Reppwand - Oselitzenbach Landslide

Ewald Tentschert
Alexander Preh

1 INTRODUCTION......3

2 REGIONAL FRAMEWORK......4

2.1 CLIMATE......4
2.2 REGIONAL MORPHOLOGY......4
2.3 REGIONAL GEOLOGY AND STRUCTURAL SETTING......4

3 LOCAL FRAMEWORK......6

3.1 LOCAL GEOLOGY AND STRUCTURAL SETTING......6
3.2 WATER CONDITIONS......6

4 LANDSLIDE......7

4.1 LANDSLIDE IDENTIFICATION......7
4.2 LANDSLIDE DETAIL......8
4.3 LANDSLIDE MORPHOLOGY......8
4.4 LANDSLIDE HISTORY......8

5 LANDSLIDE INVESTIGATION AND MONITORING......9

5.1 SURVEY AND MONITORING OF LANDSLIDE ACTIVITY......9
5.2 MONITORING OF METEOROLOGICAL AND HYDRAULIC CONDITIONS......10

6 MODELLING......10

7 STABILIZATION/PROTECTION WORKS AND LEGAL FRAMEWORK......11

8 LAND USE AND RISK ASSESSMENT/MANAGEMENT......11

8.1 LAND USE......11
8.2 ELEMENTS AT RISK......11

9 FIRST SCENARIOS......12

10 REFERENCES......12

11 PICTURES......12

1 INTRODUCTION

The area at the north slopes of the so called “Carnic Alps” in the southern part of Austria`s county of Carinthia is affected by numerous mass movements.

Thus, the Naßfeld-area, dewatered by a torrent called Oselitzenbach, consists of carbonian sedimentary beds containing clayey schists, sandstones, marls and limestones.

The Reppwand-Oselitzenbach sagging zone consists of interlayers of competent and incompetent rocks, which are highly deformed and disturbed by long-term sagging and gliding processes.

The movements (measurements since 1983) are very inhomogeneous, reaching from some cm/y up to some areas with deformations of more than 1 m/y.

The risks are in destruction of the Naßfeldroad (crossing over the Alps to Italy and touching a great ski area), as well as in possible spreadout of landslide material by the Oselitzenbach torrent (which happened partly by heavy rainfalls in 1983)

Several measures have been made to stabilize the landslide (drainages, debris dams in the river, deviation of the torrent, anchoring of the road cuts and -slopes), which led to some lowering of the movements, but they are still going on with reduced amounts.

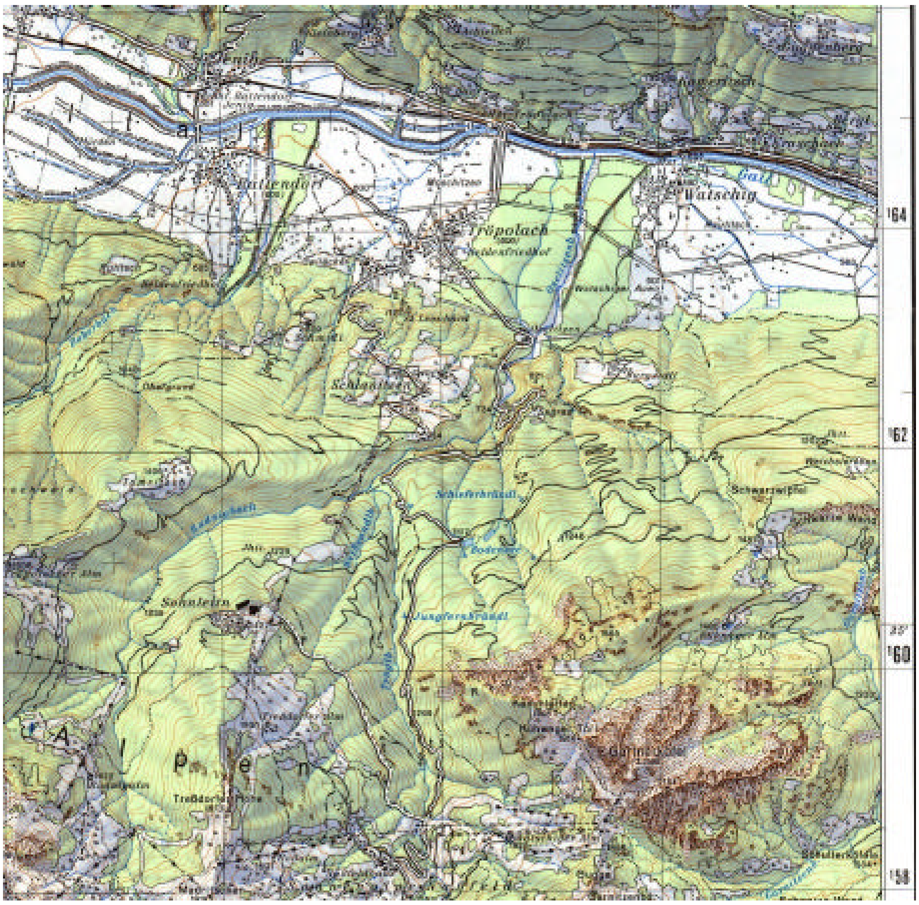

Figure 1 : topographic area

2 REGIONAL FRAMEWORK

2.1 *Climate*

Alpine-mountain climate (westward winds), influenced additionally by Adriatic lows.
Main rainfall in summer (> 50 % of annual precipitation), but even heavy rainfalls in Oct-Nov.
Annual precipitation 2963 mm/yr (one of the most intense rainfall areas of Austria, measured at a sea level of 1530 m)
Average annual Temperature: +7° C, minima : Jan.: - 18°C, maxima in Summer : +30°C.
Snow covering: depending on sea level: in 1000 m s.l.: Nov. – March, in 2000 m: Oct - May;
Snowfall is possible all over the year.

2.2 *Regional Morphology*

The Carnic Alps, making the border between Austria (county Carinthia) and Northern Italy are a East-West striking mountain chain up to 2700 m. The main valley (Gailtal, 600 m a.s.l.) in the north is parallel to these chains, whereas the smaller tributaries cut transverse through the structures by steep and narrow valleys, mainly cut after the last Ice age.

2.3 *Regional Geology and Structural Setting*

As a part of the Carnic Alps, the stratigraphical order starts with light metamorphic rocks (lower paleozoic), overlain by intensely folded and fractured schists(mainly sandstones and marlstones of Devonian-Permian Age). These complex is partly overlain by triassic sequences.

In the main valley of the Gailtal, near to the site, the continental tectonic divide of the "Periadriatic lineament" passes through (dividing the Northern from the Southern Alps from the Northern Italy to Slovenija). This leads to parallel faults to the periadriatic lineament (East-West), to some Riedel shears (diagonal) and extension joints (A-C- Joints, North-south).

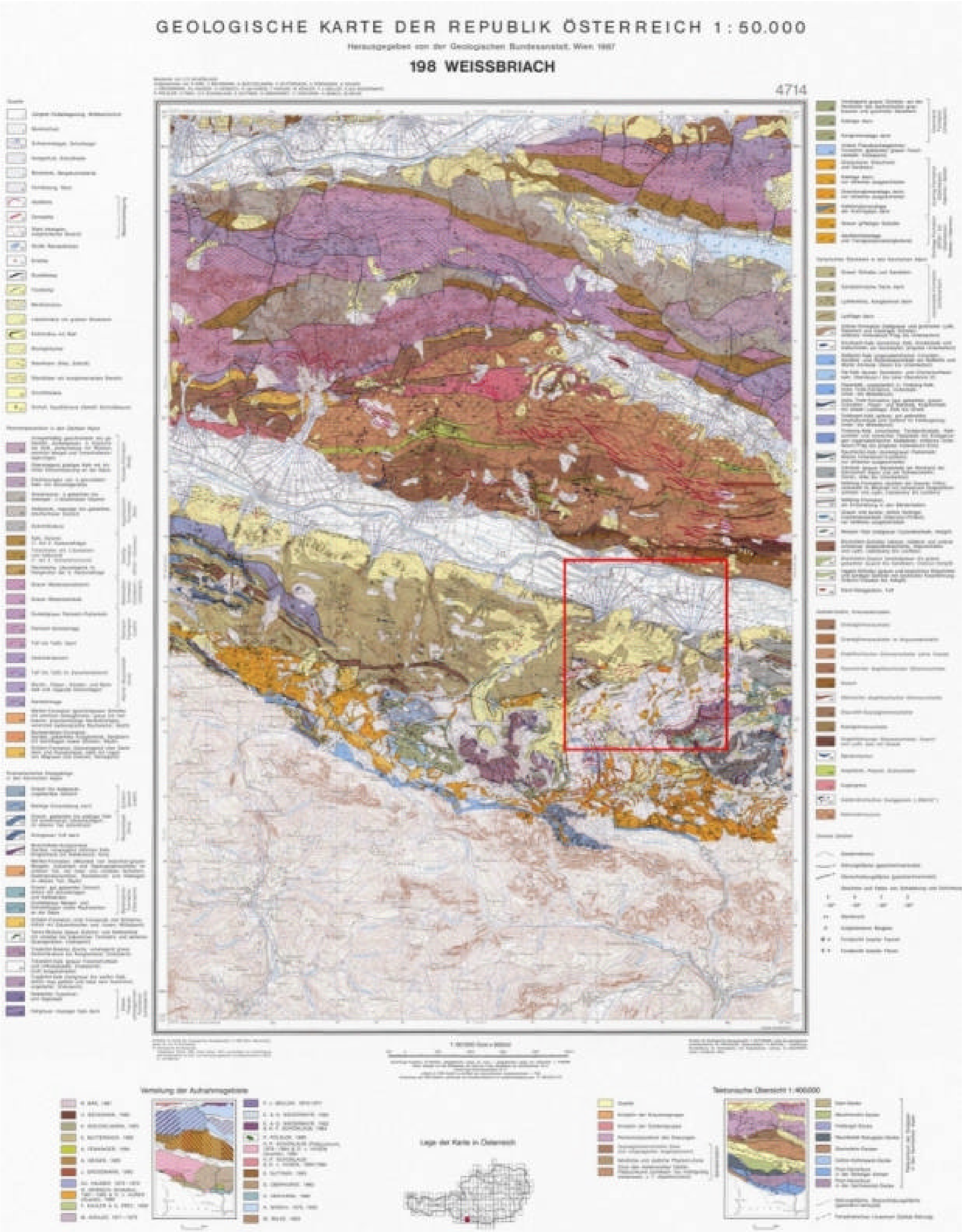

Figure 2: Regional Geology (SCHÖNLAUB, 1987)

3 LOCAL FRAMEWORK

3.1 *Local Geology and structural setting*

The project area covers an alpine valley with elevations ranging from 590 m to 2000 m within the catchment area of the Oselitzenbach.. The “rock menu” consists mainly of:

- Auernig-schists: Conglomerates, partly transgressive formed Limestone beds, partly conglomerates
- Hochwipfel-schists: dark greyish sandy-siltstones, scarcely calcareous. Well bedded, with interlayers of clayey material; partly graphtolith-schists. Mainly hard, and brittle behaviour.
- Rattendorfer Schists: limestones, dark, grey. Sometimes thin interlayers of siltstone.

Both stratigraphically and topographical above (outside the landslide area) there are also triassic sediments (limestones, marlstones, dolomites)

In the disturbed areas the Auernig- and Hochwipfel-schists cannot be precisely distinguished in the field. In this case they are summarised as the “Naßfeld-schists”.

The bedding planes are mainly dipping south, against the slope and the main scarp. The main fault zones are (sub-)parallel to the Periadriatic lineament (carving the main valley of the Gail river) striking WNW. The main joints are dipping steeply to NW.

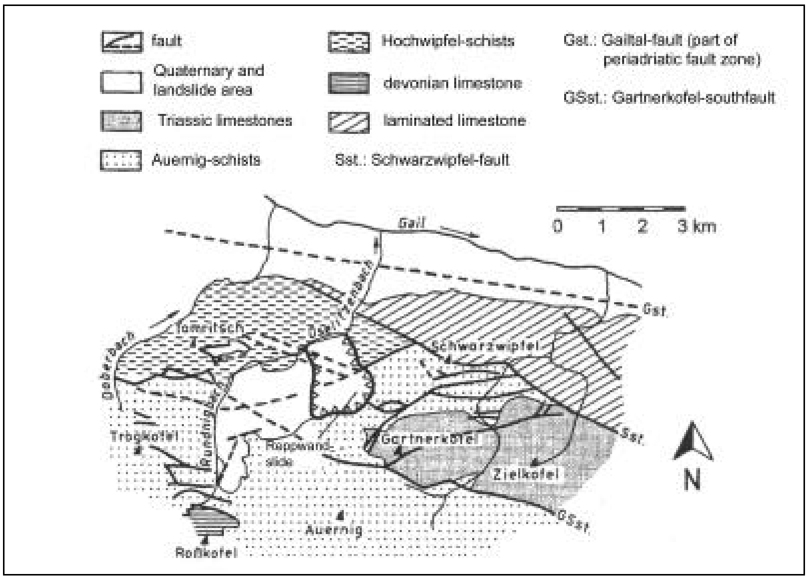

Figure 3: Local Geology (from WEIDNER, 2000)

3.2 *Water Conditions*

Groundwater conditions:

upper part: shallow infiltration, coming to daylight as springs in the middle part

In the lower part: water losses by deep rotational slide planes.

The groundwater velocities in the upper part are about 0,2-5 m/h (proved by a tracer test).

There are three horizons of springs: The highest horizon of springs lies between an elevation of 1150 and 1170m. In this horizon there are two lakes, the "großer Bodensee" and the "kleiner

Bodensee", additionally there are springs westward of the lake "großer Bodensee" and water outlets in the waterlogging zone eastward of the lake "kleiner Bodensee".

The area of the second horizon lies 20m deeper (1130-1150m), in the north of the lake "großer Bodensee".

In the third horizon there are many selective water outlets below the Naßfeld road(level 700-800).

The "bodensee" lakes lie in a small depression, made up by zones of movement. The greater lake is fed by 2 small tributaries and a small runoff river- the smaller lake has no tributary, but a small runoff (3-5 l/s).

4 LANDSLIDE

By the sagging mass of the Reppwand-landslide the valley floor of the Oselitzenbach became very narrow, the torrent eroded the toe of the mass, which increased the activity again.

Above the main scarp of the mass there are outcrops of massive limestones with steep slopes.

The morphology of the sagging area shows a very troubled surface with a diverse micromorphology.

Within the great Reppwand-slide there are several smaller slides, especially in the lower parts. The lowest part of the Oselitzenbach is a steep inclined valley to reach the deeper situated main valley of the Gail Valley.

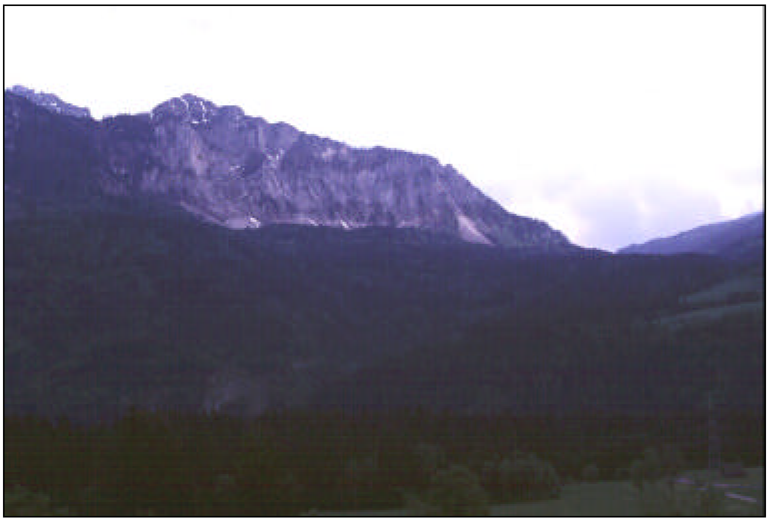

Figure 4: main scarp of the Reppwand-slide

4.1 *Landslide Identification*

The main scarp shows lower permian limestones (Trogkofelkalk) and Gröden sandstones and Bellerophon-schists (middle-upper Permian). The scarp is reaching from level 1700-1300, has an angle of 40° - the lower partial landslide mass reaches from level 1300-900, with an angle 15-17°. The covered area is about 3 Mio m², the estimated volume is 150 Mio. m³.

Within diverse homogeneous regions, there are different homogeneous regions, having different displacement rates. Since the measures were finishes in 1991, the displacement rates diminished.

Homogeneous region	1988-1991	1991-2000
“Seebach” above road	0,9 cm/month	0,5 cm/month
“Quellenbach”	1,3 cm/month	0,65 cm/month
Roadmaster hut	0,4 cm/month	0,35 cm/month

4.2 *Landslide Detail*

The main difference between the (faster) lower part to the upper part is in the clay content, which is higher in the lower part. The intensity or disaggregation is higher here, too.

The lower part, being the most active slide area, has a difference level of 165 m (from s.l. 1015-850m) and a depth of ca. 50 m. The travel angle is about 19°.

4.3 *Landslide Morphology*

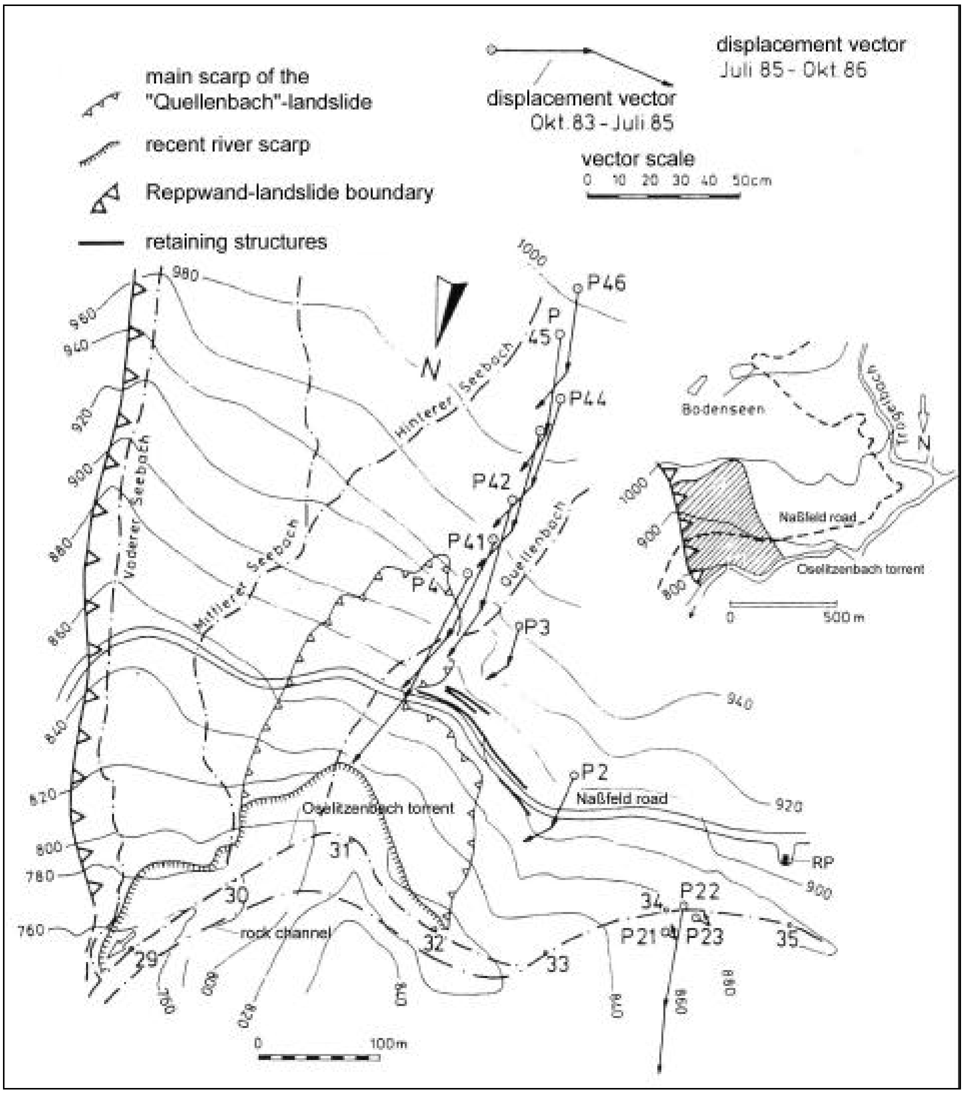

Figure 5: main scarps, landslide boundary's and retaining structures (from MOSER et al., 1988)

4.4 *Landslide History*

September 1983: Flooding in September 1983 led to massive gravel deposits at the alluvial cone of the Oselitzenbach, a cutoff of the Naßfeld road, and the destruction of old torrent control dams along the upper and middle course of the torrent "Rudingbach".

1985: Planning of an extensive construction programme carried out by the Austrian Service for Torrent, Erosion and Avalanche Control as a reaction to the events in September 1983.

August 1987: As a consequence to repeated flooding and the resulting advancing undercutting of the eastern toe of the landslide there was a run out of 60.000m³ in volume and resulting intense settlements up to some metres and formation of new cracks up to 30 m above the Naßfeld road.

1988: Realisation of the extensive construction programme. As a part of the construction measures a 400 m long channel was excavated in massive Hochwipfel formations as well as a filling up at the toe was made of the excavated material (about 170.000m³). Additional measures were:
- Drainage of the Quellenbach landslide between level 830-920 m and
- The draining off of the water, also above a level from 950m to the area of the Bodensee-lake.

Figure 6: on the left hand side : Reppwand-slide, in the middle: deviated river channel, foreground: Naßfeld road

Comparing the average values there has been a significant stabilisation after the finalisation of the construction measures in most areas. Periods A (1988 - 1991, before the construction measures) and B (1991 - 2000, after the construction measures) have therefore been compared showing the following:

- Areas of low velocity (< 5 cm/y) have significantly increased in period B, whereas zones of high velocity (>10cm/y) have decreased.
- Above the filling up an extensive stabilisation has been recorded in period B.
- The most active zone in both periods is the upper area of the Quellenbach-slide, which however shows a stabilisation as well in period B from 10-15cm/y down to 7-15 cm/y.
- Relatively high movements can still be observed east of the point RP below the Naßfeld road.

5 LANDSLIDE INVESTIGATION AND MONITORING

5.1 *Survey and monitoring of landslide activity*

8 boreholes, up to 52 m depth.
One equipped with inclinometer

Refraction seismics, 2 profiles:
three seismic layers: upper layer: 450-1200 m/s (disturbed rock) , thickness ca. 10 m
layer 2: v=1500-2000 m/s, weathered and jointed rock, thickness 10-50 m
layer 3: v= 3000-4000 m/s, jointed dock

Geotechnical Testing of the material (disturbes “Naßfeld-schists”, mainly clayey.
friction angle: 18°, cohesion = 14 kM /m²
Wn: 10,6 % (semi-stiff) to 34,3% (slurry)
WL: 22,5-26,4 %

Monitoring:
60 geodetic points, partly measured since 1985,
1 Inclinometer-probe type
1 wire extensometer, l = 45 m, digital monitoring, measures every 2 min.
9 convergence scanlines (fixed endpoints), measurement with steel tape (Fa. Soil instruments MK II) , accuracy 1/100 mm.

5.2 *Monitoring of meteorological and hydraulic conditions*

There are two meteorological stations:
1 station in the valley
1 station in the ski-area above the site (s.l. 1530) - both with daily Temperature and rain measurements.

6 MODELLING

The numerical investigations will be realised with FLAC3D and PFC2D of the Itasca Consulting Group. FLAC3D is used for modelling the continuum mechanics behaviour of the investigated area. PFC2D will be used for modelling the failure mechanism and the run out.

FLAC3D:
The FLAC3D-Model is based on the digital surface model of the BEV(Bundesamt für Eich- und Vermessungswesen) and the refraction seismic section. The seismic investigations gave a three layer structure which is implemented in the FLAC-Model.

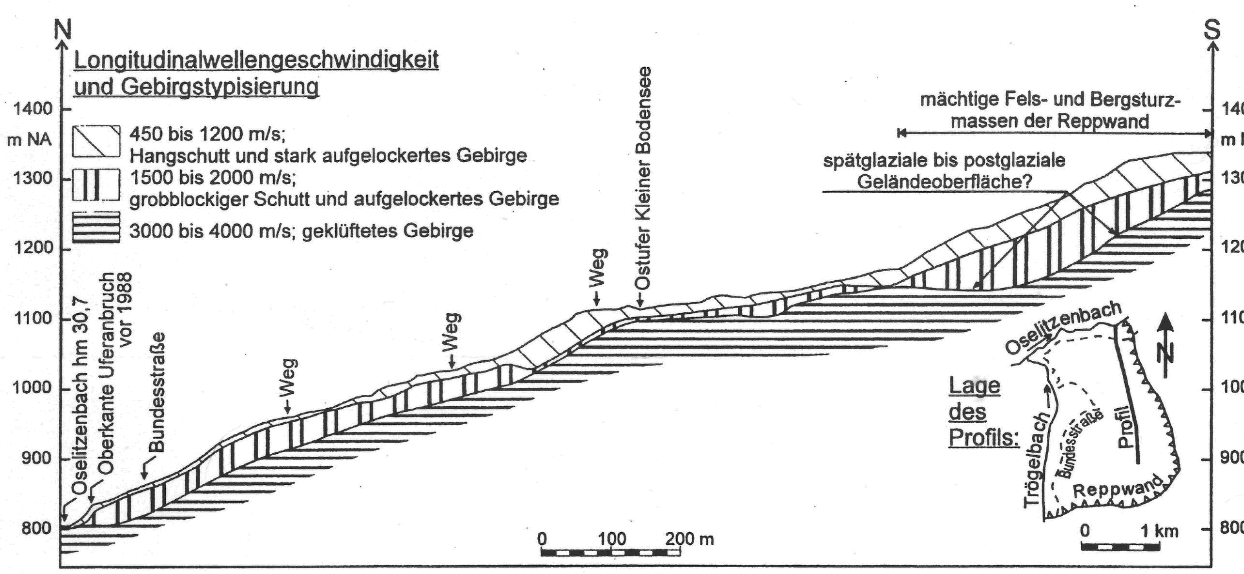

Figure 7: refraction seismic section (from WEIDNER, 2000)

PFC2D:
The location of the longitudinal section for the PFC analyses is based on the investigations by FLAC and the results of the geodetic observations.

7 STABILIZATION/PROTECTION WORKS AND LEGAL FRAMEWORK

Deviation of river:

As a consequence to repeated flooding and the resulting advancing undercutting of the eastern toe of the landslide the Oselitzenbach torrent got a new riverbed. Some meters to the north, the 400m long new bed was cut into the massive Hochwipfel formations under the left banks, those preventing the erosion at the sagging toe. A filling up at the toe was made of the excavated material.

Barriers:

Torrent barriers in the river to lower the inclination lines of the riverbed, thus reduce erosion processes.

Figure 8: debris barriers and river channel

Drainages:

The Drainage of the Quellenbach landslide between level 830-920m and also the draining off of the water above a level from 950m to the area of the "Bodensee"-lake.

8 LAND USE AND RISK ASSESSMENT/MANAGEMENT

8.1 *Land Use*

In the landslide area: wood, but downstream even fields, meadows, gardens.
Some 200 inhabitants in the two villages downstream of the landslide area. Farmhouses and agricultural land.
Intensely frequented road to ski areas and crossover to Italy

8.2 *Elements at Risk*

Spread out of landslide material by the torrent down to the villages, breakdown of the road, destruction of road, skilifts.

Since the deviation of the torrent near the toe of the sagging zone was done, the movements could be reduced to 3 cm/y. The risk doesn’t exist in the slope itself but especially in the downstream valley section. In the years 1983 and 1987, after heavy rainfalls, the toe of the mass movements was eroded with deposition of 300.000 m³ and 50.000 m³, respectively.

Nevertheless, even by the reduced movements the downstream villages of Tröpolach and Watschig in the main valley could be affected. Further the collapse of the slope could endanger the main road, the Naßfeld - Bundesstraße, which is a very important connection to another valley, the "Gailtal".

9 FIRST SCENARIOS

The first estimations for scenarios have been made without special investigations: without erosion of the toe the maximal spreadout of material could be ca. 150.000 m³.

In the case of erosion and undercutting by the torrent , max. 300.000 m³ could be activated.

In the model calculations special attention will be paid on the shear parameters of the "Naßfeld-schists", which are very sensitive in terms of water content.

The aim of the model calculations is to achieve concise runout models for different scenarios.

10 REFERENCES

GAMSJÄGER, L.: Geologisch-geotechnische Aufnahmen der Großhangbewegung Naßfeld, Gailtal/Kärnten. PhD thesis Uni Innsbruck (unpublished).

GLAWE, U.: Geologisch-geotechnische Untersuchungen an der Schlanitzenalmgleitung und der Bergzerreißung Treßdorfer Höhe (Karnische Alpen, Kärnten). Master thesis Uni Erlangen-Nürnberg unpublished.

GLAWE, U.; LOTTER, M.: Rock slope behaviour prior to failure at the Treßdorfer Höhe, Austria. In: Landslide news, Jg. 1997, H. 10, S. 11-14.

GLAWE, U.; MOSER, M.: Erste untersuchungsergebnisse zur Kinematik der Bergzerreissung Treßdorfer Höhe (Karnische Alpen). In: Jb. GBA, 132. Jg. (1989), H. 4, S. 629-644.

HÖTZL, H.; MOSER, M.; REICHERT, B.; RENTSCHLER, K.: Hydrologische Markierungsversuche in Massenbewegungen. Reppwandgleitung, Kärnten und Stubnerkogel, Salzburg. In: Steir. Beiträge z. Hydrogeologie, Jg. 1994, H. 45, S. 69-92.

KAHLER, F.; PREY, S.: Erläuterungen zur geologischen Karte des Naßfeld-Gartnerkofel-Gebietes in den Karnischen Alpen. Wien (GBA) 1963. (+ Erl. geol. Karten)

KRONFELLNER-KRAUS, G.: Beiträge zur Wildbacherosions- und Lawinenforschung. In: Ber. FBVA, Jg. 1990, H. 43, S. 7-24.

LOTTER, M.: Geotechnische und kinematische Untersuchungen an instabilen Felshängen im alpinen Raum. PhD thesis. Uni Erlangen-Nürnberg unpublished

LOTTER, M.; MOSER, M.; GLAWE, U.; ZVELEBIL, J.: Parameters and kinematic processes of spreading of mountain ridges. Aus: Moore, D; Hungr, O. (Hrsg.): Proc. 8th IAEG Congress Vancouver (Balkema, Rotterdam) 1998. S. 1251-1257.

MOSER, M.: Geologisch-Geotechnischer Bericht für 2000. Unter bes. Berücks. der Bewegungsmessungen (Per. 14-15, Juni 1999- Okt. 2000) Erlangen 2001.

MOSER, M.; ANGERER, J.; SEITZ, S.: Geotechnische Untersuchungsergebnisse im Rahmen des Verbauungsprojektes Oselitzenbach/Kärnten. In: Interprävent (Ed): Interprävent3, Graz 1988. S. 77-102.

MOSER, M.; GLAWE, U.: Das Naßfeld in Kärnten - geotechnisch betrachtet. In: Abh. Geol. BA, Jg. 1994, H. 50, S. 319-340.

MOSER, M.; WINDISCHMANN, TH.: Die Reppwandgleitung/Kärnten. Geologische und geotechnische Betrachtungen. In: Oberrhein. geol. Abh., 35. Jg. (1989), S. 157-176.

SCHÖNLAUB, H.P.: Geologische Karte der Republik Österreich 1:50000, Blatt 198 (Weißbriach). Geol.BA. Wien 1987

WEIDNER, S.: Kinematik und Mechanismus alpiner Hangdeformationen unter bes. Berücksichtigung der hydrogeologischen Verhältnisse. PhD Thesis.Uni Erlangen, 2000, unpublished

11 PICTURES

Figure 1 : topographic area 3
Figure 2: Regional Geology (SCHÖNLAUB, 1987) 5
Figure 3: Local Geology (from WEIDNER, 2000) 6
Figure 4: main scarp of the Reppwand-slide 7
Figure 5: main scarps, landslide boundary's and retaining structures (from MOSER et al, 1988) 8
Figure 6: on the left hand side : Reppwand-slide, in the middle: deviated river channel, foreground: Naßfeld road 9
Figure 7: refraction seismic section (from WEIDNER, 2000) 10
Figure 8: debris barriers and river channel 11