of fatalities)
- The type of asset exposed to flood hazard
  1. Flood is connected to sudden and violent processes (debris flow, land slides)
  2. Flood in large rivers with slow speeds

The acceptable risk levels are shown in the table below:

Safety Class	Land use, building type infra structure	Highest nominal annual probability
F 1	Smaller garages, outhouses, small warehouses	1/20
F 2	Private houses, cabins, industrial and commercial buildings, offices important infrastructure.	1/200
F 3	Hospitals, emergency institutions, critical, infrastructure.	< 1/1000

Tab. 1: Recommended safety requirements in areas at risk from flooding, erosion and ice jams

Safety Class	Land use, building type infra structure	Highest nominal annual probability
S 1	Minor consequences	1/100
S 2	Medium consequences	1/1000
S 3	Major consequences	< 1/1000 Establish in each case

Tab. 2: Recommended safety requirements in areas with danger to human lives

In the Flood zone mapping project 129 areas were mapped between 1998 and 2007. Maps show flooded area at different flood frequencies. The experts from NVE believe that most municipalities in Norway have alternative areas for development outside of the foodplains.
The Municipalities are the main target group. The maps are used as a decision tool for spatial planning and protection works. NVE also manages programmes for reducing the risk of quick clay landslides; a major problem in Norway.

4. Erosion and flood protection works especially used in Norway:

- Flood protection works
- Erosion protection works – bank protection, river bed protection, groins
- Sediment check dams

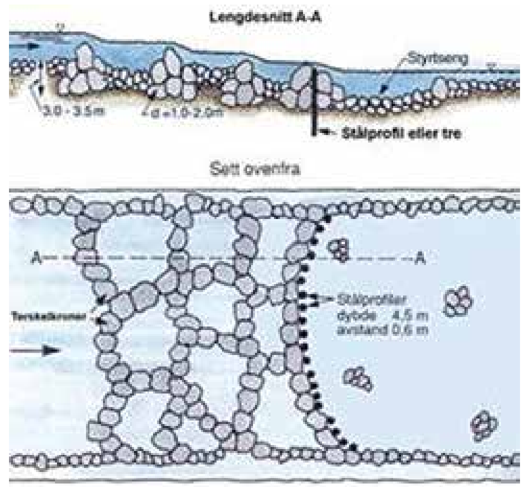

Fig. 2: Weirs – river bed protection

Protection and reinforcement of the river bank or river bed is managed by using rocks, timber, vegetation etc. to hinder undermining and erosion of the bank and bed – groins and weirs are also used as erosion protection. Levees are built along the river to confine the river to its course to prevent flooding of water, ice and sediments onto vulnerable areas.

Before planning, alternatives to physical measures like alternative land use are analyzed. The need for protection has to be substantiated by a cost/benefit analysis.! The impact of protection works on hydrology, hydraulics, sediment transport, environment – fauna and vegetation, 'public interests' is tested.

Compared with Austria where the forest technical service has more than 120 years experience and has its developed tradition close to the alpine forestry, there is not such a close relation in Norway, but also an increasing ecological awareness. Protection works in Norway are more common in large watersheds.

Fig. 3: Example of river bed structuring (NVE)

5. Natural relations in the fjord lands:

To get a good impression of Norwegian Torrent and Flood control we need to notice the different natural relations to Austria, especially in the fjord lands:

- Strong rainfall occurs over the whole year (up to 5000 mm p.a.) and high snow accumulation in the long winter period in the mountain area.
- Floods can happen over the whole year. Therefore they describe different types of season floods (spring, summer, autumn and winter flood)
- The mountains are not as high as in Austria, but the altitudinal zones are compressed, the upper regions are treeless.
- The old mountain ranges are generally built up by granite and gneiss and often covered with glaciers. The permeability off the massive rocks is normally very low and therefore the surface runoff is very high.
- The Moraines are the main source of debris flow, but the steep torrents of the fiord cliffs normally do not deliver much bed load. The rocks build up a hard and stable torrent bed.

• Typically for the fjord lands, the torrents are very steep and have short watercourses. Norway is the land of water falls.

• The country is sparsely populated; most municipalities have alternative areas for developing housing.

Fig. 4: The famous "Seven Sisters" in the Geiranger fjord

6. Important process types of torrent and flood problems in the fjords:

• Debris flow: Debris flows build up debris cones in various inclinations in the valleys, but also often directly sediment in the fjord (no cones).

• Snow melting: Quick snow melting primary can happen in the springs after long winters with much snow accumulation in the higher regions.

• Avalanches in torrents: In some places, for example in narrow canyons, avalanches can dam up a temporary torrent. Normally the snow will melt slowly, but in some cases the snow dam can break very fast and produce flood wave into the downside valley.

• Collapse of Glacier lakes: On the lower end of the glacier, we can often observe a terminal moraine, which dams up melt water.

7. Control measures and constructions:

Most of the control constructions used are simple. Normally no timber, concrete or steel constructions are built. The cost/benefit would be negative, caused by the high work and material costs. Normally natural blocks of debris and talus cones in the immediate area are used for placed rock fills.
The main constructions against debris flow are various dams for training walls or accumulation basins. The dams are built with local superficial deposits and reinforced with placed rock fills. Special forms for the dams are seldom designed.
The accumulation basins have a wide opening in the middle, which permits accumulated masses to be eroded.
Because of the topography the dams are combined with control measures against avalanches and rock fall. And therefore there have to be compromises in the design.

Fig. 5: Example of a gallery with lead over torrent, road Nr. 550 nearby Aga, Ullensvang

Sometimes sediment check dams were built. They can be used to reduce sediment transport and must be maintained and emptied regularly. They can cause erosion downstream due to sediment starvation.

Special cases are avalanche galleries for roads with lead over torrents. The galleries themselves were constructed in concrete and protected against water erosion with placed rock fills.

8. Examples off Torrent and flood problems and resolutions during the excursion

Grov near Hjelle

In the year 1995 a major flood catastrophe occurred in the valley and devastated a settlement. The reason for the flood was a collapsing barrier of avalanche snow, which dammed up the snow melting water of the torrent in a narrow gorge at the exit of the side valley. A house shows a flood-level mark at a height of over 2m above the ground. The settlement was founded in the 16th century. Additional to the dangerous torrent, the settlement lies in the area at risk from avalanches, rock fall and also the receiving river. The excursion members discussed the possibilities of reducing the height of the damming effect. For example a water bypass tube, which starts at a definite water height, could discharge the backwater.

Fig. 6: An avalanche caused a Flood by damming up the small gorge in 1995 in Folven, near Hjelle in Oppstryn. Foto credit by Edvin Folven.

Fig. 7: The Picture shows the narrow gorge at the exit of the side valley. On the left side the steep avalanche slopes reach the gorge. On the flat debris cone a protecting dam was constructed after the flood catastrophe 1995.

Kinsarvik, Ullensvang

The settlement of Kinsarvik lies in the area at risk from debris flows. Five large events in the last 400 years are known. A white channel dam with a dammed basin at the base was planned by the NGI (Norwegian Geotechnical Institute) It is a new torrent control concept in Norway.

A sediment discharge of 20,000m³ is expected during one recurrent design event (precipitation 40–50mm in 30min, watershed area = 2.5km²). Against the first plans a longer channel dam down to the fiord was not able to be constructed. Because of the interests of the settlers, there was no enough space for the channel and the dams in the housing area.

As planned, also the wide channel dam

Fig. 8: Channel dam with placed rock fills, Kinsarvik

Fig. 9: Accumulation basin with a with opening in the middle of the dam, Kinsarvik

above the basin should permit a premature deposit of coarse sediment. The dam is reinforced with placed rock fills. The basin dam has steep slopes and is also reinforced with placed rock fills without any concrete or steel. The opening in the middle of the basin dam is relatively wide (approx. 3-5m) and should permit a self-discharging process after a debris flow. The dam has no own discharging flood section. The residual risks of a dam collapse or a lateral outburst of debris in the case of an overload and the problems of housing area regulation in Norway were discussed by the excursion members.

Supphelledalen, Fjærland, Western Norway

Hedda BREIEN reports in her Master Thesis in Geosciences, University of Oslo "On the dynamics of debris flows, 2005" about a debris flow in Fjærland, Western Norway. The dramatic event of Fjærland on the 8th of May 2004 developed from a failure of a mountainous glacial moraine ridge, and caused sudden drainage of the lake behind and possibly also a lake trapped within the glacier. The torrent scoured a small river gully through a steep terrain on its way from 1000 m.a.s.l. down to elevation zero, carrying with it large amounts of material and evolving into a debris flow. The valley affected is mainly overlain by glacial deposits, but also by alluvial material.

Fig. 10: Aerial view of the extent of the flood

The movement ended in a fan of huge boulders where the valley Tverrdalen meets the main valley Supphelledalen, and fine material and muddy waters inundated the fields of three nearby farms. The terrain is relatively steep (average slope 17º), but varies from around 4º at the uppermost stretch to a cliff of around 60º. The flow behaved like a "flood" until it reached the bottom of the cliff where its eroding power developed. The torrent followed the original stream gully, widening and deepening it on its way to dimensions of 50 m wide and 8 m deep. It is believed that the water volume involved was larger than the volume of the lake behind the moraine dam itself, and the suggestion is that water was drained quickly from within the glacier.

Erosion due to the debris flow in Fjærland was extreme; the mass volume growing with a factor of ten, from around 25,000 m3 to around 240,000 m3 (+/- 10 %) in less than an hour.

As the Fjærland debris flow developed from a dam breach, water has an especially important role, both in the triggering and the dynamics of the flow. This makes the case applicable to any event where a volume of water is released at high altitude, flowing towards narrow valleys filled with erodible sediments, as well as debris flows developing from slope failures. These extreme events may result from flash floods as well as dam breaches.

Fig. 11: Deposition of sediments at the fan

Hedda BREIEN believes that Erosion and entrainment of bed material has to be regarded as very important for run-out length and velocity of a debris flow. Among the aspects mostly determining erosion, the volume of the flow has been found to be especially important.

Deposition however, seems to be determined largely by slope angle. In Fjærland deposition starts at 12º, and all boulders are settled before the slope reaches 4º. Erosion seems not to appear where the slope is below 12º, but topography also plays a role. Channelisation of the flow may increase the run-out and reduce the angle of deposition, as well as the exit of a gully favouring spreading and deposition.

Gjelgrova near Førde

Protective measure at the torrent called Gjelgrova in the valley of Angedalen near the municipality of Førde:

The experts from NVE decided to build a dam to protect the village from deposition of debris. On the right part of the fan there is only farm land without settlements. So it was possible to build a deflecting dam reinforced with placed rock fills. The river bed is managed by using rocks to hinder undermining and erosion of the bank and bed (weirs).

Fig. 12: Perotechiandem in Angedalen

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BREIEN Hedda:
"On the dynamics of debris flows- Case study Fjærland, Western Norway - a debris flow triggered by a natural dam breach": Master Thesis in Geosciences, University of Oslo

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Rock fall protection

1. Geological characteristics

In terms of geology, Norway is part of the Baltic shield, which ranges from Sweden to Finland and ultimately Russia. The oldest rocks in Norway are 3.5 billion years old. In the South and West of the country, there is the south-western gneiss province. Its rocks are 1.7 billion years old, and in the course of the gothic orogenesis, granite rocks intruded into these.
In the western part of Norway, following the shoreline, we have the Caledonides; a mountain range formed 444 to 416 million years ago. It includes late Proterozoic and Silurian sedimentary rocks and meta-vulcanites deposited in the Lapetus Ocean, which preceded the Atlantic Ocean as we know it. Today, these rocks come in the form of paragneiss, different schists and green rocks.

2. Endangered areas

The Norwegians only deal with the problems of rock fall in extreme cases and this is due to the fact that the population density is very low. Traditionally, residential areas are situated by the sea (cf. picture 1). The main focus is on securing important transportation routes for the economy and tourism (such as the fishing industry and the importance of maintaining the transport chain). Even though rock fall scenarios are the main reason for road closures, rock fall protection often goes hand in hand with avalanche protection. In areas, where a tunnel or a gallery has not yet been erected for financial reasons, (this is the safest but most expensive option, and tunnel connections are steadily being completed if the funds are available) terrain remodelling and dams boast adequate protection from avalanches and rock fall scenarios. The dams as such are designed to concentrate on overtopping of avalanche snow, and they thus provide accompanying protection against rock fall. All dams – most of them being designed as deflecting dams- are in the run out area above residential areas and roads, and they are designed to redirect snow masses and rock falls into unpopulated areas.

Fig. 1: Example of a residential area underneath a rock face

3. Control measures

The dams are embankments and on the uphill side and they are often shielded with large rocks. The rock material is gained at face. Protection from rock fall is thus a positive side effect. Former dams erected for avalanche protection lack this positive side effect, as examples show.
Due to the special geology and the fact that the rocks break into large pieces (fig. 2 and 3), one has to take into account high energies in rock fall processes. Efficient protection measures can only be provided in the form of dams (fig. 4).

Fig. 2: View of the rock formations with the breakage area of extremely hard paragneiss

Fig. 3: The extremely hard and compact base rock breaks up into large pieces

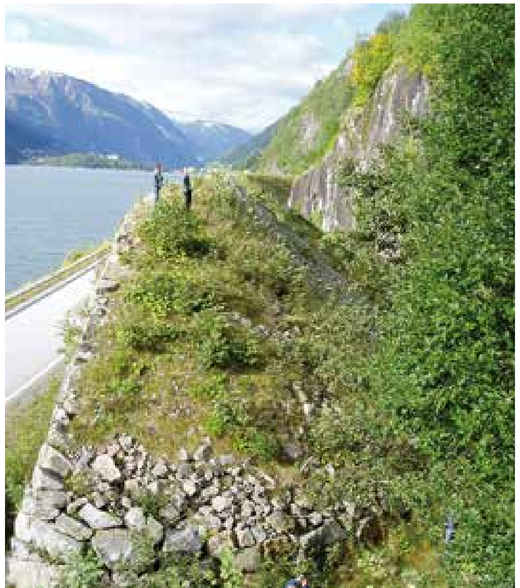

Fig. 4: Rock fall protection dam near a coast

Rock fall protection nets are only used in special cases (fig. 5). The fact that the area around the Norwegian fjords is vast and all but densely populated makes it uneconomical to set up protection nets. Moreover, the hazard potential of rock fall scenarios that affect roads cannot easily be localized; in the same way, putting up the nets as closely as possible below the possible breakage areas is extremely difficult, and often impossible.

Fig. 5: Local protection with rock fall nets

4. Example of a past scenario

On May 26th 1908 a rock slide came down from Keipen Mountain on the south side of the valley. The slide was so large that it formed a rock wall across the valley, thereby creating a dam which later became this lake. Before the rock-slide, there was a "seter" or a mountain dairy farm where the lake is. The "seter" had nine "sel" or small rock huts where the milkmaids stayed overnight. The old road through Norangsdalen, a rock fence with a gate and the remains of hut-foundation can still be seen on the bottom of the lake.

Fig. 6: A historical photograph of the rock fall in 1908

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Route of field trip

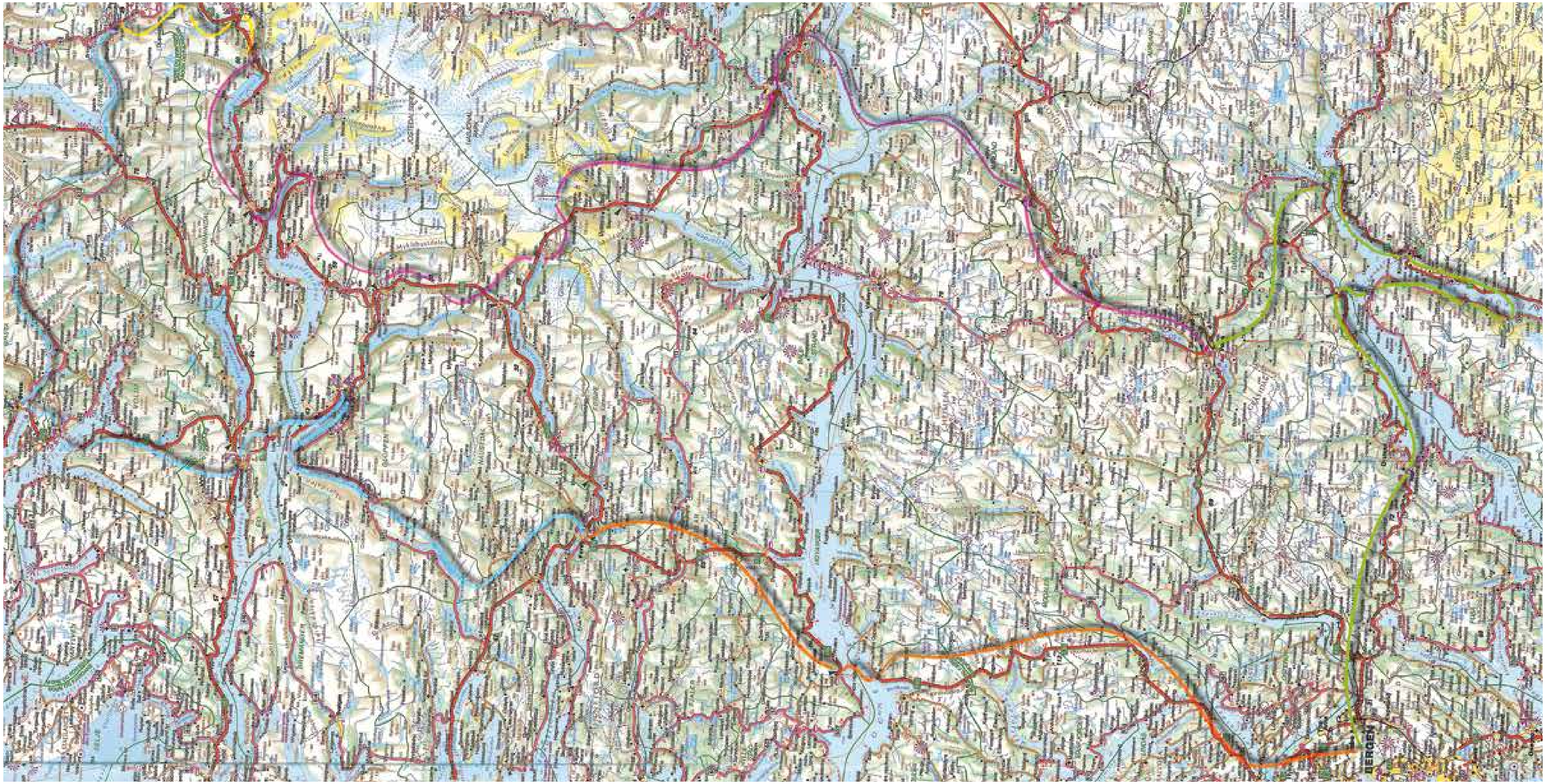
Monday, 10.09.2007
Bergen - Nordheimsund -
Kvanndal (Ferry) - Utne -
Aga - Bleie - Odda-
Kinsarvik - Brimnes (Ferry) -
Bruravik – Voss

Tuesday, 11.09.2007
Voss - Gudvangen (Ferry) -
Kaupanger - Sognedal -
Sogndalsdalen - Boyabreen -
Kjosnesfjorden - Vatedalen -
Fjaerland - Stryn - Hjelle

Wednesday, 12.09.2007
Hjelle - Hjelledalen -
Folven - Napefonn -
Godtifonn - Strynefjellet -
Researchstation Fonnbu -
Test site Ryggfonn -
Geiranger

Thursday, 13.09.2007
Geiranger (Ferry) -
Hellesylt - Nordangsdalen -
Oye - Leknes (Ferry) -
Saebo - Riisetunet - Orsta -
Nivane fra flyplassen -
Volda (Ferry) - Folkestad -
Nordfjordeid -
Lote (Ferry) - Anda -
Sandane - Hyen -
Hyenfjorden - Naustdal -
Forde

Friday, 14.09.2007
Forde - Lavik (Ferry) -
Oppedal - Bergen



The western part of Norway - A journey in pictures

City of Bergen from top of “Fløyen”, one of the hills next to the old harbour. Bergen as the second-largest town in Norway has the major harbour on the Norwegian western coast. Surrounded by several afforested hills up to 643m a.s.l. Bergen is said to be one of the most beautiful towns in Norway.

“Fleischer’s Hotel” in Voss built in 1889. Its facade, with its towers and pointed dormer windows, is reminiscent of Switzerland. The roof is completely covered by shingles in traditional style made of shist.

Newly renovated houses in the oldest part of Bergen near the harbour of “Vågen”. As most of the towns in Norway Bergen’s city burnt down several times. Only few houses from “old Bergen” are still left. Houses made of stone and wide streets form the cityscape nowadays.

In February 1968 a big avalanche in Sæbo damaged the farmhouse at Riise together with 16 other houses. Only the stairs and the damaged handrail reminds of the avalanche. The release area was located at 1200m a.s.l. The avalanche stopped at just 15m a.s.l. and was 3000m long.

Top station of famous Fløyen funicular with a working scale model on its roof. Mount Floyen is a well attended recreation area next to the town. Numerous paths offer easy walks through beautiful woodland terrain with lakes and mountains.

Smoked and boiled blockheads sold on the traditional Bergen food festival. This festival is hosted every year in September in the old Hanseatic district of Bryggen.

Nærøyfjorden with 1398m high Bakkanosa mountain in front. Nærøyfjorden, part of Aurlandsfjorden is the biggest southern fjord of the Sognefjord. The small village of Bakka can only be reached by car on an endangered road from Gudvangen or by boat from the fjord.

Cultivation of apples and cherries in the northern part of the Sørfjorden at Ullensvang. Well known Hardangerfjord which the Sørfjorden is a part of has most of Norway's crop of apples and cherries because of the favourable climate.

Museum presenting traditional agricultural buildings in the Hardangervidda. The Hardangervidda is the greatest plateau in Scandinavia with app. 7500 sqkm and a height a.s.l. from 1200 to 1600m. Most of the area is identified as a national park.

Romanic-gotic "Mariakirke" in Bergen north of the old district Bryggen. The church was owned by the Hanseatic merchants from 1408 – 1766. Till 1868 sermon was spoken in German.

Impressive mountainous scenery in Norangsfjorden with the village of Stenes on the bottom. Mountains built of gneiss without soil coverage and vegetation provide plain and steep avalanche tracks with great run-out lengths.

Limited area for housing in Odda at the south end of Sørfjorden because of frequent avalanche tracks. In 1993 and 1994 severe avalanches damaged some of the houses.

Backtracking isolated glaciers in Norangsdalen. During the last decades glaciers retreated a lot caused by global warming similar to glaciers in the European Alps.

World famous Geirangerfjord. Several avalanches on both sides of the fjord endanger the village of Geiranger and the ferry-station. During winter the village can't be reached by boat because the fjord is closed due to safety reasons on avalanches.

View in a narrow alley between the wooden Bryggen-houses. Some of them are still used to store goods. Most of them are opened for touristic attraction.

Wooden houses in the old district of Bryggen in the town of Bergen. From 1343 till 1764 the "Hanseatic Kontor" transacted all business from the Bryggen houses which where used as offices and magazines.

Stave church in Kaupanger at the eastern end of the Sognefjord called Lærdalsfjorden. The well-worth seeing church was built in the 13th century and restored in 1862.

Ferries - one of the most important means of transportation in Norway. Important rather for daily transportation of goods in Norway than for touristic attraction.

Cascades “Syv Søstre” (Seven Sisters) in the Geirangerfjord. During snow-melting the water is falling down in seven bands up to a height of 300m.




Lawinenschutzbauten aus Stahl

Schon unsere Vorfahren wurden Zeugen von Naturereignissen und seit jeher haben die Menschen versucht sich selbst und ihren Siedlungsraum durch Schutzmauern und Sperrbauten zu schützen.

Die gestiegene Mobilität der Bevölkerung und das gleichzeitig gestiegene Sicherheitsbedürfnis machen Schutzbauten mehr denn je zu einer Notwendigkeit. Stützverbauungen haben in den letzten Jahren merklich zugenommen, da sie eine permanente Schutzmaßnahme sind. Die Josef Martin GmbH aus Braz/Vorarlberg kann in der Lawi-

nenschutztechnik auf eine große Erfahrung zurückgreifen. Seit 1981 hat Martin ca. 300 km an Stahlbrücken in die Alpen geliefert.
MARTIN Lawinenschutztechnik zeichnet sich vor allem durch Qualität und Produktgüte aus. Sie ist jedoch auch:
Flexibel, weil MARTIN Lawinenschutzwerke für extreme Schneemächtigkeiten und optimalen Geländeanpassmöglichkeiten mit verschiedensten Verankerungsarten anbietet.
Modular, weil MARTIN ein montagefreundliches Baukastensystem mit längenvariablen Stützausführungen anbietet.
Rationell, weil Martin die Balkenprofile aus hochwertigem Stahl der Stärken 5, 6, 8 und 10 mm selbst herstellt und dadurch kurze Lieferzeiten anbietet. Die lange Erfahrung, die hervorragende Qualität, das Lieferkonzept und der Lieferumfang der MARTIN Lawinenschutztechnik trägt zu mehr Sicherheit in den Alpen bei.

Der perfekte Fallschutz von MARTIN bei Arbeiten an Schutzbauwerken

Das Höhensicherungs- und Rettungsgerät (HSRG) des österreichischen Unternehmens MARTIN überzeugt neben seiner Multifunktionalität und der Einsatzmöglichkeit sowohl als Fallschutz als auch als Ret-

tungsgerät vor allem durch seine maximale Sicherheit: Das patentierte MARTIN Höhensicherungs-und Rettungsgerät entspricht höchsten Sicherheitswünschen und ist zudem kinderleicht zu bedienen.

Durch die jahrelange Erfahrung der Firma MARTIN konnten in der Entwicklung des HSRG auch die speziellen Rahmenbedingungen in den Einsatzgebieten optimal berücksichtigt werden:zB. bei Wildbach- und

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