Documentation of the Disasters of August 2005 in Austria Caused by Floods and Slope Movements: Methods and Results


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Abstract

In August 2005 Austria was subject to a series of severe flood disasters. Several provinces (Styria, Tyrol, Vorarlberg) as well as the adjacent countries of Bavaria and Switzerland were hit by intensive precipitation caused by a low-pressure area rotating above the central Alps. Heavy rain falling on soils, already saturated with water, lead to excessive run-off and flood waves in large alpine watersheds. In some regions showers triggered lots of mass-movements on steep slopes (landslides, debris flows) (e.g. in the region of Gasen/ Styria). Some flood events reached extraordinary dimension, transporting huge amounts of gravel and debris and shaping the morphology of the river bed (e.g. Paznaun Valley/Tyrol). Immediately after the catastrophe the responsible Federal Ministry (BMLFUV) has ordered a comprehensive documentation of the events. This study was the first survey (in the field of torrent control) of a nationwide flood disaster in Austria so far. New standards for disaster documentation concerning the investigation methods, the registration procedure and the data management were introduced. The internationally developed procedure DOMODIS (Documentation of Mountain Disasters) was successfully used in a regular survey for the first time. The registration of every single events was carried out by means of an online web-portal integrated in the digital torrent and avalanche cadastre. The paper gives an overview of the procedures and results of the 2005 disaster documentation in Austria and summarizes the strategic consequences for future natural hazard protection. It will be a major goal to integrate disaster documentation as a standard procedure into the crisis management immediately after torrent and avalanche disasters in Austria.

Keywords: disaster documentation, flood event, mass movements, torrent processes, DOMODIS.
The flood disaster of August 2005: Processes and damages

The hydrologic event

A devastating flood disaster occurring between the 21st and 23rd August 2005 in Austria affected large parts of the country and adjacent areas of Bavaria and Switzerland. The unusual extension of this single precipitation event resulted from the dimension and movement direction of a cyclon migrating across Central Europe. The specific weather situation was characterized by an area of low pressure above Northern Italy, that separated from a trough of low pressure in the north of Europe. This type of weather situation is predestined to be the trigger of severe flood events in Austria (e.g. 1999, 2002).

On the 20th August 2005 this area of low pressure situated above the Gulf of Genoa was strengthening. It caused heavy rainfall in the south and southeast of Austria (in the provinces of Carinthia and Styria) first, and moved slowly across the eastern part of Austria to Czechoslovakia and Poland on the following day. According to the movement of the low pressure system the center of precipitation shifted to the northern Alps on the 21st and 22nd of August and was in addition intensified by a strong current from the north leading to concentration effects on the windward side of the mountain ranges. Due to the mild temperatures precipitation was stored as snow only higher than 2900 m above sea level, so most of the rain water was immediately effective for run-off. (GODINA ET AL. 2006) In the province of Styria the highest registered one-day rainfall during this event reached an amount of 105,6 mm only (total precipitation: 190 mm) which is equivalent to a recurrency interval of 3 years. Consequently the disastrous floods and mass movements of August 2005 were rather the result of a very strong saturation of soils after heavy rainfall during July and August regionally reaching an amount of 380 mm, which lies 80 % above the long-standing mean average value.

In the provinces of Tyrol and Vorarlberg soils were already saturated after heavy rainfall during the first half of August. On the 22nd of August it started to rain again, the heavy showers of rain lasted until the 23rd of August. The total precipitation for this period was between 50 and 240 mm being strongest in the windward parts of the Northern Alps (Lech Valley, Arlberg, Bregenzerwald). The spatial distribution of the rainfall intensity for Tyrol and Vorarlberg (Fig. 2) was in general corresponding the core areas of the flood disaster (Fig. 3 and 4). South of the Inn Valley as a rule the one-day precipitation was below 60 mm but local flood disasters were caused by flurries embedded in the strong northern current. One of these cells of heavy rain broke in the area of the upper Paznaun Valley and triggered a flood of enormous dimension in the river Trisanna (Fig. 1). The torrent catchment of Stubenbach on the south side of the Silvretta mountain range was also hit by this cloudburst and devastated the village of Stuben (Fig. 6) in the community of Pfunds (Upper Inn Valley, Tyrol). The highest area precipitation for a single torrent watershed was calculated with 164,6 mm for the Salaban in the community Vils (Tyrol).

Torrent processes According to the intensity and duration of rainfall, torrential flood events mainly occurred in large watershed areas (area more than 10 square kilometre). Flood waves were characterized by excessive peak discharge with extraordinary long duration and the capability to transport huge masses of gravel and debris which were eroded from river banks and bars. Sediments stored in the stream bed turned out to be a major source of bed load at this kind of events. High quantities of drift wood were transported in some rivers and streams too.

In most of the torrent watersheds that were subject to this event strong (drebis flood) or weak (fluvial) bedload transport was registered. Only few torrents reacted with typical debris flows, as the characteristic catchment-area for these processes lies below 2 square kilometres.

The registered data from torrent watersheds in the Tyrol gives evidence that the prevalent transport process (fluvial bed load transport, hyper-concentrated bed load transport, debris flow) is significantly related to the specific peak discharge (cubic meter per second and per square kilometre) of the flood wave and to the catchment area (square kilometre), as shown in fig. 5. According to this graph fluvial bedload transport characteristically occurs with a specific discharge below 5 cubic meter per second and square kilometer, above this threshold value sediment transport appears as hyperconcentrated flow or debris flow. (RUDOLF-MIKLAU ET AL., 2006)

The long duration of the flood waves and the huge masses of transported debris locally lead to an intensive deposition of sediments on alluvial fans. In few cases the sedimentation reached heights of several meters (e.g. up to 6 meters on the alluvial fan of the torrent Stubenbach in the community of Pfunds/Tyrol, fig. 6). Critical situations were also caused by a massive deposition of bed load at the confluence of rivers with their tributaries. The debris jam triggered a spontaneous reduction of the transport capacity in the torrent bed (tributary), causing the clogging of the channel and subsequently the flooding of adjacent areas. These processes as shown in fig. 1 were particularly destructive according to the dense settlement in the confluence areas or on the alluvial fans.

Mass movements (slumps, slides, debris flows on slopes) The characteristic types of mass movement,
Fig. 1. Flood disaster at the confluence of the river Trisanna and the Fimber torrent in the village Ischgl (Paznaun Valley, Tyrol).

which occurred during the 2005 event, were small slumps, slides and debris flows on steep slopes. However only few deep-seated rotational slides were registered. Regions with a high frequency and density of mass movements coincide with the core areas of the most intensive precipitation. Landslides and debris flows from slopes in large number occurred in the regions of Gasen (Styria), in the Kleinwalser Valley, in the Laternser Valley and the Bregenzerwald (Vorarlberg). (RUDOLF-MIKLAU ET AL., 2006) The process of these mass movements is mainly determined by hydrological, geological and hydro geological factors. During the 2005 events the most important reason for the triggering of mass movements was heavy rainfall on soils already saturated with water. The strong wetting of soils and the underlying unconsolidated rock (lose material) was the reason for a significant increase of gravity and a resulting reduction of shearing strength. The strong pore pressures finally lead to an efflux of soil in weak zones and triggered landslides and debris flows. Mass movements occurred preferably in areas with great hydro geologic risk (e.g. aquiferous layers, marshy grounds), but triggering of slides was also related to human action (e.g. side cutting by road construction, ground edges formed by agricultural activity, uncontrolled drainage). Naturally existing non-homogeneities in slopes (primary weakest points) have also contributed to the triggering of mass movements.

The prevalent process (mass movement) that occurred during the disaster of August 2005 can be described — with few exceptions — as “rotational slide in unconsolidated material”. A very frequent particularity of this process was the development of an initial rotational slide into a subsequent debris flow. Very often rotational slides reached down into the weathered layer overlaying solid rock. In these cases the solid rock was laid bare by the slide. However there were practically no mass movements observed with the slide face reaching into the solid rock. The existence of preformed sliding surfaces could only be proved for such slides that had the basis of the sliding surface situated in the upper weathering horizon overlaying solid rock.

The slope movements in the region of Gasen (Styria) — concerning their kinematics — were similar to the type “wet earth and debris flow”, described by BUNZA (1982). It is characteristic of these kind of slides, which mainly occur on slopes with an inclination of 20 to 40 degrees, that unconsolidated material is
spontaneously transformed to mash. The bedding of solid rock in parallel to the slope constitutes another prerequisite for the occurrence of this type of mass movement.

For the region of Gasen (Styria) 3 major types of mass movement were identified by frequency analysis (RUDOLF-MIKLAU ET AL., 2006):

Type 1  Rotation of slides with sliding surface at the boundary of unconsolidated material to solid rock

The sliding surface is identical to the boundary layer between the unconsolidated material and the solid rock.

Type 2  Rotation of slides without obvious preformed sliding surface.

Normally no preformed sliding surface can be identified.

Type 3  Initial rotational slides transforming into subsequent debris flow.

An initial slide is transformed into a mass flow which increasingly liquefies and moves down slope or through a ditch reaching high velocities.

The most frequent form of mass movement was a combination of the types 1 and 3 followed by the sole occurrence of type R1. The type R3 never was observed sole but only in combination with type 1 or 2. The destruction of building by this process was observed.
Fig. 3. and 4. Maps of the torrent watersheds in the Tyrol and Vorarlberg affected by flood events were the documentation of the 2005 flood disaster was carried out.

Fig. 5. Prevailing transport processes related to the specific discharge and the catchment area. (Data of the documented flood events on the 22nd and 23rd of August 2005 from selected torrent watersheds in the Tyrol) (RUDOLF-MIKLAU ET AL., 2006)
Three people were killed by the flood events and mass movements of the August 2005 disaster: 2 women died in a house destroyed by a debris flow (going out from an initial rotational slide — mass movement type 3) (Gasen, Styria), a third person was killed by a rock fall (single block of 40 cubic meter) in Längenfeld (Tyrol). Both accidents were the result of extraordinary mass movements, that hardly could have been forcasted.

However no person was killed by the devastating floods. It may be concluded, that the high level of safety in Austria concerning flood risks, which was reached by integrated protection measures, prevented even more losses.

Nevertheless the amount of damages in 2005 caused by torrents and mass movements in Austria was considerable (as is shown in table 1). The spatial distribution of the causes of damage was variable: While in Tyrol damages were mainly caused by torrent processes, in Styria only mass movements were causal for damages. In Vorarlberg both, torrents and mass movements, resulted in severe destruction. The damage to buildings was concentrated to few, very excessive events (e.g. torrent Stubenbach, torrent Zürsbach, mass movements in Gasen and Haslau).

Disaster documentation 2005: Methods and procedure

Standards and procedure of disaster documentation

Torrent and avalanche disasters were registered and documented in Austria since centuries. Thus for a few torrents an extensive chronicle of former floods is available. However no general standards for the documentation procedure were introduced in Austria so far and a full-coverage registration system for all events has been established only recently.

Based on Swiss experiences (MANI AND ZIMMERMANN, 1992; EGLI ET. AL., 1997) first steps
Table 1. Balance of damages caused by torrents and mass movements in August 2005 in Austria. (RUDOLF-MIKLAU ET. AL., 2006)

<table>
<thead>
<tr>
<th>Type of damage</th>
<th>Floods/Torrent processes</th>
<th>Mass movements</th>
<th>Total damages</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>destroyed</td>
<td>damaged</td>
<td>total</td>
</tr>
<tr>
<td>Public buildings</td>
<td>number</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Private buildings</td>
<td>number</td>
<td>0</td>
<td>157</td>
</tr>
<tr>
<td>Hotels and guest houses</td>
<td>number</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Industry and trade buildings</td>
<td>number</td>
<td>1</td>
<td>17</td>
</tr>
<tr>
<td>Agricultural buildings</td>
<td>number</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>Other buildings: huts, garages</td>
<td>number</td>
<td>4</td>
<td>44</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>6</strong></td>
<td><strong>261</strong></td>
<td></td>
</tr>
</tbody>
</table>

Among experts there is no doubt about the importance of disaster documentation, as this is the only favourable method giving real evidence of torrent processes and their effects. The major challenge is to perform an efficient and comprehensive disaster documentation immediately after the event in a catastrophe area.

At first methods for disaster documentation have to offer criteria for the selection of events worth to be documented. As a rule, in torrent catchments the documentation is focused on events, that caused human losses as well as damages (destruction) of buildings, traffic ways, infrastructure, other economic values or protection measures. But also events showing processes of extraordinary dimension or characteristic might be worth for documentation.

Disaster documentation needs to be integrated into the crisis management without obstructing rescue operations or urgent measures. Special trained experts, that are not directly involved in the rescue operation, have to carry out the field surveys in close coordination with the head of operations and the rescue services.

Decisive for the quality of a documentation is the availability of a standard for the parameters and informations that have to be recorded (documentation standards) and an efficient and secure system of data registration (database) including the localization and temporal allocation of the event.

Undoubtedly disaster documentations have to be carried out short after the event. For reasons of the efficiency the first phase of documentation covers only a minimum set of information including the “Who, What, When and How” of an event (5W-standard) in order to reach a full-coverage survey as soon as possible. Only in a second phase a documentation of all processes which have occurred in the torrent catchment (area of disaster) and all damages is performed (5W+ standard). It is reserved for a further phase to document in detail processes and damages of specific interest in selected (catchment) areas using special methods and technology. The process of disaster documentation is completed by the compilation of the data and the preparation of a report. The analysis of documented events represents an own procedure separated from the documentation.

A Web-based online registration for torrent and avalanche events (part of the digital torrent and avalanche cadastre) was recently established in Austria (Online Disaster Registration). With this software tool it will be possible in future to register data either short after the survey via a WWW-portal or even immediately in the field by radio data transmission using handheld recording instruments. The prototype of this online disaster registration was successfully applied in the documentation of the 2005 flood event for the
first time. It contains online forms with all relevant parameters that have to be recorded and enables the documentalist to localize the event (setting a dot) on the Austrian map scale 1 : 50,000. After the registration of all documentated events it was possible to submit the compiled data for processing and reporting.

The disaster documentation 2005

According to the extraordinary extent of the 2005 disaster, affecting three provinces of Austria, a documentation was ordered and supervised by the Federal Ministry for Agriculture, Forestry, Environment and Water Management (BMLFUW). The documentation included two levels of investigation:

- A General Documentation of all events in torrent watersheds and all mass movements, that caused significant damage (selection due to the DOMODIS criteria) based on the 5W-standard.

- Detailed Documentation of selected events, that caused extraordinary damage or showing processes of specific interest.

The General Disaster Documentation was organised as an interdisciplinary project employing torrent controllers, geologists, hydrologists, geographers and foresters from several institutions (Federal Service for Torrent and Avalanche Control, University of Natural Resources Management and Applied Life Sciences Vienna, Federal Research and Training Centre for Forests, Natural Hazards and Landscape). In general 488 single events (203 torrent events and 285 mass movements) were surveyed and registered in the online web-portal. The result of this documentation was a comprehensive data base including the most important information about all events of the 2005 flood disaster.

In addition to the general documentation a Detailed Disaster Documentation of selected events (torrent watersheds and regions) was carried out. This documentation was planned to gather as much information as possible on the causes and development of the event, the ongoing processes and the consequences (damages) caused by the disaster. The detailed documentation of natural disasters counts among the most important sources of information for the planning of efficient protection measures. The mapping of natural hazards is dependant on realistic scenarios for future disasters, which only can be developed from a detailed knowledge of natural processes.

9 torrent catchments and the mass movements of Gasen (Styria) were selected for detailed documentation. This process also included the evaluation of existing hazard maps in comparison to the recorded events.

The results of the disaster documentation were published by the Federal Ministry of Agriculture, Forestry, Environment and Water Management as an official report (RUDOLF-MIKLAU ET AL., 2006).
Contents of the disaster documentation

The survey for the detailed disaster documentation was based on a defined set of parameters (data), which covers all relevant information, that describe the development and progress of the event: * hydrological data — precipitation: total rainfall 3 days before the event, mean and maximum rainfall on the day of the event, development of the precipitation before the event.

- hydrological data — run-off, discharge and bedload transport: maximum discharge at defined cross-sections, total mass balance of the transported sediment (debris potential), bed load transport profiles, sedimentation profiles, grain size distribution of the bed load (debris).

- processes, that occurred during the event (process routing): transportation processes, erosion processes, debris flows.

- survey (mapping) of the area of flooding/deposition, height of debris deposition.

- description of the effectiveness protection measures, damage to protection measures.

- balance of damage to buildings, traffic lines and infrastructure, human losses.

Experiences from the 2005 disaster documentation

The documentation of the 2005 disaster was predominantly successful and resulted in valuable experiences for future application cases. It soon turned out to be vital for the quality of the documentation to have a pool of well trained and experienced documentalists available, which can be employed without bureaucratic obstacles, as local experts are hardly available being involved in the crisis management. Thus it is planned to establish a specific training program for this function in the near future.

Very important were also a uniform process for the selection of catchment areas worth for a documentation and an efficient coordination of all actions taken. Minimal standards for the parameters and information to be registered were indispensable although some problems occurred concerning different precision and interpretation among the documentalists. A detailed briefing at the beginning of the field works is recommended.

It was necessary to provide aerial photographs and measuring equipment immediately in order to guarantee an efficient field work.

The online registration of data following uniform standards was widely successful but cannot replace a careful quality control in advance. The 5W-standard offered enough information for basic reporting and statistics, but it clearly turned out that compared to the survey itself the actual time consuming procedure was traveling. It may be concluded that it makes sense to gather as much data as possible already in the first phase of the survey. Austrian standards take into account this need for flexibility and allow the collection of other information in addition to the 5W-standard (obligatory minimum standard).

An other important experience was that the reporting also has to be done by the documentalist themselves following a provided scheme. The process of analyzing the disaster should start immediately after the documentation process in order to preserve the collected knowledge.

Conclusions (strategic consequence) from the disaster documentation

The documentation of the 2005 disaster and the analysis of the results have proved the great importance of the “lessons learnt” from past catastrophes for successful precautions in future. Thus disaster documentations should be integrated as a standard procedure into the crisis management and be carried out immediately after an event. In order to reach this goal comprehensive standards and methods for the data registration and documentation procedure have to be developed as well as the organisational prerequisites have to be created. An online registration for all kinds of natural hazards (events) should be developed and implemented in Austria.

The results of the disaster documentation 2005 lead to the following strategic consequences:

- Successful disaster documentation presupposes the cooperation of all institutions involved in the crisis management notwithstanding separated competences. The survey teams have to gain access to the disaster area as soon as possible after the event. The corresponding legal and organisational problems
have to be solved (such as the insurance of risk or the access permission by the authorities in charge).

- Methods to describe the frequency and intensity of natural processes (disasters) have to be urgently improved. Regular disaster documentation serves as a primary source of information for this task.

- Standards and guidelines in hazard mapping and risk management have to be currently adapted to the results of the documentation and analysis of disasters. In general a current adoption of technical standards for natural hazard protection to the “lessons learnt” from documented disasters should be striven.

- Research and development in order to solve open questions and further improve investigation methods concerning the documentation of disasters have to be intensified.

- The results of disaster documentation should be easily accessible for political and administrative decision makers and serve as a basis for strategic steering of natural hazard management.

- The results of disaster documentation and analysis should also be easily accessible for the public (people affected by natural hazards) in order to improve awareness and acceptance of natural risks.

- The results of disaster documentation should be integrated as a major source of information into the development of crisis intervention planning.

- The documented effects of disasters on existing protection measures should be integrated in the development and planning of new measures and protection concepts.

- The current evaluation of existing hazard maps after disaster events should be implemented as a regular procedure.

- From the ecological point of view investigations should also focus on the impact of disasters on the condition and development of the eco-system as well as on the morphology of rivers and torrents in correlation to human demands on the use of water and protection.

References


