

1<sup>st</sup> Regional Symposium on Landslides in the Adriatic-Balkan Region

3<sup>rd</sup> Workshop of the Croatian-Japanese Project 'Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia'

# Landslide and flood

hazard assessment

March 6-9, 2013 / Zagreb / Croatia

## ABSTRACT PROCEEDINGS

Editors: Snježana Mihalić Arbanas and Željko Arbanas

1<sup>st</sup> Regional Symposium on Landslides in the Adriatic-Balkan Region  
3<sup>rd</sup> Workshop of the Croatian-Japanese Project 'Risk Identification and Land-Use  
Planning for Disaster Mitigation of Landslides and Floods in Croatia'

## LANDSLIDE AND FLOOD HAZARD ASSESSMENT

Zagreb, Croatia, 6-9 March 2013

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City of Zagreb, Emergency Management Office  
University of Zagreb  
University of Rijeka, Faculty of Civil Engineering  
Niigata University, Research Institute for Natural Hazards and Disaster Recovery  
Kyoto University, Disaster Prevention Research Institute (DPRi)  
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Pavle Kalinić  
Jadranka Veselić Bruvo  
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## **Abstract Proceedings**

**Editors:**

Snježana Mihalić Arbanas

Željko Arbanas

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University of Rijeka, Faculty of Civil Engineering

Niigata University, Research Institute for Natural Hazards and Disaster Recovery

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University of Zagreb, Faculty of Agriculture

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Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan

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Faculty of Civil and Geodetic Engineering, University of Ljubljana, Slovenia

## **Kyoji Sassa**

International Consortium on Landslides and Kyoto University, Kyoto, Japan

## **Alexander Strom**

Geodynamics Research Centre – branch of JSC “Hydroproject Institute”, Moscow, Russia

## **Fawu Wang**

Research Center on Natural Disaster Reduction, Shimane University, Matsue, Japan

## **Yosuke Yamashiki**

Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan

## **Robert Župan**

Faculty of Geodesy, University of Zagreb, Croatia

The authors are responsible for contents of their abstracts



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# Opening Ceremony

Thursday, 7 March 2013, 9:30-9:40, Hall A, City Assembly

## Intermediate outputs of the Croatia-Japan joint research project on “Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia”

**H. Marui**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**ABSTRACT:** In the previous year so-called “Intermediate Evaluation” of the Croatia-Japan Joint Project was carried out first by JICA and then by JST. It is necessary and important to have common understanding at this occasion of the Workshop among all research members concerning the current intermediate outputs of the Joint Project. The Croatian-Japanese joint research team shall develop a methodology of land-use planning in order to mitigate disasters caused by landslides and floods through the basic scientific study of mechanism and through the risk identification method which is suitable for Croatian society and natural conditions. The purpose of the joint research project is to develop an integrated landslide/flood hazard mapping technology and land-use guidelines formulation methodology for nation-wide application in Croatia. The final purpose should be attained through the following three research steps: (1) Methodologies for landslide risk assessment, prediction of affecting areas and early warning are developed adapting to hydrological and geological conditions in Croatia. (2) Flash-flood/debris-flow simulation models and early warning systems are developed adapting to hydrological and geological conditions in Croatia. (3) Integrated landslide/flood hazard maps and land-use guidelines for landslide/flood risk mitigation are developed for target areas. Almost all individual research items in the first two steps (1) and (2) are already accomplished. The following items are intermediate outputs already attained through the Joint Project: (1) Aerial photos were purchased for target areas in Croatia. Individual landslide topographies in each target areas were identified based on the photo interpretation of landslide topography. Further, the danger degree of the each individual landslide topography was evaluated by the Analytical Hierarchy Process (AHP) method. (2) Comprehensive monitoring system on landslide movements was installed in Grohovo landslide area near Rijeka and also in Kostanjek landslide area in Zagreb City. (3) Prediction of travel distance for selected landslides was carried out using shear strength parameters measured by the newly developed portable ring shear apparatus. (4) Simulation methods on flash-floods and debris flows were developed. (5) Flood discharge monitoring system was installed in selected target areas. (6) Flood risk was analyzed by the advanced distributed hydrological model. In addition to the research items capacity buildings and technology transfer are also important aspects of the Joint Project. Croatian young researchers were invited to several training courses prepared in Japan for capacity building. 1st and 2nd Regional Workshops were organized in Croatia for technology transfer to the neighboring countries. Now at the last stage of the Joint Project, the research team is going to formulate the integrated landslide/flood hazard map and then to make up land-use guideline for target areas.

# Session WG1: Landslides

Thursday, 7 March 2013, 10:20-12:30, Hall A, City Assembly

CHAIRS: KYOJI SASSA (KYOTO UNIVERSITY, INTERNATIONAL CONSORTIUM ON LANDSLIDES) AND ŽELJKO ARBANAS (UNIVERSITY OF RIJEKA)

## WG1-01 – Manual of transportable ring shear apparatus, ICL-1

**M. Oštrić**

*Graduate School of Engineering, Kyoto University, Kyoto, Japan*

**K. Sassa**

*International Consortium on Landslides, Kyoto University, Kyoto, Japan*

**K. Ljutić, M. Vivoda**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**B. He, K. Takara**

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**ABSTRACT:** A new Croatia-Japan Joint Project “Risk identification and land-use planning for disaster mitigation of landslides and floods in Croatia” was initiated in 2009. A new transportable undrained ring shear apparatus, ICL-1, was designed for laboratory soil test and landslide simulation test as a part of Project activities. The aim of ICL-1 was to develop much inexpensive and transportable undrained ring shear apparatus to be used in different counterpart organizations with a standard electricity available anywhere.

To make this apparatus effectively and practically used in Croatia and also in other countries, a detailed manual has been made based on the experiences of students and researchers invited from Croatia to Japan. This paper introduces the manual including the concept, design and construction of this apparatus as well as test procedures and data analysis.

The ring-shear apparatus was designed to investigate the residual shear resistance under the drained condition along the sliding surface at large shear displacements in landslides because it allows unlimited deformation of the specimen. Sassa et al have developed undrained high speed ring shear apparatus (DPRI-5, 6, 7) to reproduce a rapid landslide motion after failure and to measure the generated pore pressure and the shear resistance mobilized on the sliding surface during motion. It needs high electricity and the great capacity of servo-motor of 37 kW to shear soils at a high velocity up to 2-3 m/sec in the center of the sample. High velocity required a high power motor and a great size of apparatus. However, the series of test results presented that the generated pore pressure and the mobilized shear resistance at the steady state motion is hardly affected by the velocity, but they significantly depend on the shear displacement.

The developed transportable ring-shear apparatus (ICL-1) has weight of app 100 kg, maximum height of 95 cm, and dimensions 50x50 cm and it is set on a handcart. The dimensions of the sample box are 100 mm of inner diameter and 140 mm of outer diameter. The significant reduction in dimensions of the latest apparatus was possible because of smaller shear velocity and new loading system in which the normal stress is loaded by pulling the central axis of the apparatus. The large and tall loading frame to give vertical load is not necessary. The shear velocity of ICL-1 is only 5.4 cm/s. The 200 W servo-motor is used for normal stress loading and the 400 W servo-motor is used for shear stress loading. Electricity is single phase 100 V or 200 V. Beside the smaller dimensions, ICL-1 can succeed to maintain undrained condition up to 1 MPa of pore water pressure which is almost double than in previous apparatus (300-350 kPa of pore water pressure

in DPRI 5, 6 and 7 apparatus). This became possible because of new loading system with a short loading axis and higher precision of upper and lower ring height; and the smoothing of inner and outer rubber edge height.

Since one of the goals of this apparatus was to be transportable and used in Croatia, the modifications were made in order to be easily maintained outside of Japan. Most of these modifications have practical meaning. Rubber edges can be easily replaced because they are not pasted with glue, but fixed by screws through a Teflon ring and a stainless steel ring. In original design of DPRI apparatus, full round length of annular metal filters with pore sizes of 100  $\mu\text{m}$  and 40  $\mu\text{m}$  (from inside) were pushed and placed inside the annular gutter. Those metal filters were often filled with mostly used fine grained materials taken from Croatia. In ICL-1 apparatus, a half round length of 100  $\mu\text{m}$  and 40  $\mu\text{m}$  filters were fixed by screws, which has enabled filter changing and cleaning, only by unscrewing of the gutter. The height of the lower half of the shear box can be adjusted by adding porous metals so it can be used for testing of low permeable soils, like it is the case in the tested Croatian landslides.

## **WG1-02 – Manual of LS-RAPID numerical simulation model for landslide teaching and research**

**B. He**

*Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan*

**K. Sassa, O. Nagai**

*International Consortium on Landslides, Kyoto University, Kyoto, Japan*

**K. Takara**

*Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan*

**ABSTRACT:** LS-RAPID is user-friendly landslide simulation software based on the program, “Integrated Landslide Simulation Model”, produced by Kyoji Sassa (International Consortium on Landslides). It can assess the initiation and motion of landslides triggered by earthquakes, rainfall or the combined effects of rainfall and earthquakes. It is the first simulation model to reproduce the initiation process and the runout process from stable state until deposition within the same model. The model is based on the key parameters; the shear resistance at the steady state, the peak friction angle, cohesion, the shear displacements at peak and the onset of steady state, the lateral pressure ratio with physical meaning, which can be measured or estimated from experiments. It uses a visual interface which enables the user to input topography parameters, sliding surface parameters, and parameters of soil characteristics to simulate results in 3D. It is designed to be easily operated by both experienced and first time users. The latest one, Version 2.02 Beta17, has been developed in 2012. Currently, it has been used in different cases of landslides, including large scale submarine landslides, urban long travel landslides, and subaerial megalandslides triggered by earthquake and heavy rainfall. In this paper, the English manual of LS-RAPID numerical simulation model is introduced. Firstly, the detailed steps about how to use LS-RAPID were described based on an example of the simple slope landslide. The procedures of generating LS-RAPID format topographical DEM data, creating sliding surface topography using ellipsoidal method, defining the soil parameters, setting the landslide simulation conditions and viewing the 2D or 3D results of landslide results have been introduced. Then, four cases studies including the Leyte Landslide (Philippines), the Suruga Bay Landslide (Japan), the Grohovo

Landslide (Croatia) and the Kostanjek Landslide (Croatia) were described. Core parts of the manual are introduced in this paper.

## **WG1-03 – Application of integrated landslide simulation model using LS-Rapid software to the Kostanjek Landslide, Zagreb, Croatia**

**K. Gradiški**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia*

**K. Sassa**

*International Consortium on Landslides, Kyoto University, Kyoto, Japan*

**B. He**

*Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan*

**M. Krkač, S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia*

**Ž. Arbanas**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**M. Oštrić**

*Graduate School of Engineering, Kyoto University, Kyoto, Japan*

**P. Kvasnička**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia*

**ABSTRACT:** This paper describes numerical modeling of the Landslide using the LS-Rapid software. The Kostanjek Landslide is located in the western part of the City of Zagreb, in residential area at the base of the southwester slope of the Mt. Medvednica. It was initially activated in 1963 after approximately  $2.1 \times 10^6 \text{ m}^3$  excavated marl for cement production in the foot of the slope. The excavation in the quarry stopped in 1988, but the landslide remediation was never done. According to Stanić and Nonveiller (1996) possible causes for the landslide activation may be extremely high pore pressures and/or the dynamic effects caused by the excavation of marl by mass blasting.

The analyses using LS-Rapid software were made for three different triggering factors i.e. excess pore water pressure, earthquakes and combination of these two effects, and it was applied for two different cases.

The first case is used to re-examine the landslide model for the Kostanjek landslide reported by Ortolan (1996), Mihalinec and Stanić (1991) and Stanić and Nonveiller (1996). This model was based on results of the drained ring shear tests using the Bishop type ring shear apparatus, in which pore water pressure was not monitored and the zero pore water pressure generation in the shear zone was assumed. In this case it was used the peak shear strengths and the residual shear strengths reported by Stanić and Nonveiller (1996) as the peak shear resistance and the steady state of shear resistance assuming the zero excess pore pressure.

In the second case for the Kostanjek Landslide model confirmation will be used model in which the sliding surfaces will be initially developed within the soil mass. During the initial shearing, the excess pore pressure would be often generated during the landslide activations by triggering factors and the post failure-motion of landslide. The strength parameters used in this analysis

were derived from tests in undrained ring shear apparatus carried out by Oštrić et al. (2012) and Sassa et al. (2012). It is expected that results of the Kostanjek Landslide simulation using LS-Rapid software and parameters obtained from undrained ring shear apparatus should give more realistic results those would be used for better understanding of the Kostanjek Landslide behavior.

## **WG1-04 – Mineralogical composition of the Kostanjek landslide sediments and its possible influence on the sliding and swelling processes**

**J. Martinčević**

*Croatian Geological Survey, Zagreb, Croatia*

**S. Mihalić Arbanas, M. Krkač**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**S. Bernat**

*Associate Researcher, Zagreb, Croatia*

**Ž. Miklin, L. Podolszki**

*Croatian Geological Survey, Zagreb, Croatia*

**ABSTRACT:** The Kostanjek landslide was activated in 1963, when it was noticed substantial damages on buildings and infrastructure facilities in the residential zone, as well as on factories and commercial buildings in landslide foot. The landslide was mainly caused by anthropogenic factors, including massive uncontrolled blasting for mining purposes and excavation in a marl quarry at the foot of the hill. According to the results of the first geotechnical investigations, swelling of the marl layers unloaded by the excavation was identified as a possible cause of the damages. Several years later, in 1976, Nonveiller analysed the incurred movements and concluded that the displacements could not be caused by swelling process. Excavation in the quarry was stopped in 1988 after intensive mining activities those were identified as the main triggering factors of the landslide. Geological model of the Kostanjek landslide was developed by Ortolan in 1996 on the basis of geotechnical investigations which can be summarised as follows: engineering geological mapping from 1984; exploratory drilling from 1931, 1972 and 1988; geophysical surveys in boreholes from 1988 and seismic reflection survey from 1989. According to Ortolan's model from 1996, the Kostanjek Landslide is a complex landslide with three sliding surfaces: (1) sliding surface with maximum depth of 50 meters on lithological contact between thickly and thinly bedded marls, (2) sliding surface with maximum depth of 65 meters along thin layer of clay in thinly bedded marls, and (3) sliding surface with maximum depth of 90 meters on the contact between thinly laminated clayey marls and coarse grained rocks from Sarmatian age. Ortolan's model was based on the correlation of data from four boreholes. The main criteria which were used to define that model were stratigraphical identification of rocks and plasticity index of marls. This landslide model is in use even today as a base for design of remedial measures.

One of a key point in the investigation and interpretation of landslides behaviour is the role of mineralogical composition in physical and mechanical soil properties, and sensitivity of landslide sediments to swelling. The main aim of this work was to investigate mineralogical composition of sediments from the Kostanjek landslide area which is one of the pilot areas of Croatian–Japanese joint research project on “Risk Identification and Land – Use Planning for Disaster Mitigation of Landslides and Floods in Croatia”. This research encompassed the following activities: review of

existing data from mineralogical analyses carried out by Balen et al. in 1975, and Slovenec in 1989; both on samples which stratigraphically belong to the Lower Pannonian and Sarmatian ages; mineralogical analyses performed on samples collected from B-1 borehole drilled in 2011; establishing relationships of results obtained by mineralogical analyses with results of laboratory testing of physical and mechanical properties on samples taken from B-1 borehole.

Based on microscopic observations of 6 samples from the Bizek and Sloboda quarries, Balen distinguished two types of marl: (1) marl with homogenous structure without visible lamination; and (2) thin laminated marl with visible alteration of calcite-rich and clayey-rich layers. Calcite component in these samples varies from 57.30 – 82.90%. X-ray diffraction analyses on these samples, as well as on core samples carried out by Slovenec (in 1989) indicate presence of the following minerals: calcite, quartz, aragonite, micas, pyrite, plagioclase, chlorite, clay minerals (kaolinite, illite, smectites) and amorphous minerals.

The total depth of B-1 borehole, drilled in the frame of Croatian–Japanese project is 100 meters. In the borehole core the following groups of material types differ: engineering soil (0-10 meters), Quaternary age; massive marl (10-45 meters), Upper Pannonian age; marl intercalated with limestone (45-60 meters), Lower Pannonian age; varved clay also known as “Tripoli” sediments (60-100 meters), Sarmatian age.

Mineralogical analyses were performed on 17 samples collected from the B-1 borehole; samples K1–K3 represent engineering soil, coarse to fine grained. Samples K4–K11 represent massive marls which are recognized as fresh, slightly weathered and strongly weathered. Sample K12 represents marl intercalated with limestone while samples K13–K17 represent thin laminated varved clays (“Tripoli”) recognized in two forms: flat laminated and wavy laminated.

Mineralogical analyses were obtained by X-ray powder diffraction method (XRD) on random and oriented mounts of air dried material, and after glycol treatment and heating to 400°C and 550°C. The analyses were performed in Croatian Geological Survey on PANalytical X-ray diffractometer X’Pert PRO.

First results of x-ray diffraction analyses show a bulk composition of each engineering geological unit. In most samples are predominant sheet silicates, followed by carbonates and quartz. Dolomite and pyrite occur in some samples at trace levels. Smectite component is present in all samples and it is the most abundant among clay fraction.

# WG1-05 – Geochemical constraints on the origins of groundwaters from the Kostanjek landslide in the western part of Zagreb, Croatia

**S. Yamamoto**

*Department of Geology, Faculty of Science, Niigata University, Niigata, Japan*

**N. Watanabe**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**M. Krkač**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**G. Furuya**

*Faculty of Engineering, Toyama Prefectural University, Toyama, Japan*

**C. Wang**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**ABSTRACT:** Most of groundwaters from the Kostanjek area in the western part of Zagreb, Croatia are hydrochemically characterized by Ca-HCO<sub>3</sub> type because aquifer lithologies in the research area are composed of calcareous strata such as limestone and several types of marls. It is useful for understanding the mechanism of the Kostanjek landslide that the origin and behavior of groundwaters in the research area is revealed using hydrochemical tracers. On the basis of slight difference of hydrochemical characteristics, we classified water samples of 74 ground waters, 11 spring waters from the mining tunnel and 7 stream waters into four types by cluster analysis as follows; (1) Type-A is typical Ca-HCO<sub>3</sub> type water, (2) Type-B is weaker water in Ca-HCO<sub>3</sub> component than type-A, (3) Type-C is Mg-rich Ca-HCO<sub>3</sub> type water, (4) Type-D is Mg-Ca-HCO<sub>3</sub> type water. Both type-A and type-B waters are predominately distributed over the research area and are closely related to the shallow aquifer lithologies. Type-A waters are derived Ca<sup>2+</sup> and HCO<sub>3</sub><sup>-</sup> from the marl aquifers. Type-B waters are formed by the mixing of Type-A water with dilute subsurface water from soil zones where soluble solids were removed during weathering processes. Type-C waters are limitedly distributed around the eastern margin of the landslide and Type-D waters are discharged from fissures in the dolomitic rock in the inner part of the mining tunnel. In particular, Type-D waters from the tunnel are more enriched in Mg<sup>2+</sup> and depleted in Sr<sup>2+</sup> than type-C waters in the landslide. For this reason, it is most likely that the dolomitic rock is a main source of Mg<sup>2+</sup> in waters. The isotopic compositions of δ<sup>18</sup>O and δ<sup>2</sup>H of all waters from this area plot close to the local meteoric water line although type-D waters are depleted in δ<sup>18</sup>O and δ<sup>2</sup>H comparing with others. These isotopically depleted compositions suggest that type-D waters are recharged in the higher area of the northern dolomitic mountains and migrate through dolomitic aquifer to the depths of the landslide mass. Here we should pay attention to the formation of type-C waters because there is no dolomitic rock in the Kostanjek area and the massive dolomite is distributed in more than 1,000 m north away from this area and also underlies in more than 200 m depth beneath the landslide mass. Type-C waters show a tendency to be slightly depleted in δ<sup>18</sup>O and δ<sup>2</sup>H comparing with type-A and type-B waters. This result and graphical plots of Mg/Ca vs. Sr/Ca ratios of waters indicate that type-C waters are formed by the mixing of type-A and type-B waters with type-D waters ascending from the deep dolomitic aquifer. Continuous intrusion of artesian waters from the deep aquifer has an impact upon the

groundwater behavior in the landslide mass and is also one of the key factors controlling the landslide susceptibility.

## **WG1-06 – Analysis of water fluctuation dynamics in the wider area of the Kostanjek landslide**

**M. Krkač**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**J. Rubinić**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** The Kostanjek landslide is the biggest landslide in Republic of Croatia with total volume of  $32 \times 10^6 \text{ m}^3$ . In the frame of Croatian-Japanese scientific project on 'Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia' (2009-2014), it was established initial monitoring system at the Kostanjek Landslide which encompasses: geotechnical, geodetical and hydrological monitoring. The subject of this paper is hydrological monitoring, established in 2011 and analysis of monitoring results for two-year period, 2011-2012. This monitoring consists of rainfall measurement using tipping buck rain gauge, and water fluctuation measurements at the two locations: (i) exit of the transportation tunnel which passing through the landslide body; and (ii) Dolje stream spring, in the abandoned Bizek Quarry, outside the landslide body. Measuring of water fluctuation dynamics included indirect monitoring of groundwater discharge using water level sensors for continuous measurements and current meter for periodical measurements. In 2012, hydrological monitoring becomes more comprehensive. Additional two water level sensors have been installed in wells for continuous measuring of the shallowest aquifer water level. In this paper measured hydrological monitoring data from the period 2011 to the end of 2012 are presented together with results of water fluctuation analysis. Based on performed analyses, the interrelationships between rainfall regime registered at the area of the Kostanjek landslide and rainfall measured on meteorological station Zagreb-Grič, situated in the central part of the Zagreb city in similar geomorphologic environment, were established. Analyses also enabled establishment of the relationship of rainfall data measured at the landslide with water leakage data from the tunnel and Dolje stream, and between rainfall data and water level fluctuations in wells, so as relationships between measured data at all hydrological monitoring stations. The aim of the analyses was to the find out relationships between water fluctuation rates and groundwater discharge related to precipitation values, as well as estimation of the discharge dynamics of groundwater reserves using Maillett recession analysis method.



# WG1-07 – The Kostanjek landslide - Monitoring system development and sensor network

**M. Krkač, S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**O. Nagai**

*International Consortium on Landslides, Kyoto, Japan*

**Ž. Arbanas**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** The Kostanjek landslide is an example of reactivated deep-seated large translational landslide formed in soft rock-hard soil, e.g. marls. Landslide velocities have been changing in last 50 years, from landslide activation till today, in range from extremely slow to very slow. Initial landslide was developed as a consequence of loss of global stability of gentle to steep slopes placed above open pit mine of marl and cement factory 'Sloboda' in urbanized western suburb of the City of Zagreb. Slope movements were caused by mining activities, i.e., undercutting of slope toe and uncontrolled massive blasting. Following the initial slow movements that caused settlements and fractures of industrial cement factory objects in 1963, and damaging numerous private houses at the area of approximately 1 km<sup>2</sup> in very short period, attention shifted to unstable slopes above cement factory known as Kostanjek landslide.

Although numerous surface exploration and visual studies were undertaken between the 1966 and 2010 the rudimentary nature of the monitoring undertaken did not provide conclusive evidence regarding the rate and extent of the movement of the Kostanjek landslide. Recently, more detailed assessments were carried out in the frame of the Japanese-Croatian scientific bilateral project 'Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia' to assess the status of the historical monitoring points on the area of landslide, assess the hazard of a slope movement, and review the options for updated instrumentation to monitor movements of the landslide. Based on the joint research of Croatian-Japanese scientists from the period 2009-2011, the Kostanjek landslide monitoring project activities were initiated; this included installation of the instrumentation in a two-year period 2011-2013.

In this paper the general design of the integrated monitoring system of the Kostanjek landslide will be briefly presented. A comprehensive integrated real-time monitoring system has been installing as a part of the research activities in the Croatian-Japanese bilateral project on landslides from 2011. The monitoring system will consist of 40 sensors for geodetic, hydrological and geotechnical monitoring. Equipment for landslide monitoring at the surface and in the underground will include: 15 precise GNSS rovers, long- and short-span extensometers, pore pressure gauges in boreholes, water level gauges in wells, rain gauge, weather station and accelerometers aimed at monitoring of landslide triggering factors. All monitoring equipment will be connected in one system with continuous monitoring and data transmitting to the central data unit. Installation of the system will be finished in 2013. All measurements will be integrated in GIS monitoring software for landslide risk management and early warning system. Establishment of an early warning system and defining of alarm thresholds will be based on existing cognition of the Kostanjek landslide behavior so as from collected consequent comprehensive monitoring data.

# WG1-08 – Geographic information system of landslide Kostanjek: integration of real-time GNSS monitoring data with other sensor data

**M. Baučić**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Croatia  
Geodata d.o.o., Split, Croatia*

**S. Mihalić Arbanas, M. Krkač**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**ABSTRACT:** Geographic information system (GIS) of landslide Kostanjek has been developed with the primary objective: integration of real-time GNSS monitoring data with other sensor data. At first, the broader information architecture has been designed. The main users, functions and subsystems are identified. The four subsystems are: GNSS monitoring, Measurements, GIS and Alerting. The identified GIS subsystem functions are: storing geodata, integrating and visualizing geodata from other subsystems, geo-analyzing, preparing views and downloads. The prerequisite for integration was to establish connection to GNSS monitoring data and to store, read and geolocate other measurements data.

The GNSS monitoring data is transferred to server via communication devices. Trimble T4D monitoring software resides on server and manages with GNSS data in MS SQL database. To integrate and visualize GNSS monitoring data, GIS Subsystem is connected to MS SQL database and it reads GNSS data of 5 predefined types. The measurements are geolocated to 15 GNSS devices installed at 15 fixed poles at the area of 1.2 km<sup>2</sup>.

Measurements subsystem contains different types of measurements coming from geodetic, geotechnical and hydrological sensors covering more than 50 locations at the area of the Kostanjek landslide: 37 stable geodetic points temporarily measured by GNSS; 9 extensometers, 1 inclinometer, 7 accelerometers, 4 water level sensors and 1 rain gauge. Data is stored in sensor specific device (e.g. data logger, memory card), and using sensor specific data format and structure (e.g. CSV file format). Measurements data is now exported from the sensor manually, by copying file from sensor data logger or memory card to server. To avoid accidental deletion or overwriting of data, manual procedures and scripts are developed. All imported measurements files are registered in new developed Measurements database together with sensor data and location of measurements. To integrate and visualize measurements data, GIS subsystem reads sensor specific data stored on sever as files of various format. Additional functions are developed for reading sensors data.

The GIS subsystem functions are realized using ESRI ArcGIS software. An ArcGIS map is created and it shows topographic data, landslide features, GNSS monitoring data and other measurements data. The users can use all the ArcGIS functions for creating their own maps and analyze geodata. GIS database is created and stored on server. Creation of e-services (viewing and downloading) for external users will be considered later.

The improvement of existing system will be to automatically transfer data from the sensors to the server. In order to achieve this it is necessary to add communications equipment to each sensor, and to install an application to server that will import and store measurements in a database.

The effort described here has proved all the complexity of collecting different types of data for landslide characterization and monitoring. There are also additional types of data collected from time to time (e.g., seasonally) by sampling in the field (e.g., water level measurement, chemical and mineralogical content of water, rock and soil etc.). Here, we coped only with data and all its heterogeneity. The main advantage of data integration into one GIS system is to enable consistent and reliable framework for long-term archiving of all types of data which will be used in further analyses. We hope that we will continue with analysis. Landslides are dynamic features of reality, and as such require advanced models of spatiotemporal data, spatiotemporal analysis and spatiotemporal reasoning.

## **WG1-09 – Residence-time of groundwater from flysch formation at the Grohovo Landslide in the Rječina valley, Croatia**

**N. Watanabe**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**K. Asai**

*Geo Science Laboratory Co., Ltd., Japan*

**G. Furuya**

*Faculty of Engineering, Toyama Prefectural University, Toyama, Japan*

**C. Wang**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**Ž. Arbanas**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** Chlorofluorocarbons (CFCs) are useful tracers for age dating of young ground water and spring water. However, the dating groundwater using CFCs is a minor approach in the landslide researches. The CFCs concentrations of two ground waters from the observation wells of W-1 and W-3 in the foot part of Grohovo landslide in the Rječina valley, Croatia were measured in order to better understand the groundwater behavior in the landslide mass. Both ground water samples have detectable concentrations of CFC-12 (186-259pg/kg), CFC-11 (191-384 pg/kg) and CFC-113 (12-20 pg/kg), suggesting that these were mainly recharged after the 1970s. These CFCs concentrations under the oxidative environment usually indicate a simple relationship showing  $CFC-11 > CFC-12 > CFC-113$ , CFC-11 is approximately two times larger than CFC-12, reflected by the concentration of atmospheric CFCs and solubility of CFCs. However, CFC-11 and CFC-12 concentrations in each sample are relatively close to each other's value. Under the reductive environment, some kind of bacteria can break out CFC-11 and CFC-113 so that both CFC-11 and CFC-113 were reduced during the ground water circulation. Therefore, we accepted the data of CFC-12 concentration for age dating of ground waters. Assuming that the average temperature and altitude of recharge area are 11°C and 400 m a.s.l, the groundwater ages of W-1 and W-3 are calculated in comparison of equivalent air concentrations (EAC) of the groundwaters with the historical atmospheric concentrations. Apparent ages of waters from W-1 and W-3 are respectively 31 and 24 years old based on the piston flow model (PFM). Other ages of W-1 and W-3 are respectively 38 and 19 years old estimated by the exponential mixed model (EMM). Both ground waters are hydrochemically characterized by Na-SO<sub>4</sub> type because ground waters migrate

through the  $\text{Na}_2\text{SO}_4$ -rich flysch formation. Both Na and  $\text{SO}_4$  in water from W-3 is less concentration than those of the older water from W-1 because of dilution with much younger  $\text{Ca-HCO}_3$  type water in the overlain limestone formation.

## **WG1-10 – Remote monitoring of a landslide using an integration of GPS, TPS and conventional geotechnical monitoring methods**

**Ž. Arbanas, V. Jagodnik, K. Ljutić, M. Vivoda, S. Dugonjić Jovančević**  
*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** Case studies of monitored complex landslides presented in scientific papers are numerous but, owing to variability of landslide types and behavior, goals of investigation, field conditions and the ongoing technological development of monitoring sensors, no standardized approach regarding the setting up of a monitoring system can be adopted as an universal solution. The monitoring results should provide a basis for develop and validate confidential numerical models and adequate hazard management. There are a lot of examples used in landslides practice those used different techniques and different devices (sensors) to monitor landslides activity. The use of multiple devices (sensors) at same points and for the same purpose (equipment fusion) should be very useful to guarantee redundancy of measurements that can prevent loss of data if one instrument fails. Selection of the same position for different type of monitoring devices (sensors) will also enable spatial correlation of measurement data on the landslide surface and trough the landslide profile. Using of geodetical and geotechnical equipment fusion in combination with hydrological monitoring equipment, which should be consisted of pore pressure gauges and pluviometer or/and weather station, enable reconstruction of the relationship between rainfalls, groundwater level and appropriate landslide behavior as a basis for early warning system establishment. In beginning of the an early warning system establishment, the most important step is to link device measurement and possible failure mechanism and consequences those should following the sliding occurrence (the landslide risk). Based on presumptions described before, an advanced comprehensive monitoring system was designed and applied on the Grohovo landslide. The crucial role in equipment (and sensor fusion) selection was based on scientific requirements; the equipment fusion request was based on consideration of possible ranges of monitored values and sensors precision. Establishment of an early warning system and defining of alarm thresholds should be based on existing cognition of the Grohovo Landslide behavior so as from collected comprehensive monitoring data. The focus of the early warning system establishment at the Grohovo Landslide must be on effective device combination (equipment fusion) results with respect to device malfunction detecting and reduction of false alarms in the future. Reliability of an early warning system is dependent on the weakest link in the system. The weakest link in the Grohovo monitoring system is power supply and data transmitting from the field PC, where all field data are collecting, to the control room at the Faculty of Civil Engineering University of Rijeka.

In this paper the main ideas and advances of the monitoring equipment fusion so as weaknesses of the monitoring system at the Grohovo Landslide will be presented. Based on 18 months period of measurement results the weaknesses of existing monitoring system were located and necessary

improvements are analyzed. Without these improvements, the future early warning system will be vulnerable and reliability of the system will be too low to use it as a practical application.

## **WG1-11 – The Grohovo Landslide Monitoring System - Experiences from 18 months period of monitoring system operating**

**K. Ljutić, V. Jagodnik, M. Vivoda, S. Dugonjić Jovančević, Ž. Arbanas**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** The Grohovo Landslide, the largest active landslide along the Croatian part of the Adriatic coast, is located on the north-eastern slope of the Rječina Valley. In 2009, the Croatian-Japanese research joint project “Risk identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia” was initiated and the Grohovo Landslide was chosen as a pilot area for a monitoring system development. A comprehensive monitoring system was designed, consisted of geodetical and geotechnical monitoring equipment which installation was started in March 2011, and in major part completed till the end of 2011. Integrated monitoring system generally can be divided in two major parts. One part is geodetical, consisted of GPS system (9 rovers and 1 master unit), and robotic total station with 24 geodetical prisms. Second part is geotechnical one, consisted of pore pressure gauges, inclinometers and extensometers. Establishment of the monitoring system was carried out in stages according to monitoring equipment purchasing process and its delivery. Installation of inclinometer casings and pore pressure gauges was started in March 2011, and foundations and poles for long span extensometers finished in May 2011. Main part of geodetical monitoring equipment was installed in July 2011.

After monitoring system was powered up and turned on, several problems in equipment functioning were observed and equipment re-adjustment was carried out until the end of November 2011. Installation of long span extensometers was completed until the end of 2011, while the short span extensometers, vertical extensometers and pore pressure gauge data loggers were installed during the year 2012. Observations from geodetic prisms with robotic total station and GPS system are collected and processed in the automated integrated monitoring system software. Geotechnical part of the equipment (long and short span extensometers, pore pressure gauge, rain gauge) should be included in the same integrated system during February and March 2013. During the first 18 months of monitoring system was being operating, equipment calibration, system improvement and maintenance took considerable part of the system establishment. The first 12 months period of data collection was needed for understanding relation between disturbing effects and their causes and procedures for calibrating equipment and eliminating effects of weather impacts on measurements accuracy was established. Seasonal meteorological and atmospheric conditions influenced on the system not only from the measurements point of view. Extreme temperatures during late June and whole July 2012 influenced in uneven bending deformation of the main pillar which affected on total station's position and leaning, and consequently - its measurements. During the spring and summer time, vegetation blocked the view from the total station to the several prisms located in the forested part of the landslide. While solar panel system for GPS rovers at the landslide are sufficient for electric energy production, hybrid power system consisted of 1 kW solar panels and 500 W wind

mill located at Veli vrh, during the late autumn and winter is not able to efficiently produce enough electric energy to keep main computer workstation, robotic total station, GPS, web camera and wireless network system continuously working, especially during continues cloudy days. However, collected measurement data are sufficient for observing the landslide in whole period, because of their consistent data trends and correlation between different data sets. In this paper previously mentioned issues and problems are closely described, as well as solutions for them that we carried out to maintain the monitoring system for successful continuous work.

## **WG1-12 – Terrestrial laser scanning and slope movement monitoring, Croatian experiences**

**I. Žižić**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Split, Croatia*

**B. Kordić**

*Faculty of Geodesy, University of Zagreb, Zagreb, Croatia*

**G. Vlastelica**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Split, Croatia*

**ABSTRACT:** In this paper the usage of terrestrial laser scanning for the purpose of landslide monitoring in Croatia will be presented. Locations defined as pilot areas of Croatian-Japanese collaboration project “Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia” are used as examples. Terrestrial laser scanning (TLS) is one of the most interesting and promising surveying techniques for slope movements and rockfall monitoring on large active geological sites. Slope movements and deformations measured with the TLS can be detected by means of comparison of sequential scans in different time periods. In this study Optech ILRIS pulse-3D Terrestrial Laser Scanner is used. Data are collected on four pilot location defined by the Japanese-Croatian project: Grohovo, Kostanjek, Duće and Omiš.

All input parameters for scanning (such as raster of points, the number and location of TLS station, stations marks etc.) were defined at the Žnjan testing site, located in Split. Also, a number of tests were made in laboratory conditions at Faculty of Geodesy in Zagreb and Faculty of Civil Engineering, Architecture and Geodesy in Split.

The Žnjan Testing location is an unstable cut which has noticeable changes in geometry due to rockfalls and erosion. Main goal of this test is to find a mean of calculating and presenting the results of change in geometry of the cut. The amount of that change was presented in terms of volume difference between two data sets which were collected in a six month time period. Another method of presenting that difference was a comparison of cross-sections of the cut. Both methods will be presented in the article.

Guided by this example, the necessary input parameters were defined for scanning the pilot locations. For the Duće location only two stations for slope survey were selected. A first station was on breakwater where it was possible to scan the whole area. Disadvantage of this scan is relatively large distance from the slope considering the expected displacements and deformations. Therefore, the second station was much closer to the slope, from where a small part of the same slope was scanned.

Location in Omiš is an example of monitoring of rockfall phenomena. The whole area of Omiš was scanned from two stations, with different distances to the scanned surface. Purpose of these tests

was to define the optimal distance for this type of slope. After scanning the whole area, the several potentially unstable blocks on the slope were chosen for detailed observation. It is assumed that their movement will be significant before the loss of stability.

The Grohovo Landslide area consists of two landslides located on the opposite slopes of the Rječina Valley, the northeastern and southwestern slope. Apart from being sequential monitored with TLS, landslide on the northeastern slope is also permanent monitored with GPS, total station, vertical inclinometers, pore pressure gauges, long and short-span extensometers. Classical geodetic methods of monitoring enable highly accurate measurements at discrete points. On the other side, the TLS allows periodical measurements of landslide surface. Therefore in the future it will be interesting to analyze the collected data by these different measurement techniques and interpolation between different types of data. Southwestern slope of the valley is monitored only with TLS, where input parameter for raster of measured points is much denser than the northeastern, because of increased caution in its possible geological activity. Distance between station and landslide surface is about 800 – 1000 m.

The Kostanjek landslide is also permanent monitored and scanned with TLS. Due to characteristics of the Kostanjek landslide, only the surface at the eastern part of cut in the abandoned marl quarry was scanned. Distance between station point and cut is about 300 m. Station point is also in the landslide area near to permanent GPS station.

## **WG1-13 – Rockfall monitoring by terrestrial laser scanning - Case study of the rock cliff at Duće, Croatia**

**G. Vlastelica, P. Mišćević**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Croatia*

**ABSTRACT:** Dalmatia region in Croatia has dozens of registered active rockfall zones. Virtually whole area along main coastal road from city of Split to town of Omiš is a potential danger zone for inhabitants and community infrastructure. Every year, in periods after heavy rain and/or considerable low air temperature, many sudden rockfalls in these areas are recorded. Stabilizing and managing the entire area without localizing potential threats would require considerable funding, which private owners and local communities cannot afford, so more suitable method for forecasting and detecting potential rockfalls is needed.

For this study a specific location named Luka in Duće area is selected. Slope over Luka location is made of Eocene flysch, which is covered by a relatively thin and hard layer of breccia. Main component of flysch is marl, a rock material which is prone to weathering when submitted to atmospheric agents. As a result of weathering, surface formed of weaker marl is deteriorated and eroded with rain. A layer of a harder breccia remains and in time start to form "cantilevers" on the slope. With the development and elongation of joints in these "cantilevers", parts of breccia start to fall off in large blocks.

LiDAR (Light Detection and Ranging) is an optical remote sensing technology used in Terrestrial Laser Scanners. TLS are often used to perform periodical monitoring in large landslide and rockfall areas. In this study Optech ILRIS-3D with enhanced range was used. Scanning was performed from two scanning positions. The first position is located at the breakwater of a local marina that has a complete overview of the slope. The second position is located at the bottom of the slope which ranges as the shortest distance to the target area. Scanning from both positions was repeated in 3

months interval. In both cases first scan is georeferenced and it will be used as a reference scan for comparison of all future periodical monitoring at this location. Comparison of the two scans was made by using IM Survey module of Polyworks software and the results are presented in the article.

Except for detecting unstable blocks at steep slopes, this temporal model of surveying can also be applied for observing erosion process in marl in this area. In combination with the results obtained by a spectroradiometer, some of previously mentioned triggering factors for rockfalls in these materials could be better understood. Non-destructive proximal in-situ stationary quantitative measurements of marl reflectance were performed using portable field spectroradiometer TerraSpec 4 Hi-Res (ASD Inc., USA) with wavelength range from 350 to 2,500 nm. So far investigations have proven that in the process of weathering gypsum is being formed on crack walls and the surface of marl. As does the first tests with spectrometer suggest development of gypsum, as a significant indicator of a degree of weathering in marls, can be observed and detected by means of spectroscopic analyses.



# Session WG3: Hazard Mapping

Thursday, 7 March 2013, 14:00-15:30, Hall A, City Assembly

CHAIRS: HIDEAKI MARUI (UNIVERSITY OF NIIGATA) AND SNJEŽANA MIHALIĆ ARBANAS (UNIVERSITY OF ZAGREB)

## WG3-01 – Overview of historical landslide inventories in the Podsljeme Area, Zagreb

**L. Podolski**

*Croatian Geological Survey, Zagreb, Croatia*

**S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**Ž. Arbanas**

*University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia*

**Ž. Miklin, J. Martinčević**

*Croatian Geological Survey, Zagreb, Croatia*

**ABSTRACT:** Landslides are, together with earthquakes and floods, one of the main natural hazards with significant consequences around the world and generally tend to occur repeatedly and more often than other types of hazard. Because of this reason, it is important to collect continuously historical and up to date data about landslide occurrence, as an input data for any further analyses for the purpose of landslide susceptibility, hazard and risk assessment. These data are usually collected in the form of landslide inventories. Landslide data to form a landslide inventory must contain all available data about multiple landslide occurrences from different time periods in encompassed area. It is preferable for landslide inventory to have a detailed description of each landslide in the area and at least some basic data about date of activation, type, activity, mitigation measures, etc. These data are necessary to define and explain spatial distribution and temporal landslide activity at the study area. Landslide inventory maps could be different according to their purpose, size of research area, map scale and availability of historical data. Preparation of landslide susceptibility, hazard and risk maps are recommended for any urban and land-use planning of modern cities in areas and zones subjected to sliding.

The area of the City of Zagreb covers 640 km<sup>2</sup> and it is still not adequately documented by geohazard thematic maps which can be used in land-use planning. The lack of a landslide inventory in the Podsljeme area (south-east hilly area of the Medvednica Mt.) with systematic records of historical and present landslide occurrences is one of the most important drawbacks which disable safe land use planning regarding landslide risk. The geotechnical archive of the City of Zagreb with collection of landslide data contained in geotechnical documentation was in function only between 1961 and 1993 but after this period, this kind of City's achieve was never established. To establish a comprehensive landslide inventory for the area of the City of Zagreb it is necessary to collect all existing data about landslides, and one of important sources should be historical landslide inventories. There are three historical landslide inventories available for the area of the City of Zagreb (obtained from three major City studies) which can be valuable sources of historical data. Identification of landslides in these studies was mainly carried out by geomorphological field mapping, using conventional mapping method. In all of these three studies the hundreds of landslides were identified at the area of more than 100 km<sup>2</sup>. All of identified

landslides were caused by two main triggering factors: heavy rainfalls and anthropogenic factors mostly related to construction activities, e.g., change of slope geometry. To establish a high-quality and useful landslide inventory for the hilly area of the City of Zagreb it is necessary to analyze and review historical landslide data contained in existing inventories. This is also necessary step before using them for analysis of landslide susceptibility, hazard and risk.

## **WG3-02 – Derivation of historical Land Cover Map based on digital orthophoto images of the Zagreb Area**

**N. Belić**

*Associate Researcher, Zagreb, Croatia*

**S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**D. Gajski**

*Faculty of Geodesy, University of Zagreb, Zagreb, Croatia*

**D. Šiško**

*City of Zagreb, City Office for the Strategic Planning and Development of the City*

**ABSTRACT:** Land Cover Map was made based on digital orthophoto images classification. The objective of the research was to develop a land cover map with emphasis on using open source GIS software and existing, available input data. With the approval of the City Office for Strategic Planning and Development in Zagreb, digital orthophoto images were used for classification and processing. The automated supervised classification method was applied, using open source software MultiSpec and GRASS GIS. Both applications can be downloaded via the Internet free of charge. ESRI's ArcGIS was used for Land Cover Map layout development and spatial analyses.

Digital orthophoto images of Zagreb area from 2007 were used as an input data. Besides the orthophoto images, a clip of the project's test area was made, and was also used for classification. Automated supervised classification was performed on 18 color digital orthophoto images and clip of the test area. The scale of orthophoto images was 1:5,000, the resolution was 6,000 x 4,500 pixels, and spatial resolution was 0.25 square meters per pixel. For the research purposes, resolution was changed to 3,000 x 2,250 pixels, and spatial resolution was changed to 1 square meter per pixel.

MultiSpecWin32 (developed by prof. David Landgrebe and Larry Beihl at Purdue University in Indiana, U.S.A.) is the system used for interactive analysis of multispectral satellite (Landsat) and space hyperspectral image data and aerial photographs of the Earth (AVIRIS), and also has important applications in the processing of digital images in medicine. GRASS (Geographic Resources Analysis Support System) is an open source GIS, originally developed by the U.S. Army (1982-1995). Since 1997 it is developed by an international team of scientists and experts gathered in the OSGeo (Open Source Geospatial Foundation), a non-profit organization whose mission is the promotion and development of geospatial technologies and data.

Automated supervised classification was applied to the orthophoto images using MultiSpec and GRASS GIS software with maximum likelihood and SMAP (sequential maximum a posteriori) option. Each of the 18 orthophoto images covers the area of 6.75 km<sup>2</sup> and the total area amounts to 121.5 km<sup>2</sup>. The images consist of RGB channels (Red, Green and Blue) with absence of NIR (Near Infra - Red) channel. Using the NIR channel would increase NDVI (Normalized Difference

Vegetation Index), which would improve classification results for the green channel, and differentiation of vegetation cover type. However, the classification resulted in differentiation of three basic types of land cover: urban areas, high vegetation areas and low vegetation areas.

First results were relatively accurate, but with no clear class distinction. Due to software imperfection, within one class value, pixels with other class values were scattered. This problem was solved with GRASS GIS, using a combination of different raster processing algorithms. The key was to process each class separately, as a bitmap file. After processing, classes were put together to make a final result - a land cover map with three separate classes. Disadvantage of this approach is relatively small number of classes which due to absence of NIR channel. One of the advantages is using automated classification which increases the overall speed of map developing process. Other advantages are the availability of data and software and its financial feasibility.

Resulting land cover map (with 3 classes: urban areas, high vegetation areas and low vegetation areas) was compared with the official land use map of the City of Zagreb (which depicts 23 classes of land use types) derived on the basis of semi-automated classification of airborne LiDAR DEM scanned in March 2012. The objective was to make quantitative evaluation of the classification. Both maps were also compared with landslide inventory map to calculate landslide frequency in different land cover and land use types. Landslide inventory map, derived on the basis of visual classification of airborne LiDAR DEM scanned in April 2011, was used as an input data for derivation of landslide frequencies. Analysis shows that more than 80% landslide area is placed in high vegetation zones (forest), which implies necessity of use of landslide data before planning changes of land use types (e.g. deforestation).

## **WG3-03 – Shallow landslides susceptibility mapping using SINMAP in Zagreb hilly area, Croatia**

**C. Wang**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**G. Furuya**

*Faculty of Engineering, Toyama Prefectural University, Toyama, Japan*

**H. Marui, N. Watanabe**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**ABSTRACT:** This study was carried out to map the landslide susceptibility of the hilly area of Mt. Medvednica located in the northwestern part of the City of Zagreb, Croatia. Landslides in this region are mostly shallow movements of superficial deposits along contacts with fresh deposits of soil and cause significant economic losses by damaging houses and the urban infrastructure. The method used here is the deterministic slope stability analysis model SINMAP which is developed by Pack et al. (2005). SINMAP is a raster based slope stability predictive tool based on coupled hydrological-infinite slope stability model. This approach applies to shallow translational landsliding phenomena controlled by shallow ground water convergence. The input data required for this model are: (i) inventory of past landslides in a point vector format; (ii) Digital Elevation Model (DEM) of the study area; (iii) geotechnical data such as soils strength properties, thickness of soil above the failure plane; and (iv) hydrological data such as soils hydraulic conductivity and the rainfall. Because the geotechnical data and hydrological data are highly variable in both space

and time, the method does not require numerically precise input and accepts ranges of values that represent this uncertainly. The major output of this model is the stability index grid theme, which can be used as a landslide susceptibility map. The results also provided slope area plot charts and statistical summary for each calibration region in the study area facilitating the data interpretation. The landslide susceptibility map which is developed in this study is also compared with the results from the Analytic Hierarchy Process (AHP) method.

## **WG3-04 – Use of a GIS-based 3D deterministic slope stability predicting tool for landslide hazard assessment in Zagreb hilly area, Croatia**

**C. Wang, N. Watanabe, H. Marui**

*Research Institute for Natural Hazards and Disaster Recovery, Niigata University, Niigata, Japan*

**G. Furuya**

*Faculty of Engineering, Toyama Prefectural University, Toyama, Japan*

**ABSTRACT:** The hilly slopes of Mt. Medvednica are located in the northwestern part of Zagreb City, Croatia. In this area, landslides, e.g. Kostanjek landslide and Črešnjevec landslide, have brought damage to many houses, roads, farmlands, grassland, and etc. Therefore, it is necessary to predict the potential landslides and to enhance landslide inventory for hazard mitigation and security management of local society in this area. We combined deterministic method and probabilistic method to assess potential landslides including their locations, size and sliding surfaces. Firstly, this study area is divided into several slope units that have similar topographic and geological characteristics using the hydrology analysis tool in ArcGIS. Then, a GIS-based modified three-dimensional Hovland's method for slope stability analysis system is developed to identify the sliding surface and corresponding three-dimensional safety factor for each slope unit. Each sliding surface is assumed to be the lower part of each ellipsoid. The direction of inclination of the ellipsoid is considered to be the same as the main dip direction of the slope unit. The center point of the ellipsoid is randomly set to the center point of a grid cell in the slope unit. The minimum three-dimensional safety factor and corresponding critical sliding surface are also obtained for each slope unit. Thirdly, since a single value of safety factor is insufficient to evaluate the slope stability of a slope unit, the ratio of the number of calculation cases in which the three-dimensional safety factor values less than 1.0 to the total number of trial calculation is defined as the failure probability of the slope unit. If the failure probability is more than 80%, the slope unit is distinguished as 'unstable' from other slope units and the landslide hazard can be mapped for the whole study area.

# WG3-05 – Deterministic landslide susceptibility analyses using LS Rapid software

**S. Dugonjić Jovančević**

*University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia*

**O. Nagai**

*International Consortium on Landslides, Kyoto, Japan*

**K. Sassa**

*International Consortium on Landslides, Kyoto University, Kyoto, Japan*

**Ž. Arbanas**

*University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia*

**ABSTRACT:** One of the key objectives of the Japanese-Croatian Project 'Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia' within the Working Group 3 (WG3) is landslide susceptibility zonation and hazard mapping of the investigation areas. Using deterministic approach in landslide hazard and risk analysis includes gathering of fundamental data about geometry, soil strength parameters, cover thickness and groundwater level, as well as the application of numerical models in safety factor calculation. Such an approach is often used in geotechnical engineering in slope stability analysis for common engineering problems. Most common is the one the dimensional deterministic model, and one of the mostly used methods inside its framework is stability analysis of infinite slope. Accuracy and reliability of safety factor calculation in each model is defined by the level of field investigations at the location, accuracy of the input data and understanding of the stress history. Detailed study of the whole area can give relatively accurate input parameters for the model, but is hard and demanding work. In some cases, heterogeneous areas are simplified and the gained input parameters are extrapolated to a wider area than the investigated location. These are basic limitations of the deterministic model.

Using Geographic Information System (GIS) can ease deterministic as well as probabilistic geotechnical approach, as part of landslide hazard assessment methodology. However, high accuracy in data preview inside GIS cannot replace high impropriety in the assessment of the failure probability which is result of the wrong selection of the geotechnical model or inappropriate failure mechanism. Two dimensional and three dimensional deterministic analyses currently cannot be performed inside GIS, yet the data are being exported in some external software for 2D and 3D slope stability calculation and then restored in GIS as the results preview tool. That is applicable on a very small investigation area with huge amount of available information, where data conversion between software presents the highest challenge.

Landslide susceptibility is function of the present slope stability (expressed through the safety factor), together with the existence and activity of triggering factors which cause increasing of active forces or decreasing of strength and, consequently, landslide activation. LS-Rapid software uses three dimensional models for simulation of progressive failure phenomena, developed to assess the sliding initiation and activation of landslides triggered by earthquake, rainfall or their combination. LS-Rapid aims to combine the process of landslide initiation and process of sliding mass movement (dynamic analysis), including the process of the sliding mass volume enlargement on the sliding path. This model is based on the key parameter- shear resistance in the steady state which can be measured or established by investigation. The software offers the recommended values for the input parameters in case when no detail data of the investigation area are available.

The basic concept of simulation is based on the analysis of the forces acting on a vertical column inside the moving mass. Increase in pore pressure during the rainfall affects the development of the sliding surface and initiation of the landslide. Detail distribution of pore pressures or the groundwater level inside the slope is usually not known, so the influence of the pore pressure is taken into account through the pore pressure ratio  $ru$ , which gradually increases until the failure appearance in a certain part of the slope. If this approach is applied on the wider area, in which is possible to define the relative position of sliding surface, it would be possible to obtain the values of the critical pore pressure ratio that causes conditions in which failures occur in a specific parts of the investigation area. Connecting this critical pore pressure ratio with distribution of rainfall through the run out coefficient and the infiltration, it is possible to obtain the landslide susceptibility and landslide hazard. In similar way it is possible to use LS-Rapid in seismic analyses to establish landslide susceptibility and landslide hazard caused by earthquake motions.

Results of the performed analyses have shown that LS-Rapid can be used a powerful tool in deterministic analyses in landslide prediction, susceptibility and landslide hazard assessment. Deterministic model performed in LS-Rapid provided the critical area for landslide appearance which corresponds to the real conditions in the slope. The validation of the model was carried out by interpretation of stereopairs and engineering geological mapping. It was concluded that landslides inside the zones that in model were characterized as highly susceptible, occurred in the nearest of farthest past. In other words, it can be concluded that the results of performed analyses confirmed that LS-Rapid, except for the detailed analysis of slope stability at one specific location, can also be used for the landslide hazard assessment on wider area. Another conclusion is that the performed analyses using LS-Rapid are more accurate and give more reliable results than alternative methods used in deterministic landslide hazard analyses.

## **WG3-06 –Slope movements and erosion phenomena in the Dubračina River Basin: A geomorphological approach**

**S. Bernat**

*Associate Researcher, Zagreb, Croatia*

**P. Đomlija**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**S. Mihalčić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**T. Miyagi**

*Faculty of Liberal Arts, Tohoku-Gakuin University, Sendai, Japan*

**E. Hamasaki**

*Advantech Technology Co. Ltd., Sendai, Japan*

**ABSTRACT:** The Dubračina River Basin is located north-east of the City of Crikvenica in Primorsko-Goranska County, Croatia. It stretches northwest-southeast, parallel to the Adriatic coast, as a part of unique morphostructural unit Rječina Valley – Bakar Bay – Vinodol Valley. The size of the research area is 43.5 km<sup>2</sup> and it encompasses mostly unpopulated and rural areas with approximately six settlements. This basin is formed of karstified carbonate rocks (mostly Upper Cretaceous and Paleogene limestone) visible on the top of the slopes, while the siliciclastic rocks (sandstones and siltstones interlayered with breccioconglomerates and limestone) are situated in the lower slope parts and in the bottom of the valleys, but they are mostly covered by superficial

deposits. The main geological hazards in the Dubračina River Basin are dominant geomorphological processes, different types of slope movements and intensive erosion. They cause significant economic losses by damaging roads, facilities, houses and watercourses. In 2009, the Croatian-Japanese joint research project "Risk identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia" was initiated and the Dubračina River Basin was chosen as a pilot area for landslide mapping to generate a landslide inventory, mapping of causal factors for landslide susceptibility and hazard analysis and zonation, derivation of hazard maps for use in the systems of land-use planning and civil protection and the development of guidelines for the application of susceptibility and hazard maps.

This paper presents results of mapping of active geomorphological processes at the area of the Dubračina River Basin, several types of slope movement and erosion phenomena. Different landform units were outlined and are characterized regarding to geological settings, geomorphological features and hydrological conditions. There are no scientific papers about geomorphological processes in the Dubračina River Basin, their characteristic and causes. The only one exception is area of the Slani Potok sub-basin which represents unique phenomena within the Dinaric flysch and has been investigated by many authors. Active geomorphological processes (rock falls, sliding, creeping and mudflows) in the area of Slani Potok are caused and followed by intensive and extensive erosion.

Slope movements in the Dubračina River Basin are small rockfalls and active talus movements in the upper part of the slopes. Landslides are dominantly small and shallow movements of superficial deposit (a mixture of silty clay and fragments of sandstones and limestone) along the contacts with the fresh flysch rock mass in the middle and lower parts of the slopes. Mudflows occur in steep gullies and on concave slopes without vegetation cover (removed by erosion). Remote sensing can be valuable tool for the identification and mapping of active geomorphological processes for the whole research area. Available remote sensing data for the Dubračina River Basin are stereopairs of aerial photographs from 2008 and high resolution DEM derived from airborne LiDAR survey conducted in March 2012. Visual inspection of aerial photographs and LiDAR imagery was undertaken to derive landform classification map with typical types of slope movement and erosion phenomena. It is evident that each landform unit has unique types of hazardous active geomorphological processes. Presented analysis will result in establishing of methodology for multihazard inventory map preparation of the Dubračina River Basin.

## **WG3-07 – Landslide occurrence prediction in the Rječina River Valley as a base for an early warning system**

**M. Vivoda, S. Dugonjić Jovančević, Ž. Arbanas**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** The Grohovo Landslide is a reactivated complex landslide in the outback of the City of Rijeka, Croatia. Several historical episodes of landslide movements and consequences demonstrate the needs for a landslide forecasting and an early warning system in order to reduce related hazard and risk and to protect human lives.

The part of the Rječina River Valley between the Valići Reservoir and the Pašac Bridge is the most unstable part of the City of Rijeka area, with a highest hazard of possible sliding. Numerous

historical descriptions, figures and maps describing landslides were found in the Croatian State Archive in Rijeka.

An early warning system for possible landslide occurrence and assessment of landslide risk in the Rječina River Valley should be established based on possibility of prediction of instabilities appearances in the zones where the monitoring equipment is installed. Prediction of possible movements would be carried out on the basis of the results of 2D or 3D landslide stability analyses of wider landslide area in combination with the results of existing monitoring data. Critical limit values must be also defined for indicating of new sliding appearance and starting up the alarm.

The 3D landslide stability analyses enable indication of possible hazard and risk for further landslide occurrences under unfavorable hydrological conditions in the most unstable part of the Rječina River Valley. The 3D stability analyses were carried out using landslide simulation model software LS-Rapid. LS-Rapid software could integrate the initiation of the landslide process triggered by rainfalls and the development of sliding due to strength reduction and the entrainment of deposits in the run out path. Stability analyses are based on strength parameters obtained by laboratory test on soil samples taken from the zones in which should be developed sliding surfaces. Soil testing were conducted on representative samples in a portable ring shear apparatus ICL-1 designed for testing the residual shear resistance mobilized along the sliding surface at large shear displacements under static and/or dynamic local conditions. The results of the ring shear tests are necessary to enable input data for analyses of the development and propagation of the sliding mass in LS-Rapid software.

In this paper will be presented deterministic 3D stability analyses using LS-Rapid software applied on the wider zone of the Grohovo Landslide at the north-eastern slope of the Rječina River Valley. The results of these analyses enabled prediction of possible sliding zones so as critical groundwater conditions (expressed by saturation ratio) those will cause sliding. Critical groundwater conditions could be connected with precipitation values, run off coefficients and infiltration ratios and these correlations will be used as an indicator of possible sliding in an early warning system. The most important indicators for alarm decision should be measured values on installed monitoring equipment in the moment when measured values reach proposed critical values.

## **WG3-08 – Hazard assessment methodology for pilot sites in Split Area**

**S. Knezić, I. Andrić, G. Vlastelica, P. Mišćević, O. Bonacci, S. Antunović**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Split, Croatia*

**ABSTRACT:** Split case study comprises areas exposed to both flash floods and rock-falls. Areas directly exposed to flash floods are mainly related to Cetina river watershed while areas endangered by rock-falls are two limited areas: town of Omiš and area in the municipality of Duće. The paper shows a methodology for hazard assessment for both phenomena.

The hazard assessment for flash floods is based on the measured data and other spatial information and/or analysis provided by GIS. The methodology takes into account European Flood Directive. The criteria for the hazard of flood assessment are based on the available, collected and processed data. Use of satellite remote sensing data enables DEM analysis (topography, geomorphology, flow accumulation, land use and vegetation), whereas traditional collected data



give information on hydrology, meteorology, geology, infrastructure, human settlements and historical record.

Since spatially distributed assessment of rock-fall hazard is a difficult due to high uncertainty and lack of exact mathematical methods for calculation of rock movements the main principle for the proposed methodology is based on GIS and results from both LIDAR and Spectrometer measurements as well as satellite remote sensing. The criteria for the hazard of rock fall assessment are mainly connected to geology, geomorphology and topography (slope angle, approximation of mass of the potential loose blocks, cracks distribution) and meteorological data (precipitation, temperature fluctuations). Traditional integrated development planning information such as structure of endangered base of rock fall slope (infrastructure, settlements and historical record) is another significant criterion.

The main outcome of analysis is unique hazard map for the endangered areas, which will be used as a tool by all stakeholders involved in future planning, budgeting, risk assessment and development of protection measures.

## **WG3-09 – Development of landslide data base conceptual model on the basis of historical landslide data from the City of Zagreb and Primorsko-Goranska County**

**S. Mihalić Arbanas, S. Fabijanović, D. Perković**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**Ž. Arbanas**

*University of Rijeka, Faculty of Civil Engineering, Rijeka, Croatia*

**S. Bernat**

*Associate Researcher, Zagreb, Croatia*

**ABSTRACT:** Landslides in Croatia cause significant economic losses, which trend is increasing due to urbanization of hilly areas. There is no national archive about landslides, nor geotechnical archive about landslide investigation reports and remediation designs in Croatia. Moreover, landslide regulation related to preventive mitigation measures of landslide hazard and risk exist only in the City of Zagreb (Capitol of Croatia), but according to current practice there is need for improvement of mitigation measures applied in the phases of urban planning, construction and civil protection. In the frame of Croatian-Japanese project ‘Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia’ it is planned to develop methodologies for landslide mapping and guidelines for application of hazard maps for selected pilot areas (in the project period 2009-2014). Croatian landslide data base is aimed at collecting and dissemination of landslide information to enable perception of existing landslide hazard and risk by wider society, public and governmental entities involved in development and implementation of landslide mitigation measures.

General objective of the research is to introduce systematic collection of data about landslides in Croatia in the form of data base aimed at dissemination of information to landslide professionals and wider society, primarily to public and governmental entities. Specific objectives are: (1) development of a web based landslide database; and (2) collection of data about past and present landslides in Croatia. The core data which database will collect and maintain are the following: catalog of Croatian landslides (with landslide location, description and schematic presentation);

bibliographic database of published and unpublished landslide maps and reports accessible by title, author, year, or keywords; photographic materials (photos and slides). Activities related to development of data base encompass the following: (1) development a data model and data dictionary (data base content, structure, and terminology for describing landslide), and (2) development and implementation the pilot system architecture based on user needs (end-user 'search' interface and an administrative web interface).

This paper presents results of collection of landslide data from various sources: geotechnical reports, diploma thesis, landslide inventories and unpublished landslide maps. Conceptual model of the data base is made on the basis of historical landslide data for the following landslides in the City of Zagreb, Primorsko-Goranska County and Istra County: Črešnjevec landslide, Granice landslide, Kvaternikova landslide, Podvinje landslide, Vidovčica landslide, Vinogradska landslide, Sloge landslide, Grohovo landslide and Juradi landslide.

## Session WG2: Flash Floods and Debris Flows

Thursday, 7 March 2013, 16:00-17:40, Hall A, City Assembly

CHAIRS: YOSUKE YAMASHIKI (KYOTO UNIVERSITY) AND NEVENKA OŽANIĆ (UNIVERSITY OF RIJEKA)

### WG2-01 – Hydrologic data analysis in the Grohovo landslide area

E. Žic, I. Sušanj, I. Ružić, N. Ožanić

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

Y. Yamashiki

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**ABSTRACT:** The paper describes the hydrological analysis of measurement data obtained from the measuring instruments installed on the Grohovo landslide and Valiči accumulation. Hydrological analysis is based on hydrologic data obtained from the meteorological station mounted on the crown of Valiči Dam, immediately upstream of the Grohovo landslide. Meteorological station measures 35 hydrologic parameters, some of which are required as input model parameters to create numerical models of debris flow and mud flow propagation. Hydrological analysis on the Grohovo landslide is related with the determination of water discharge and volume of storm water in real time, in the part of the drainage canal in front of the gabion retaining wall situated at the bottom of Grohovo landslide. The analysis is based on data indicating changes in the surface water level in the drainage canals read by Mini Diver instruments installed. The paper provides a comparison of 2011 and 2012 hydrologic data, as well as guidelines for future research in the Grohovo landslide area.

### WG2-02 – Analysis of flash flood occurred at Slani potok

I. Sušanj, N. Ožanić

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

Y. Yamashiki

*Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan*

**ABSTRACT:** The basin of Slani potok (Salt Creek) has area of approximately 2 km<sup>2</sup>, and its altitude extends from 50 m a.s.l. to 700 m a.s.l. The lower part of the catchment area (0.9 km<sup>2</sup>) is formed in flysch sediments (mainly siltstone), and it represent the majority of surface runoff. The upper part of catchment area is a karstic plateau from which the runoff is insignificant.

Slani potok catchment area may be considered as an example of combined erosion. Excessive surface erosion occurs on the area of 600 m in length and 250 m in width. Side effects around the erosion center are landslides, which are the results of weathering of the flysch rock mass. The size of this affected area is about 3 km<sup>2</sup> and the surrounding settlements Belgrad, Baretići, Grižane and Kamenjak are at risk as well as the surrounding roads.

Average slope of the catchment area is 22% varying between 5% and 100%, which is characteristic of very steep basins. Slope of the catchment area determine runoff and the erosion processes.

Due to flash floods and erosion processes, Slani potok catchment area has become one of the research areas of the Japanese-Croatian Project "Risk identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia".

During the night of 19th September 2012 to 20th September 2012 an episode of flash flood occurred at the mouth of Slani potok into the Dubračina River. Flash flood was induced by intensive short time rainfall. Rainfall was measured by meteorological station Davis Vantage Pro2 installed on Slani potok catchment area. It recorded 79.50 mm of rainfall. Recorded monthly rainfall for the September 2012 was 155.7 mm. According to recorded data at that particular location, the largest amount of rainfall occurred in September 2012 since the beginning of measurements within the mentioned Project (April 2011).

This paper describes the calculation procedure of river discharge that is based on flash flood water table traces (left after flash flood) and riverbed geometry. The measurement profiles were determined on the part of the river where the water table traces are visible. Complete analysis, results, and consequences of analyzed rainfall event will be presented in this paper.

## **WG2-03 – The flow characteristics estimation of a karstic ungauged catchment: The Sutina River case study, Croatia**

**I. Andrić, O. Bonacci**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Split, Croatia*

**Y. Yamashiki**

*Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan*

**ABSTRACT:** The Sutina – Karakašica is an ungauged karst catchment in southern part of Croatia with relative small area, but with existing records of several events of flash flood that compromised the structures as bridge and roads along the stream. This work gives an overview of the creation of the experimental catchment and establishment of the hydrological monitoring system which has for a goal a better understanding of runoff processes within the experimental karst area as well as flash flood occurrence analysis. The studied catchment is located in Dalmatia, a region of Dinaric karst in the southern part of Croatia. Although it is very difficult to determine catchment borders in the karstic terrain, for the purpose of the study the area of the catchment is estimated to eighth km<sup>2</sup>. The length of the stream flow up to the control cross section is 4.4 km. The highest point of the studied catchment area is on the 941 m a.s.l. and the lowest at the 300 m a.s.l. The geological settings of the catchment are characterized by the sedimentary rocks, mostly limestone and dolomites with discontinuities (cracks, and fractures) filled up with terra rossa and breccia. The presence of mudstone patches in the surface ensures the continuous surface flow of the studied stream. Some caves are also to be found in the catchment area. In the karst watersheds the occurrence of flash floods can be registered due to the exceptional meteorological events during the year. The intensive rainfall in the short time can trigger a flash flood that can induce over bank flow, immense changes in channel morphology and in sediment distribution. In order to produce a hydrological model that could predict the events of flash flood in the studied area, a continuous monitoring of meteorological and hydrological parameters in the catchment is established. The predictions of exceptional flooding events derived from a useful hydrological model based on the study site can be used further on to quantify the possible flooding risk. The study site can be useful by extrapolating procedure as well as obtained results to a larger scale.

## WG2-04 – Discharge measurement in natural open stream flow using probability approach

**I. Andrić, B. Skroza**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Split, Croatia*

**S. Fujiki**

*Disaster Prevention Research Institute (DPRI), Kyoto University, Kyoto, Japan*

**ABSTRACT:** This work presents effective methods of measuring discharge on the natural stream flow. During extreme hydrologic events such as floods, measuring the discharge can be problematic, therefore alternative methods of discharge determination should be considered. The goal of this work is determination of discharge by use of available emerging technologies such as radar and ADCP (Acoustic Doppler Current Profiler). The surface velocities obtained by radar were used to compute the vertical velocity distribution using the probability concept and finally to determine the discharge on the studied cross section. Verification of the results was conducted for the discharge measured by ADCP. The radar based current velocity meter used by measurements was WJ7661 RYUKAN and the ADCP was Workhorse Monitor by Teledyne RD Instruments. The discharge was computed by analytical method and by the integration of the 2D velocity distribution on the cross section given by linear vertical velocity distribution and vertical velocity distribution using the probability concept. The measured cross section was located at the Cetina River, Čikotina Ladja. The percent difference in stream flow at Čikotina Ladja ranged from 0% to 12.17% depending on the computation method applied and the calibration of entropy parameter. Results have shown that the probability approach by discharge measurement was able to provide satisfactory estimates of velocity profiles and discharge for the observed cross section.

## WG2-05 – Triggering model parameters defining the debris flow movement - Laboratory research

**E. Žic**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**Y. Yamashiki**

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**N. Ožanić**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**N. Bičanić**

*Faculty of Civil Engineering, University of Glasgow, Glasgow, UK*

**ABSTRACT:** This paper describes numerical model parameters as well as some of the most remarkable natural phenomena that initiate the launch of debris and mud flows. Some of the most important hydrological model parameters, required as input parameters for the development of numerical models of debris flow propagation, are rainfall intensity, pore pressure, density of water and known kinematic and dynamic coefficient of viscosity. The most important geo-mechanical model parameters, described in this paper are, inter alia, the erodibility (erosion rate), the slope of the landslide, friction angle, cohesion coefficient, friction coefficient and density of coarse or fine-grained materials. In the framework of the Croatian-Japanese bilateral scientific project entitled

"Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods in Croatia", a physical model of debris flow propagation will be created at the Faculty of Civil Engineering, University of Kyoto (Japan). Such physical model will provide some of the most significant quantitative values of input model parameters used to create numerical models of debris flow.

The paper will also define and describe the impact of rainfall on incoherent coarse and fine grain rock mass movement triggering. The paper gives a description of the seismic activity which can drastically affect the formation of debris flows.

## **WG2-06 – Development of Hydro-Debris 2D and 3D applicable for stony debris flow**

**Y. Yamashiki, S. Kurokawa**

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**E. Žic**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**T. Takahashi**

*Association for Disaster Prevention Research, Kyoto, Japan*

**M. Ramy Rozainy M. A. Z.**

*School of Civil Engineering, Universiti Sains Malaysia, Penang, Malaysia*

**I. Sušanj**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**S. Fujiki**

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**ABSTRACT:** The aim of this survey is to develop numerical prediction method "Hydro-Debris 2D" and "Hydro-Debris 3D" applicable for Croatian catchment. They are Euler-Lagrangian Coupling method for stony debris flow with particle sizes, applicable both for experimental field and estimation of real rock movement.

We investigate velocity of each sediment movement through steep-slope channel experimental study, and then compared with numerical simulation results using Hydro-Debris 2D. We employed three different slope angles (15, 20, and 25 degrees) both for experimental and numerical studies. The average velocity values are well simulated in numerical study within 10% difference, in most cases, while some specific case differs much, especially at the last part of debris flow.

Based on these results, Hydro-Debris 3D model has also developed and applied for Grohovo Landslide zone. Although there is no "experimental" study for the landslide zone, our model may predict movement of individual particles, as we assumed that the grain sizes are uniform.

## WG2-07 – Mošćenička Draga Early Warning Systems development using Machine learning

I. Ružić, N. Ožanić, Č. Benac

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** The paper presents a machine learning model for predicting Mošćenička Draga torrential stream water levels and discharges based on meteorological and hydrological data. Possible use of machine learning algorithms for early warning system development is presented as well.

One of the most important goals of Croatian – Japanese Project: Risk Identification and Land-Use Planning for Disaster Mitigation of Landslides and Floods is development of the Early Warning Systems (EWS). The most important task of the EWS in Mošćenička Draga is identification of the critical torrential discharges and precipitations that can cause floods, early enough to inform the authorities and public. The paper describes an artificial intelligence model that has been developed by integrating meteorological and hydrological data. The WEKA Data Mining Software was used for a model development. Model has been validated on measured hydrological and meteorological data from May 2012 till December 2012. Water levels predicted by the model are in accordance with the measured data. Model validation showed that the machine learning algorithms can be used in the EWS development.

## WG2-08 – Involving the public in flash flood and erosion mitigation

N. Dragičević, B. Karleuša, N. Ožanić

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** Despite rapid technological development, the vulnerability of society to flash floods and their consequences is still great. Successful flood management depends on a systematic and long-term integration of structural and non-structural measures. Today, non-structural measures are more favored as basic measures, whose purpose is primarily mitigation, and not necessarily prevention of flash floods and erosion. These measures are sustainable require much less capital investments and their impact on the environment is negligible. Information and public participation is one of non-structural measures of great significance in protection against erosion and flash flood. It is based on long-term planning and well-timed notification of local population on protection measures against flash flood and erosion. Local governments have the task to include planners and decision makers at all levels, as well as the general public, in planned procedures and measures which are aimed to protect people and material assets. This contributes to easier public acceptance of necessary protection, better response of local population at the time of the imminent danger from flash flood and erosion, and potential impairment of human, material and environmental damage at the time of the disaster. Education and active involvement of the local community, that is most affected by the consequences of the disaster, is necessary to achieve success in fight against them. Good local organization effects on faster, or immediate public reaction at the time of the disaster, long before help arrives.

In this paper, an overview will be given of the research conducted as a part of bilateral Croatian-Japanese project "Risk Identification and Land – Use Planning for Disaster Mitigation of Landslides and Floods in Croatia", at the Faculty of Civil Engineering, University of Rijeka, about awareness and involvement of local population in the protection of flash flood and erosion in research areas. The study was conducted through the local population and government survey using prepared questionnaires on two research areas: Salt Creek and Mošćenička Draga, and its implementation is planned as well at the research area Grohovo-Rječina. Familiarity of local population on above mentioned problems will be analyzed, as well as the shown interest for the topic and also the need for more education of population in this area. Conducted research presents the base for defining the criteria significance of the human factor, as one of the elements that contributes to the consequences of flash flood and erosion, and whose concept and criteria approach will be presented in this paper. Awareness about the problem of local flash flood, as well as knowledge on prevention measures, flood and erosion mitigation, cooperation with local authorities and proper and well-timed reaction of local population at the time of the disaster, all together form the human factor criterion, and will be analyzed in this paper.

## **WG2-09 – Citizens' awareness and preparedness for disasters in Zagreb, Croatia**

**N. Kimura**

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**Y. Yamashiki**

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**I. Kisić**

*Faculty of Agriculture, University of Zagreb, Zagreb, Croatia*

**ABSTRACT:** This research aims to make a proposal to raise citizens' awareness towards emergency cases, especially floods, through analysis of results from a social survey in Zagreb. It also seeks a possible way to build a bridge between past experience and today's life regarding awareness-raising and preparedness in the context of Croatian society. The City of Zagreb is located between Medvednica Mountain and the Sava River, a tributary of the Danube River. In 1964, the city experienced a huge flood caused by heavy rainfall and the river bank breakage. Due to the characteristic of its location, a large amount of water was flowed into the city. The central part of Zagreb city was flooded and the deepest was about 1m. The city had to be suffered from extensive damages on many of its infrastructures and 17 casualties. Having learned from this bitter experience, drainage canal (Sava-Odra Canal) and retention dams/flood storage on mountain-rivers were constructed, and there have been no outstanding floods occurred since then. This paper deals with results from two social surveys, a preliminary survey to 40 citizens and another survey to 480 citizens in Zagreb held in 2011. The preliminary survey showed that most people know about the historical flood event in 1964, however, their preparedness seemed not enough and they want to know more about how to prepare and what to do in emergency cases such as flood and/or earthquakes. It was also observed from the result that dependency on mobile phone or internet was rather high, which implies that they assume electricity or mobile phone line services are available even in any emergency cases. They may not have image that phone lines get malfunctioned or flooded on a phone line by a number of access at a time. Another finding is experience of senior citizens or those who experienced a disaster has been less used for disaster



risk reduction and/or awareness-raising in public arena. Their disaster experiences are brought down to younger generation only at individual base such as family. An interesting finding is the ratio of people who have preparation at home and that of people who think there might be another flood in 10 years' time. Nearly the 75% think there might be a flood in Zagreb in 10 years' time, but the ratio of their preparation at home or their knowledge about evacuation is not correlated. They may think that a flood is caused only by heavy rain, but actually, this region in Europe has some earthquakes and the possibility of the river bank break or crack cannot be fully denied. The municipality government of Zagreb city has made efforts having produced leaflets on reactions in four types of emergency – earthquake, flood, chemical materials, and radioactive materials – and disseminated to citizens, yet, the survey found that the leaflets are not well recognized and some university students do not have exact knowledge about evacuation or reaction in emergency case such as earthquake and flood. This paper discusses the status of disaster risk reduction in Zagreb based on findings of the social survey, and then proposes possible means and holistic approach for further knowledge dissemination and education on disaster risk reduction by taking the activities of the ongoing bilateral project – the Japanese-Croatian Project – into account. It also seeks applicability of Japanese experiences in disaster risk reduction as well as if computational tool, as way forward, can be effective enough as educational tool for awareness-raising.

## WG2-10 – Seasonal changes of CO<sub>2</sub> emissions in tillage induced agroecosystem

D. Bilandžija, Ž. Zgorelec, I. Kisić, M. Mesić, A. Jurišić, I. Šestak

*Faculty of Agriculture, University of Zagreb, Zagreb, Croatia*

**ABSTRACT:** Carbon dioxide (CO<sub>2</sub>) is the primary greenhouse gas (GHG) emitted throughout human activities which are responsible for the increase of carbon dioxide in the atmosphere since the industrial revolution and thereby causes the global warming. Soil carbon dioxide flux is very important flux within the global carbon cycle. To reduce the global temperature, Kyoto Protocol has been adopted in Kyoto in 1997, and Republic of Croatia has become the Kyoto Protocol Annex I country in 2007 by which has made a commitment to reduce the GHG emissions by 5% in the period between 2008 and 2012 compared to the base year (1990). One of the six sectors under the Kyoto Protocol, from which each country has to report their GHG emissions every year, is agricultural sector. Due to the lack of research on long term carbon dioxide emissions in tillage induced agroecosystem in the Republic of Croatia, the aim of our study is to determine the influence of different tillage treatments on soil carbon dioxide flux. Field experiment with six different tillage treatments common to this area was set up on Stagnic Luvisols in Daruvar (N 45°33'937", E 17°02'056"), Central Croatia in 1994 with investigation goal on determination of soil degradation by water erosion and later, in 2011, expanded to the research on soil CO<sub>2</sub> fluxes. Field experiment is characterized by continental climate. Tillage treatments differed in tools that were used, depth and direction of tillage. Tillage treatments were: check plot (black fallow) - BF, ploughing up/down the slope to 30 cm - PUDS, no-tillage - NT, ploughing across the slope to 30 cm - PAS, ploughing to 50 cm across the slope – VDPAS and subsoiling to 60 cm plus ploughing across the slope - SSPAS. Field measurements were conducted during one vegetation year (n=8), from May till October 2012, when cover crop was corn (*Zea mays* L.), the main arable crop in Croatia. Average precipitations at the experimental field in 2012 were 789 mm and average temperature

was 11,8°C. In situ measurements of accumulated carbon dioxide in closed static chambers were conducted with portable infrared carbon dioxide detector (GasAlertMicro5 IR, 2011). In this paper the results of field measurements of carbon dioxide fluxes during one vegetation year of corn are presented. The treatment with lowest measured fluxes of carbon dioxide was black fallow (treatment without cover crop - BF) where range of carbon dioxide flux varied from 17.1 kg CO<sub>2</sub>/ha/day to 82.8 kg CO<sub>2</sub>/ha/day and the average carbon dioxide flux at BF treatment was 38.0 kg CO<sub>2</sub>/ha/day. Between the treatments with the corn, minimal average carbon dioxide flux was measured at ploughing up/down the slope to 30cm treatment (PUDS) where average CO<sub>2</sub> flux was 70.1 kg CO<sub>2</sub>/ha/day while maximal average carbon dioxide flux was measured at no-tillage treatment (NT) where mentioned average was 118.8 kg CO<sub>2</sub>/ha/day. The smallest range of CO<sub>2</sub> flux was measured at BF treatment but among the treatments with corn, smallest range has PUDS and the largest one NT treatment. The range of average carbon dioxide flux at PUDS treatment varied from 25.7 kg CO<sub>2</sub>/ha/day to 128.4 kg CO<sub>2</sub>/ha/day and the average carbon dioxide flux at NT treatment varied from 37.1 kg CO<sub>2</sub>/ha/day to 241.1 kg CO<sub>2</sub>/ha/day. After all mentioned, we can say that in these agroecosystem conditions, best tillage practice in terms of lowest carbon dioxide flux is ploughing up and down the slope to 30 cm although the lowest carbon dioxide flux was measured at treatment without any cover crop but further research is recommended.

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# Session 1: Landslide Investigation, Modeling, Remediation and Monitoring

Friday, 8 March 2013, 9:00-12:30, The Aula, University of Zagreb

CHAIRS: KYOJI SASSA (KYOTO UNIVERSITY, INTERNATIONAL CONSORTIUM ON LANDSLIDES) AND ŽELJKO ARBANAS (UNIVERSITY OF RIJEKA)

## S1-01 – Engineering-geological study of landslide instability in quasi-horizontal terrains on Lasi ring-road, Romania

E. Oltean, V. Nita, D. Ungureanu, M. Stanescu, C. Calugaru

*Design Institute for Road, Water and Air Transports – IPTANA, Bucharest, Romania*

**ABSTRACT:** From a geo-technician's point of view choosing the path for a new road is generally based on a set of rules. Among these we mention: detailed geotechnical mapping, specific geotechnical investigations related to the works to be performed, and studying all relevant documentation pertaining to the area in question.

However, there are times when all these turn out to be insufficient for predicting instability phenomena. Such is the case, for example, when preexistent natural factors to be found at certain boundary conditions, will randomly combine with human factors arising in the course of fulfilling such an objective.

The present paper is trying to illustrate the way in which the above-mentioned joint factors - natural and man-made - may lead to landslide hazards. The case study chosen is "Lași city ring road, km (7+900) section – Romania".

In this area, the road is in the form of a viaduct which crosses over a slightly tipped large valley (slopes of approximately 7°) whose discharge flow is variable and in direct connection with precipitation levels registered. All through the time of the geological mapping performed on the valley, the terrain was dry and showed no sign of instability. In addition, none of the 4 boreholes carried out for the planned structure, each 25 – 30 m in depth, indicated any sign of ground instability (e.g. sliding planes, friction mirrors, mixed-soil material etc).

However, the presence in the proximity of the surface level of soil characteristics such as soils with strong swelling and shrinkage, or low consistency, as well as high-pressure underwater levels, all have led to the recommendation that the viaduct should be indirectly founded at around 10 m underground upon circular concrete columns embedded in very stiff marly clay.

Therefore, while the geo-technical data available revealed a section with a "major geo-technical risk" and with "a high landslide potential", important information such as the exact timing or location of the landslide could not be derived and thus remained unclear.

Once the structure and joining ramps works done, a road crack occurred following a period of heavy rain. The crack was located behind the A1 bridge abutment and continued along the ramp reaching downwards into the ground, somehow following a level curve. In addition, the road crack was accompanied by a geometrical deformation which was noticed on the right side of the embankment. With an approximate landslide area thus roughly pinned down, further examination of EuroCODE 7, Part 1 - Observational Method suggested proceeding a topographical, inclinometrical and piezometrical monitoring process.

Three geotechnical drillings were then performed, each being 20 m deep, so that the standpipes and inclinometrical tubes could be mounted. The data provided confirmed indeed the presence of plastic clay layers close to the ground surface, as well as of water infiltration throughout the thin sand layers. Also, as a result of the inclinometrical measures carried out, a critical area was identified some 7 m below surface level. This critical area had clearly originated the failure and the plastic-consistent soft clays noticed here were quite different in terms of consistency from the ones noticed during the initial stage of the investigation.

Finally, the phenomenon under discussion was described as being a slow, plastic landslide, of the “deep creep” type, whose cause seems to have been the quick pace of building the embankment combined with the heavy rain water which had infiltrated through the sand layers down into the high-plasticity clay layers.

The undisturbed soil samples which were collected during the three drillings were then modeled in the laboratory in order to obtain values of the shear strength parameters as close to the values in the actual critical slip section as possible.

Based on the results obtained as well as on the topographic, inclinometric, and piezometric measurements, a further analysis of the massifs’ stability could be pursued.

The stability analysis carried out under various assumptions with the help of the SLOPE/W software has led to choosing the appropriate solution of designing and dimensioning the consolidation works: caissons with a double role - of drainage and of structure consolidation.

## **S1-02 – Causes of landslide occurrences in Plio-Quaternary sediments of Vukomeričke Gorice**

**S. Željem**

*Geotehnički studio Ltd., Zagreb, Croatia*

**M. Čabraja**

*Geotehnički studio Ltd., Branch office Zadar, Zadar, Croatia*

**Ž. Sokolić**

*Geotehnički studio Ltd., Zagreb, Croatia*

**ABSTRACT:** Region of Vukomeričke gorice is a mildly hilly area situated in the south peripheral part of Zagreb. Geologically, this region is formed of Plio-Quaternary sediments. These sediments are a complex of interchanged layers of sands, silts, clays and gravels. In some parts this complex is characterized by strong limonitization in the form of limonite concretions. Locally, sandstones and conglomerates could be found. In some parts, remains of coal and peat are also found.

Exchange of soil layers with different engineering geological, hydrogeological characteristics and physical - mechanical properties of soils, in combination with geomorphological factors and structural-tectonic characteristics, represent the medium very susceptible to the instability occurrences. This is confirmed by numerous landslides and land creeping areas in the described region, especially in inhabited areas where slope instabilities are initiated mostly by human activities.

Numerous geotechnical investigation works carried out on many landslides in the Vukomeričke Gorice region have shown similar geotechnical conditions, causes and sliding mechanisms in all locations. The majority of landslides emerged on the mildly inclined slopes (10-17°). It is

determined that their lithology is the sediment complex represented with the exchange of the cohesive (clays and silts) and cohesionless (mainly sands) layers of soil exchanging vertically as well as laterally. On the large number of those landslides the layers, interbeds or irregular lenses of coal and mostly peat were found. The soil layers are inclined in the same directions as the slope, with the same or lower inclination angle. Hydrogeologically such complex represents the exchange of permeable and non-permeable layers of soil. More permeable, mostly sandy layers and layers of coal and peat have often been of limited spreading either because of the sedimentary or afterwards tectonic conditions. In hydrogeologically unfavorable periods of the year, the permeable layers can be saturated with groundwater. Depending on the layer thickness, the significant hydrostatic pressures can be developed, having unfavorable effects on the slope stability. Concentration of the emerged landslides is in the zones of roads and settlements, where the problem of unsolved drainage of the surface and waste waters is present. The inflow of the surface waters from the roads or the precipitation and waste waters from housing directly into the ground increases the water saturation degree of soil and it is often the cause for initiating the landslide activity. Sliding surfaces are activated along one or more surfaces of lowered shear strength of clayey layers on the contact with the water bearing layers of sand, coal and peat.

Accordingly, there are two main factors for creating the landslides. First lays in the natural conditions and the second is a human factor. For the majority of landslides it has been shown that the basic remediation measure is draining the slope. Depending on the depth of sliding surfaces and on the depth of appearance of permeable materials that act as the natural drainage along whose planes the sliding most often occurs, the appropriate and applicable drainage solution is chosen. In the case of the landslide activity along the shallower surfaces, the slope drainage can be successfully implemented with the vertical drains.

In the case of instability, along the deeper sliding surfaces, the latest considerations are directed towards the application of innovative methods of deep drainage systems, siphon and electropneumatic drains system.

In the article, authors will show a description of the geotechnical settings, causes and mechanisms of sliding/instability, conducted stability analyses and applicable methods of improvement.

## **S1-03 - Investigation of landslides on inner slope of Mt. Aso caldera triggered by heavy rainfall in Northern Kyushu, Japan in July 2012**

**H. Yang, F. Wang, T. Sonoyama, Y. Mitani**

*Research Center on Natural Disaster Reduction, Shimane University, Matsue, Japan*

**ABSTRACT:** Mt. Aso is the largest active known volcano in Japan. It is located in Kumamoto Prefecture, Kyushu island of Japan with relative peak of 1592 m above sea level housing one of the largest calderas in the world. Mt. Aso caldera has an area of about 350 km<sup>2</sup>, extending 17 km in the east-west axis and 25 km in the north-south axis with relative circumference of 120 km. High rainfall and typhoons observed within the area are due to geomorphological and topographic natures of the terrain. These relatively annual events have triggered shallow landslides and debris flows from several parts of the moderately consolidated walls of the caldera. These shallow landslides and debris flows have caused severe casualties, destroyed properties and displaced local city dwellers thus, a need for comprehensive study to understand the factors contributing to



the occurrence of these shallow slope failures and evaluate the failure mechanism. Precipitation around this area is usually high throughout the year with highest rainfall intensity (500~700 mm) in June and July. Rainfall data obtained from five local meteorological stations around the northern Kyushu Island were over 500 mm for 11th to 14th July, 2012; a value higher than the highest local precipitation recorded in the last decade. This high precipitation triggered shallow landslides, especially around the rim of the caldera, which affected many villages and local settlers. Detailed field investigation was conducted to study the motion mechanism of shallow slope failures triggered by the heavy rainfall. A representative site, which is located in Ichinomiya, Aso-gun, Kumamoto Prefecture was selected for this study. Several field geotechnical tests were carried out in the landslide site. Portable cone penetration tests were conducted to evaluate the nature and degree of consolidation of the sediments which are mainly composed of tephra and pyroclastics; in-situ permeability tests were conducted with variations in depth of hand-drilled boreholes so as to measure rainfall infiltration rate. Representative soil samples were collected from different layers of the main scarp for particle size distribution analysis, shear strength tests, and other laboratory soil strength analyses.

Material composing the area around the main scarp was divided into three distinct lithologic units (layers 1~3) based on physical observations and variations in structural features and color. The topmost unit (layer 1) is composed of relatively fresh sediments rich in humus, plant debris, and volcanic ash with characteristic dark color often showing streaks of glassy luster. The middle lithologic unit (layer 2) shows a fining upwards sequence with maximum particle diameter of about 20 mm. The basal lithologic unit (layer 3) is relatively made up of small amount of fine sands set in a coarse-grained sediment matrix which is composed of weathered volcanic tuff. Field observation shows that the probable slip surface of the shallow landslide could be from the basal lithologic unit (layer 3). Cone penetration test result shows that the topmost humus-rich unit (layer 1) has varying thickness which decreased down slope from 3.5 m at the main scarp to 1 m at the slope toe. Results obtained from in-situ permeability tests show that at shallow depth of 25 cm,  $k$  is  $1.125 \times 10^{-3}$  cm/s, while at a depth of 75 cm  $k$  is  $4.985 \times 10^{-4}$  cm/s. Results obtained from laboratory constant-volume direct shear tests show that the effective friction angle and cohesion of the soil above the slip surface are 32° and 12 KPa respectively.

Results obtained from detailed field and laboratory investigations carried out in the area show that the main factors contributing to the occurrence of shallow landslides and debris flows are incessant rainfall, surficial drainage and runoffs, topography, geologic and soil strength properties. These factors are enhanced by the interplay between the steep wall of the caldera (over 300) and high precipitation coupled with high number of irregular cracks that acts as conduits for easy infiltration to subsurface drainage system. Another process that could have affected the slope stability could be from steady undercutting of the slope toe by strong surface floods, which overtime reduces the shear strength of the material leading to shallow sliding failure. Results presented above are based on preliminary field investigation and laboratory analysis conducted on a representative landslide site in the area; we hope to carry out more research work using stationary monitoring devices which would help in long term study of the shallow slope failures.

# S1-04 – The geotechnical analysis of the Poravi landslide in Albania based on new geological investigations

**Y. Muceku**

*Institute of Geosciences, Energy, Water and Environment, Polytechnics University of Tirana, Tirana, Albania*

**O. Korini**

*Faculty of Civil Engineering and Architecture, EPOKA University, Tirana, Albania*

**ABSTRACT:** The instability phenomena of the hill's slopes are well known in Albania. They are related to lithological characteristics of rocks and soils, geomorphologic conditions, physical and mechanical properties of rocks and soils, hydro-geological and hydrological conditions, seismo-tectonics and seismicity characteristic. In this paper we are analyzing the Poravi landslide, which a larger one of mass movement occurred in Albania. It is an old landslide. The Poravi landslide is located on left bank of artificial Lake of Fierza, which is built since 1974 for electrical energy production on valley Drini's River, Albania. The Fierza artificial lake has volume 2.7 billion m<sup>3</sup> and water's surface 73 km<sup>2</sup>. The Poravi's landslide extends 2.4 km far away from Fierza Dam is 165 m high and 500 m long. The dam is built by earth fill type with impermeable clay core. In the case when the lake is in maximum level by water the dam is threatened from Poravi's landslide's occurrence. The Poravi landslide is earth slide type that moved on lake's bank with slope inclination angle range from 16o-20° up to 25-31°. The mass movement's body consists of soils are inorganic silt with pebbles in middle-upper part and rocks blocks contents in lower part. The dimension of this landslide are 1.0-1.5 km long, 0.5-1.0 km wide and 50-70 m up to 120-125 m thick with total volume 34.0 million m<sup>3</sup>. The slides plain is situated on red clay's shale. The formations on which is occurred the mass movement is tectonically overlies over melanzhe rocks, which are composed by schist's and argillaceous shale's formations. As is seen it, the geological environment in this Poravi area is intensive affected from tectonics movements, which has favored the landslides occurrence. From our investigation it is found that the Poravi landslide has been more active last three decades, when hydro-technical works started to be used. From hydropower operation as result of reservoir waters fluctuation the mass movement is reactivate as result of decrease of resistivity properties of landslide's body soils, causing a series risk to dam's stability. Also, from landslide's moving several engineering's objects (village's buildings and road) built on this landslide are damaged (fractured). For that, last year a special attention has been paid to geotechnical condition investigation of this landslide. So, are carried out some boreholes from which are taken several soils and rocks samples to test in laboratory for physical and mechanical properties. Also, from these boreholes are taken some more additional lithological information according to mass moving setting, because of the base of geotechnical data are taken by engineering geological and geophysical investigation before reservoir construction. Moreover, are done geophysical investigations as vertical electrical soundings, seismic and electrical resistance tomography-(ERT) measurements. From these works was determined the sliding plain and geotechnical characteristics of mass movements body and the rocks are situated below it. These data show the sliding activity is different for different parts of the landslides body. The most dynamic zones of this sliding massif are located in down and middle part of landslides. Based on the physical mechanical properties of landslides body was calculated the safety factor. For calculating the slope stability the Slide 6.0 (Rockscience, 2010) software is used.

# S1-05 – Sliding causes and triggering mechanisms at the Bogatić landslide

S. Zekan, N. Suljić

*Faculty of Mining, Geology and Civil Engineering, University of Tuzla, Tuzla, BIH*

**ABSTRACT:** The paper describes the geotechnical investigation at the Bogatić landslide. It was found that the low strength of organic silt was one of the main causes of landslides launching. The Bogatić landslide is located near the Sarajevo-Foča road in Bosnia and Herzegovina, about 15 km south of Sarajevo, on the left bank of the Željeznica river. Activation of landslide occurred in May 2010 and after heavy rainfall period. Reactivation occurred in June 2011 caused by a new heavy rainfall. Two houses were completely destroyed. The Bogatić landslide is about 1,400 meters long and from 80 to 100 meters wide with widening at the toe to about 300 meters. Sliding surface is about 10-15 meters depth in the upper part and up to 30 meters in the foot. One of the causes of landslide activation was a presence of cracks with the infiltration of water at the higher parts of the landslide, and the presence of high plasticity organic silt in the landslide toe. Extreme rainfall was causing rising of ground water table in the sliding body. These results indicate that the landslide has a seasonal occurrence. It was found that the process of instability at this site has a long-time character. There are indications of the existence of fossil landslide. Large blocks of sandstone and limestone are mixed in the sliding mass. Reactivation of the landslide occurred several times in recent history, and always after extreme rainfall.

Presence of the following materials was established within the main landslide body: red-brown clays and silty-sandy clays, soft and medium plastic consistency, with limestone and sandstone inclusions; gray-brown sandy organic silt, soft; red-brown clayey shale; gray and gray-brown sandstone; limestone.

Organic silt was identified in the landslide toe at a depth of 30 meters. The layer thickness is variable and different in sliding body. It is often mixed with other soils. Laboratory tests have shown extreme plasticity limit values: liquid limit is from 65 to 95%, and plasticity index from 25 to 50%.

This paper presents the results of boring investigation, engineering-geological map, the characteristic cross-section through landslide, the results of laboratory tests and slope stability analysis. Slope stability analysis was performed with the software package GGU using Bishop method. It was concluded that presence of a high level of groundwater caused the instability of the slope in the layer of organic silt. Remediation of landslide can be affected the lowering of groundwater level. Slope stability analysis had shown that after the lowering of the groundwater level, the safety factor increases the value from 1.0 to 1.25.

# **S1-06 – Using microtremor array surveying to evaluate the possibility of piping induced landslide dam failure**

**F. Wang, Y. Mitani, H. Yang, Y. Kuwada, A. Chukwueloka Okeke**

*Research Center on Natural Disaster Reduction, Shimane University, Matsue, Japan*

**ABSTRACT:** The downward movement of relatively weathered slope sediments into steep confined valleys led to the formation of landslide dams and the evolution of barrier lakes due to blockage of stream courses. Stream channel impoundment often leads to the development of potential hazard which could trigger landslide dam-break, and pose serious threat to the downstream area, as barrier lakes formed in the upstream area rises steadily. Eventual landslide dam flood outbreak could lead to loss of lives and properties, especially in inhabited areas thus, a need to assess and evaluate the stability and longevity of landslide dams.

Generally, common failure mechanisms of landslide dams are piping and overtopping. Predicting landslide dam failure by overtopping seems to be easier due to the relative ease of monitoring variations in upstream lake. Unlike overtopping, piping failure of landslide dams is relatively complex due to physical constraints in evaluating internal structures of landslide dam materials. A complete study and evaluation of internal structures of landslide dam materials could help in the monitoring of subsurface fluid flow paths and pipe development that leads to catastrophic failure.

Based on this concept, a geophysical exploration method known as microtremor array method was employed in the study of two recent landslide dams in Nara prefecture, Japan, which were formed in 2011 during a heavy rainfall event, with sole purpose of evaluating the internal structures of the dam materials which would help to understand the possibility of pipe development and failure.

The application of microtremor array method in velocity analysis helps in the study of subsurface sediments which is usually represented in a shear-wave velocity-depth profile, based on phase-velocity vs. frequency. This principle is based on lateral propagation of surface-waves with particle motion amplitude which decreases with depth as wavelength varies with change in subsurface lithology.

This paper introduces results of preliminary investigations carried out on these landslide dams. Results discussed in this paper are limited to phase-velocity profiles obtained from field investigations; other results will be discussed in a subsequent paper. Results obtained may help to obtain more insight on subsurface fluid flow paths, drainage pipe buried beneath the dam material, and overall fluid-sediment interactions from the upstream area through to the downstream area.

# S1-07 – Experimental study on the motion mechanism of submarine landslides and the impact force on communication cables

Y. Kuwada, F. Wang, M. Honda, T. Sonoyama

*Research Center on Natural Disaster Reduction, Shimane University, Matsue, Japan*

**ABSTRACT:** Globally, fiber optic cables are important communication equipment used in transmission of information, but these cables are sometimes damaged by submarine landslides. When cable failure occurs, the economic loss is vast for cable restoration coupled with temporary to permanent breach in transmission of information. Submarine landslides are usually triggered by many factors which include rapid sedimentation, retrogressive failure, earthquake and tectonic activity, gas hydrate dissociation and wave loading. These activities cause severe damage to subsea fiber optic cables. Direct observation of this phenomenon is still unclear because these events occur deep beneath the sea surface, and direct observation of submarine landslides would be extremely expensive and difficult because of its unpredictability. The aim of this study is to use experimental approach to analyze and understand the motion mechanism of submarine landslides and its effect on communication cables. An experimental apparatus to study submarine landslides was developed for this purpose. The apparatus consists of a wheel-shaped hollow disc of height 1.8 m, an axle shaft at the center and trough with width of 0.4 m at the inner circumference. Submarine landslides are reproduced by using silica sand-water mixture fixed in the lower part of the trough, as the wheel rotates in an anticlockwise direction on the axle shaft with silica sand-water mixture in the same direction of motion, all controlled by a speedometer. Using this apparatus, with silica sand no.7-and no.8-water mixtures for these experiments, normal stress, shear stress, pore water pressure on the bottom of the apparatus and impact force on communication cable models were measured using high definition transducers, sensors and data loggers. From data obtained from series of experiments, the friction angles of submarine landslides and impact force on communication cables were obtained. Also, small plastic balls which have specific gravity similar to silica sands were used as tracers to observe the characteristic bulk movement of soil masses during the experiments; results obtained were compared with the friction angles and impact forces on communication cables. Experiments were carried out considering four factors: (1) the effect of motion velocity of submarine landslides; (2) the effect of submarine landslide volume; (3) material composition of submarine landslides; and (4) the effect of different cable diameters. Result obtained from the experiments show that four critical values of velocities and five stages of soil mass flow evolution conditions exist in these experiments. Impact force on the communication cable model is high for submarine landslides with low motion velocity, but decreases until the velocity gets to a critical value where liquefaction occurs, and subsequently increases in a linear fashion with velocity. On the other hand, friction coefficient is positively correlated with velocity of soil mass, but shows varying tendency before and after the critical value of velocity. Also, large diameter cables are subjected to high impact forces. When the diameter of the cable is increased by 10%, the impact force also increases by 50%. The experiment with setting height of 20 mm shows high impact force. Conversely, experiments with higher setting height (40 mm and 80 mm) show low impact force. This may be due to the influence of different relative densities of submarine landslide sediments. Although the dimension of the test apparatus are quite small compared to actual submarine landslides, we hope the test results can provide some knowledge in the study of submarine landslides and communication cable design.

# S1-08 – Effect of rainfall on matric suction and stability in natural unsaturated soil slopes

G. Hadži-Niković

*University in Belgrade, Faculty for Mining and Geology; Belgrade, Serbia*

**ABSTRACT:** The occurrence of landslides in natural unsaturated soil slopes is attributed to many factors. Rainfall has been considered to be the main causes of the majority of landslides. Most of the rainfall-induced landslides consist of relatively shallow slip surface above the groundwater table. The mechanism of failure is that the water infiltration causes a reduction of matric suction in the unsaturated soil, resulting in a decrease in the effective stress reflected in a decrease in the soil strength to a point where equilibrium can no longer be sustained in the slope.

In the situation where the ground water table is deep or when slip surfaces are shallow, in the slope stability analyses have to incorporate the effect of negative pore water pressures. Such type of analyses requires specific site and laboratory investigations and presents an extension of conventional limit equilibrium equations.

Slope stability analyses were performed for real engineering-geological cross-section at the location near the King Alexander Boulevard in Belgrade. Typical Quaternary loess sediments with a destroyed soil structure in the zone above the groundwater level are unsaturated. Unsaturated soil has absorption possibility – matric suction or negative pore pressure. Unsaturated shear strength is function of the two stress variables: net normal stress and matric suction. Constitutive equations „unsaturated shear strength – matric suction“ and „angle  $\varphi^b$  – matric suction“ were defined for these silty soils. These equations were established on the basis of primary constitutive relationships for unsaturated soil – soil water characteristic curves „effective degree of saturation – matric suction“. Soil-water characteristic curves were obtained from results of experimentally testing on draining saturated soil samples, under different pressures, performed the first time in Serbia, in 15 bar pressure plate extractor, according ASTM standards: D2325-68 for coarse grained soil and D3125-72 for fine grained soil. Effective shear strength parameters  $c'$  and  $\varphi'$  were also experimentally obtained from direct shear tests. Stability analyses were performed using the General Limit Equilibrium Method for different climate conditions, before and after rainfall, i.e. for different values of matric suction.

Results of such analysis show that reduction of matric suction in terrain, caused by the infiltration of rain water into the soil, decreases factor of safety. Matric suction near the ground surface is the first to be affected by rainfall, followed by those at greater depths. Matric suction increases during dry season and decreases during wet season. Maximum change in matric suction occurs near the ground surface and the magnitude of matric suction change decrease with depth. For all the other same conditions, importance of negative pore pressure on stability, increases with lowering water level, and factor of stability decreases with decreasing  $\varphi^b$  for natural unsaturated soil.

Stability analyses were performed for the same groundwater level, too. It was confirmed that rainfall decreases the angle  $\varphi^b$  and stability of natural unsaturated soil slopes. Decreasing the  $\varphi^b$  angle of unsaturated soil, due to rainfall, decreases the safety factor of the slope faster for coarse grained soil than for fine grained soil.

That would keep in mind for all temporary slopes, short-term and back-calculated slope stability analyses. These conclusions are important for the design of remedial works. It seems possible to

control the deformations of the slope keeping the values of matric suction constant as much as possible.

## **S1-09 – FEM modeling and analyses of remediation measures for the reactivated Botun landslide**

**Lj. Dimitrievski**

*Faculty of Civil Engineering, Skopje, Macedonia*

**D. Dimitrievski, B. Bogoevski, A. Strasheski, H. Dimitrievski**

*GEING Krebs und Kiefer International & Others Ltd. Skopje, Macedonia*

**ABSTRACT:** This paper deals with analyses, modeling and design of remediation measures for stabilization of the reactivated Botun landslide. The Botun landslide is located on the A2 state road; section Trebenishta – Kicevo, in the vicinity of the Botun village (western region of R.Macedonia). The last sliding in 2011 affected the A2 state road which is located in the toe of the landslide and endangered the traffic. In the past, the landslide has been reactivated several times. It is known that before road construction this location was detected as a landslide which has been stabilized over the time. Regardless this fact the road was construction in the toe of the landslide. The events which triggered the landslide reactivation were the excavation works during construction of the A2 state road. During the road construction retaining wall was also constructed which collapsed in 1976. As remedial measures new retaining wall was designed and constructed in 1977.

In 2011, retaining wall (constructed 1977) had undertaken large deformations manifested with significant cracks and deformations on the road and on the wall itself. After the last sliding in 2011, the new remediation measures were foreseen which are the subject of this paper. The new measures should stabilize the landslide by new retaining wall construction in the landslide toe. In order to analyze the stability of proposed construction, as well as the stability of overall landslide, a finite element method analyses were carried out. The analyses involved stability checks of potential and known slip surfaces for several load cases. In order to simulate the condition which led to the reactivation, the back analyses were carried out. Furthermore, in the back analyses the real deformations of the existing retaining wall were considered and the deflected wall is also modeled using the Plaxis 2D software. The influence of the ground water on slope stability was checked for different ground water levels that enabled a clear view on a ground water conditions during the sliding. In these analyses, the ground profile is modeled according to the geotechnical properties of the soil obtained from carried out field investigations and laboratory test. The stability back analyses using limit equilibrium method were also conducted. These analyses were considered as preliminary ones, but they also clarify some uncertainties regarding triggering conditions. From the results of all conducted back analyses, it could be concluded that old retaining structures could not adequately sustain landslide stability.

As it was mentioned before, the Botun landslide is a landslide, that has been reactivated several times in the past and regardless the remediation measures which had been undertaken in 1977, it was activated again in 2011. In this paper an approach for modeling and analysis of landslide is presented, which took into account the deformations of the existing retaining structure, the residual soil parameters in the slip surface zone as well as variations of the ground water level. This paper also deals with chronological events in the landslide history and ground conditions

which led to last reactivation and occurrence of deflections and cracks of existing retaining structure in 2011.

## **S1-10 – Rockfall occurrences along the Croatian railways – Raspadalica location**

**M. Grošić, D. Vidović**

*Geotech Ltd., Rijeka, Croatia*

**D. Udovič**

*Monterra Ltd., Rijeka, Croatia*

**I. Igrac, S. Špehar Kroflin**

*HŽ Infrastruktura Ltd., Zagreb, Croatia*

**ABSTRACT:** In mountainous regions, infrastructure facilities and settlements are commonly exposed to rockfall hazard. Transportation facilities, such as railways, often have to pass through potentially hazardous mountain areas. Rockfall appearance is defined as free falling rock (rock block) which is detached from rock mass and is moving (toppling, sliding, bouncing and rolling) downwards while energy and velocity of it increasing by time.

There are about 2,700 km of railways in Croatia and the most part of railway routes passes through potentially hazardous mountain areas. During last decades some large rockfalls occurred on the steep limestone slopes and caused serious damages and especially on railway facilities with injured persons, as well as delayed traffic.

One of the biggest rockfall on railways in Croatia occurred at the Raspadalica location in Istria on railway Croatian State Border – Buzet – Pula. About 100m high rock cliff Raspadalica is situated on the north side of the railway from chainage km 36+350 to km 36+810. On 10 February 1990 the rockfall occurred and total volume of 500 m<sup>3</sup> with one unique limestone block of 20 m<sup>3</sup> and several limestone blocks of 10 m<sup>3</sup> hit and completely destroyed the railway facilities.

The rockfall protection management begins with rockfall hazard analyses to identify potential of rockfall occurring so as possible accidental consequences – the rockfall risk. On the locations where hazard with related risk was determined the detailed field investigations were provided and analyses of motion and resulting paths were conducted. Trajectories, impact energy and height of bouncing are depending of slope geometry, slope surface roughness and rockfall block characteristics. Depending on these analyses rockfall protection measures were designed. Protection measured consists of installing of rockfall barriers above the railway.

## **S1-11 – Ramina landslide: From a natural hazard to remediation**

**J. Josifovski, S. Gjorgjevski, B. Susinov**

*Faculty of Civil Engineering, Ss. Cyril and Methodius University, Skopje, Macedonia*

**ABSTRACT:** This paper presents the investigations and modeling of remedial works of Ramina landslide in highly urbanized hilly area of Veles in R. Macedonia. According to the existing data, the main mass movements occurred during 1963 then after longer period without visible mass



movements, a landslide zone was reactivated during 1999 and 2002. The extent of the damage on the individual housing and infrastructure had been estimated as in a magnitude of real natural disaster with potential to endanger even the center of the town near the river Vardar. The situation asked for immediate intervention where in the beginning large set of investigations including geophysical, geological, geotechnical methods, inclinometer and geodetic measurements took place. The results from the investigations indicated that the landslide character is very complex. The total landslide length has been estimated to about 320 m with 90 m average width, where the landslide depth on certain places reaches up to 24 m. The volume of the sliding mass is in a range of about 400,000 m<sup>3</sup>.

After the definition of potential sliding zone and surface, the next phase of landslide modeling had been enabled. The models were first calibrated through the process of so-called back analysis, which gave a clear picture of the sliding potential. Moreover, a (limit equilibrium) stability analyses and simulation the stress-deformation behavior (finite element analyses) had been performed, where the stage modeling had helped to understand to sliding mechanism and establish set of different measures to secure further instabilities.

Different types of remediation measures had been planned such as, slope reconfiguration with soil excavation, but main elements in the stabilizing process had been the three retaining soldier pile walls, upper- in the head, middle- and lower- in the toe of the landslide. Additionally, a system for evacuation of rainfall has been planned as well as horticulture. Due to the complexity of the landslide and the wide range of remedial works they have been divided in three construction phases.

In the first phase, by unloading of the landslide top (head) had created scattered profile with total excavated mass of 27,712 m<sup>3</sup>, which in combination with a pile retaining wall with length of L1=100 m had been able to stabilize the upper part of the landslide. The wall had been comprised of 67 soldier piles with diameter of 90 cm and depth up to 16 m which were placed in two rows spaced on 3 m.

In the second phase, in the middle of the sliding mass (where the largest deformation had occurred), another retaining wall with length of L2=88 m has been constructed. This one had three rows of 89 soldier piles with diameter of 90 cm. Additional stabilizing elements were used in form of 42 pre-stressed geotechnical anchors with ultimate tension force of 900 kN.

In the third phase it has been planned to construct another third Retaining wall positioned in the toe of the landslide. This phase together with the horticulture plan had never started. The retaining structure should have been with length of L3=67.5 m comprised of 48 soldier piles positioned in two rows spaced on 3 m with depth up to 15 m.

In August 2005 the retaining wall at the top of the landslide had finished followed by the second retaining wall in October 2006. From then on the Ramina landslide had been regularly monitored without detection of significant mass movement.

The conclusion could be that the urbanization must follow the logic of the natural environment and every kind of unplanned construction can only lead to high level of risks on the surrounded area and disaster.

## **S1-12 – Evaluation of landslides and engineering measures on lignite open pit slope in south east Sibovc-Kosovo Coal Basin**

**A. Bytyçi**

*KEK, Prishtinë, Kosovo*

**Y. Muceku**

*Institute of Geosciences, Energy, Water and Environment, Polytechnics University of Tirana, Tirana, Albania*

**H. Quela**

*Trepçë, Mitrovicë, Kosovo*

**ABSTRACT:** Open Pit Mine South East Sibovc represent the most powerful source of electricity production in Kosovo, with an annual coal production of about 8 million tones and 13 million m<sup>3</sup> of overburden. According to the lithological description the coal layer is foreseen to reach the deepness about 100 m creating on such manner a surface about 1.6 km<sup>2</sup> which is equally 160 ha, by the end of the fifth year of planed mining activity on North Direction. After a lot of researches made on this area or exactly in the in the Western boundary of Kosovo Basin including the passive slope it has been determined that the possibility of lignite slope side in the internal part based on the angle flow which is above 15°. Possible movement of this slope may produce a serious consequences for habitants living in Berisha square also for the whole Conveyer belt system which passes in to these area. Therefore the further development of mining activities on this area should precede the permanent analyses and constant monitoring having in the consideration that this area includes the underground water and the possibility of spontaneous combustion which will directly impact the process. The stability of this slope will be achieved by choosing the proper technology based on the projected geometry and by applying the inside dump in the earliest stage of the technical process as a reaction on the dumped gauge. In this paper we will represent our experience on identification and preventing steps on treating slopes such is the case nearby habitat in South west Sibovc in Kosovo Coal Basin treated from the stability point of view.

## **S1-13 – New methods for strengthening of shallow landslides affecting the roads**

**K. Anguelov**

*University of Mining and Geology "St. Ivan Rilski", Sofia, Bulgaria*

**ABSTRACT:** The shallow landslides are among the most common landslides. The first type of shallow landslides affects the slopes of the cut above the road carriageway and buries the asphalt and the second type – affect the embankments beneath the asphalt courses and often demolish significant part of the roads. In both cases landslides occur very fast during intensive rainfall, snow thawing or immediately after intensive water saturation of cuts and road embankments.

The approaches to allow traffic of vehicles on the roads affected by both types of shallow landslides and strengthening of landslide sections are rather different.

In the first case, earth masses fallen on the road have to be removed and nevertheless of the risk of new landslide the traffic is allowed again. Sometimes, removing earth masses from the same

section is required at certain periods of time during the time of preparing the engineering-geological investigations and detailed design for construction of strengthening structures. Evaluating the active landslide pressure, which is continuously increasing, is the most significant issues.

In the second case traffic is allowed again only after strengthening of the landslide section by strengthening structures. Often the execution of construction works without large embankments for access roads is impossible. The most recent drilling machines employ the function for drive anchors, piles and IBO-piles from drilling pads outside of the affected road sections.

Examples of strengthening of both type shallow landslides are discussed in the present paper. The first examples comprise landslides, which have suddenly affected the slopes and cuts, hanging over the carriageways. Strengthening is performed by retaining walls with IBO – anchors, driven through them, which fully bear the stress of landslide. Draining structures are envisaged in addition to the strengthening structures in order to maintain ground water at levels, which provide sustainable condition of the slope.

In some cases piles are driven and common retaining walls are constructed in order to perform the same protective function against the active stress of the landslide. Permanent water levels are maintained by a system of horizontal boreholes, positioned like fan around. That is the technique for strengthening one of the largest landslides in Bulgaria (near to Dobromir village, Burgas district).

The second case of shallow landslides, which have affected carriageways and embankments beneath asphalt courses, sometimes require driving of the so called IBO-piles. They aim to keep rather thin retaining walls (30-40 cm) close to the massif and the IBO-anchors are driven through them. The IBO-anchors themselves are driven by a special equipment from the carriageways.

Drilling of IBO-anchors is performed side by side with injection 10-15 % cement grout, which penetrates through fine cracks round boreholes and landslide surfaces. Consistence of cement grout is modified, when design anchor depth is achieved (31 % water and 69 % cement), and thus wider cracks round the borehole and the borehole itself are filled up. That approach is applied in order to establish zones of very good cementing near the borehole openings and thus the landslide massif is strengthened, including the landslide surface (zone) as well.

## S1-14 – Monitoring and warning tool for landslide risk prevention

**C. Marunteanu**

*Faculty of Geology and Geophysics, University of Bucharest, Bucharest, Romania*

**ABSTRACT:** The proposed model is a functional model to permanent monitoring of slope movements in unstable areas and to develop a software tool for risk managers so they can create warning and civil protection strategies. First steps are the zoning of the landslide probabilities (hazard map) based on calculation of the critical slope angle and on calculation of the probabilities of sliding in a network of points. The hazard zoning is followed by the choice of the monitoring alignments and points in the prone area. The monitoring is then realized by real-time data acquiring from sensor modules (displacements, water level, precipitation, temperature) in

inclinometers and by transmission of field data through wireless communication to a risk management hub.

The next stages of monitoring are dedicated to the forecasting of the paroxysm phase of the slope movement. Evaluation by deterministic methods (using the program PLAXIS, for instance) of the critical displacements in the monitoring points at different levels of underground water. The data provided by PLAXIS calculation are converted in diagrams stability factor – displacement for the monitoring inclinometers. The diagrams provide also the stability, attention and alert levels considering the calculated stability factors. The results of measurements on-line are automatically compared with the theoretical curves of critical displacements from the diagram and the alert could be triggered in real time via internet.

The proposed model is a functional model for permanent monitoring of slope movements in unstable areas. The monitoring is based on real-time data acquiring from sensor modules (displacements, water level, precipitation, temperature) and transmission of field data through wireless communication to a risk management hub. Following a decisional support solution, the results of measurements on-line are automatically compared with the theoretical curves of critical displacements and the alert (in real time) is triggered via internet. The system was successfully tested using test and measured data and the functional model is installed and working on some sites.

## **S1-15 – The analysis of Umka landslide dynamics based on automated GNSS monitoring**

**B. Abolmasov**

*Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia*

**M. Pejić**

*University of Belgrade, Faculty of Civil Engineering, Belgrade, Serbia*

**V. Šušić**

*Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia*

**ABSTRACT:** The Umka landslide is situated on the right meander of Sava river 25 km south-west from Belgrade in the settlement of Umka. First written records of the landslide activity date from the beginning of the 20<sup>th</sup> century. Landslide is formed in Neogene sediments; at the contact between weathered zone of Pannonian clay gray marls ( $M_3^2GL$ ) and fresh grey marls ( $M_3^2L$ ), with variable thickness of 10-25 m. Quaternary sediments comprise a relatively thin cover of Neogene sediments with layer thickness of 2-15 m. The Umka landslide has a triangular fan shape, with total area of 100 ha, average depth of 14 m and its volume is approximately 14,000,000 m<sup>3</sup>. Average slope of the slide is 9°. Genesis of the landslide is, apart from geological predisposition caused by contact between weathered clay marls and fresh marls, closely connected with erosion of the right bank and evolution of the meanders of the Sava river. The Umka landslide is one of the largest active block landslides in Serbia.

Landslide area has been investigated over the last 30 years, and the last conventional monitoring has been completed in 2005; at that time the depths of the sliding surfaces in various blocks have been definitively confirmed, based on the results of numerous inclinometric measurements.

Completely automated monitoring system was installed at the Umka landslide in March 2010. A double-frequency GNSS receiver Leica SR530 & AT502 with monitoring and recording of satellite

observations every 30 seconds was installed. Two referent station have been set as stable points from March 2010 to June 2011 (Belgrade and Lazarevac) and from June 2011 three additional referent stations were set up (Belgrade, Indjija and Grocka). Together with the displacement monitoring, daily climatological data was collected (amount and type of precipitation, temperature and air humidity), as well as hydrological data: the levels of Sava river at measuring stations Beljin and Belgrade.

The analysis of data from GNSS monitoring over the last three years has shown that the surface movements are continuous and that cumulatively add up to approximately 70 cm (2D and 3D movement). Variations in movement speed are related to the regime of Sava levels and the precipitation. Based on the research results, the Umka landslide belongs to the group of deep and very slow to slow active landslides.

## **S1-16 – Landslides in Vietnam and the JICA - JST joint research project for landslide disaster reduction**

**Q. Khang Dang**

*VNU University of Science, Hanoi, Vietnam*

**K. Sassa**

*International Consortium on Landslides, Kyoto University, Kyoto, Japan*

**D. Do Minh**

*VNU University of Science, Hanoi, Vietnam*

**V. Tien Dinh**

*Institute of Transport Science and Technology, Hanoi, Vietnam*

**ABSTRACT:** Vietnam has a ratio of mountainous terrain up to ¾ area of its territory, which has very complex geological settings. Vietnam's geographical location is bordered by Pacific Ocean. It is influenced by the monsoon climate with the average annual rainfalls from 2,000–2,500 mm/year. Due to its geological, geographical conditions and climate characteristics, Vietnam is subjected to frequent slope disasters, those causing annual damage of nearly 100 million USD. Landslides often take place extensively during the rainy seasons. The transportation routes in the north-western mountains and in the central part of Vietnam have the highest density of landslides, with the total length of roads threaten by landslides over 3000 km and a total estimated annual volume of landslide mass from 300,000 m<sup>3</sup> to 600,000 m<sup>3</sup>. Therefore, it is required to develop methodologies and models to help reducing the vulnerability of the country with respect to landslide disasters. The project "Development of landslide risk assessment technology along transport arteries in Vietnam" was approved and supported by the Science and Technology Research Partnership for Sustainable Development (SATREPS) which is under the auspices of the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA). The Ministry of Transport of Vietnam (MOT) has assigned the Institute of Transport Science and Technology (ITST) to collaborate with the International Consortium on Landslides (ICL) in implementation of the Project in 5 years period (2011-2016). The goal of the Project is to contribute to geo-disaster reduction along main transport arteries and residential areas through developing of new landslide risk assessment technology and its application to forecast, monitoring and disaster preparedness of landslides in Vietnam. This paper presents the state of landslide activity and the ability of application of the new ring shear apparatus ICL – 2 for landslide study in Vietnam.

## Session 2: Landslide Hazard Mapping: Inventories, Susceptibility, Hazard and Risk

Friday, 8 March 2013, 14:00-16:30, The Aula, University of Zagreb

CHAIRS: HIDEAKI MARUI (NIIGATA UNIVERSITY) AND SNJEŽANA MIHALIĆ ARBANAS (UNIVERSITY OF ZAGREB)

### S2-01 – Specification of East-European landslide terminology and classification systems

O.V. Zerkal

*Geological Faculty, Moscow State University, Moscow, Russia*

**ABSTRACT:** Elaboration of the unified terminology that should be used for landslides' description and forms the basis for slope deformations classification is an important stage of systematizing of our knowledge of the landslide phenomena. Landslide-related Eastern-European scientific school is characterized by integrity of description and systematization of landslides formed in quite variable environmental conditions. Climate varies from subtropical to arctic; geology and geomorphology – from mountain ranges and areas of modern volcanic activity to ancient cratonic plains incised by river valleys and to coastal regions.

Numerous landslide classifications developed within the frames of Eastern-European scientific school can be divided in several groups:

- Universal classifications based on wide range of classification criteria;
- Morphogenic classifications for which displacement mechanism and types of rocks/soils affected by landslide are used as classification criteria;
- Regional classifications that take into consideration local geological and geomorphic conditions of the study area;
- Special classifications based on one or several specific parameters used as classification criteria (for example, plan shape of landslide, nature of scarps, etc.).

Use of morphogenic classifications is the present-day mainstream in the international landslide studies. Such classifications elaborated in Eastern Europe consider geological conditions preceding slope deformations that are inherited during landslide evolution and affect its motion.

### S2-02 – BeoSLIDE – Belgrade landslide inventory

P. Lokin, U. Đurić, B. Trivić, R. Pavlović

*Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia*

**ABSTRACT:** After huge number of landslide events in Serbia during 2006 (some of them with catastrophic damage on households), Belgrade City Government has initiated defining a strategy for landslide damage prevention. City Government and Assembly adopted suggested proposal to finance new landslide inventory, since the old inventory has been made 30 years ago. By project proposal, task was to create modern landslide inventory in a GIS oriented software for Belgrade General Plan area (approx. 360 km<sup>2</sup> with more than 1,2 mil. population). All noted landslides were categorized by level of hazard and risk of their activation. This information system and landslide

database should enable continuous monitoring of the landslide processes and possibility of early warning system development. Such information should be at disposal to: planners, investors and builders. In others words, it should enable rational landslide risk management. Inventory should also enable possibility to define priorities objectively, which would ease the management effort of the local authorities, when preventing and stabilizing active landslides or protecting affected structures. Basic goals for creating a new inventory were: to archive all documentation of Belgrade landslides in one place and to make data publically available; to collect data in digital form (database) in order to have them continuously updated during time; to make a database searchable by various parameters which are crucial for city governance (by municipality location, different urban zones, infrastructure locations etc.); to generate full .pdf or .doc format reports with quality data about inventoried landslides (with included maps, diagrams, laboratory data, core sampling etc); to provide local decision makers with information on priorities in landslide investigations for civil engineer projects or for landslide prevention and remediation, in different stages of project design. Landslide inventory was funded by Belgrade Land Development Public Agency and it was developed by University of Belgrade, Faculty of Mining and Geology science/research team with support of numerous external associates, experts in different geological engineering disciplines. During two and a half years of developing and field investigations the following has been done: collecting, systematization, critical analysis and reinterpretation of available landslide data; photogeological analysis of terrain; additional field investigations engineering-geological mapping and reambulation; creation of land stability maps; landslide hazard and risk assessment; developing and programming information system and database for inventory; inputting collected data into digital inventory and alpha-testing of developed application. Digital landslide inventory with database and information system for Belgrade General Plan area was made during 2008-2010 yr. 1150 individual landslides were registered and for each of them the following information has been added to the database: location, geological conditions, existing exploration works and their results and works on prevention and stabilization. Beside geological and engineering-geological data, various datasets important for decision makers and City Government branches have been inputted in the database. These included: 89 sheets of Belgrade topographic maps (scale 1:5000, in raster .jpg and .tif format); orthophoto images of Belgrade with 30 cm resolution; Complex Geological map of Belgrade (digitalized from sheets in 1:10000 scale); 89 scanned maps from old landslide inventory (scale 1:5000, in raster .jpg and .tif format); photogeological map for comparing data in time series. Final product was land stability map with generated level of landslide hazard and risk. Inventory was created as tool/sub-shell inside ArcGIS© software, with localization on Serbian language (Latin script).

## S2-03 – Landslide database on the road network in Serbia

**S. Milenković, M. Jotić, V. Vujanić, B. Jelisavac, Z. Berisavljević**

*The Highway Institute, Geotechnical department, Belgrade, Serbia*

**ABSTRACT:** The landslides as one of the most frequent slope gravitational processes not only exert direct influence onto the safety of traffic operation, but at the same time they cause great material damages on the road network in the Republic of Serbia. In the last few decades, very important geotechnical focus and investigation field has been methodological approach regarding landslide dynamics and consequently its damage potential on human life and material goods. Related to that, in the most of the countries, landslide hazard and risk assessment are essential

part of geotechnical documentation for planning, design and maintenance of the road network. In Serbia, (also in the neighboring countries) nevertheless absence of the continuity in the landside data collection on road network, adequate analysis and utilization of the data for hazard and risk assessment is missing throughout proper prediction of material losses. Also, as a constant, there is lack of institutions for central gathering, systematization, analysis and proper storage at the state level.

The purpose of creating and updating the database on landslides on road network is to provide for prompt, complete and exact information to competent authorities regarding the number and state of occurrences of unstable terrains, level of jeopardy of transport facilities, rating of priorities in undertaking repair measures, as well as information to road users on conditions, passability and safety of road transport facilities.

All the collected data will further serve for the production of the hazard and risk maps, which will gradually improve usability of the data. We hope that presented data base will not end its life, like many times before at the phase of forming description sheet with recording of the present state without clear vision about implementation of the results towards better prediction levels, with regular updating of the database.

Authors of the paper present the principles of database formation which provide for prompt, technically correct and successful completion of maintenance works and protection of roads with minimum disturbance to the traffic, along with qualitative technical supervision and reliable repair measures.

## **S2-04 – Program of the landslide database development of the Republic of Srpska, BIH**

**C. Sandić, K. Leka**

*The Republic Institute for Geological Researches of the Republic of Srpska, Zvornik, Bosnia and Herzegovina*

**ABSTRACT:** The process of landslides activation and other phenomena of the terrain instability is a complex and complicated problem and it is very common in the territory of the Republic of Srpska. Landslides endanger the population, traffic and construction safety and cause major damage. People with different profiles and professions occupy with problems of slopes stability: geologists, engineers, designers of different types of objects, planners etc., but the population are still the most endangered.

The main aim of the landslide database (inventory) is a long-term engineering geological study of the terrain in order to fully understand and define the properties of the terrain for planning and rational use. The Republic of Srpska does not have one centralized base of landslides, rockfalls and other geohazards. The establishing of landslide database is necessary, because the data mostly storage on a local level. The establishment of this system for the observation of geohazards provides valuable information for preventing the problems of instability and landslide remediation. The landslide database (inventory) is a national project with the aim to identify and map landslides over the whole territory of the Republic of Srpska, based on the standardized criteria.



The complete database will be made in the GIS and will consist of: general information about the landslide; geomorphological and geological characteristics; hydrological and hydrogeological characteristics; the type of the processes and the type of landslides on the slopes; causes of the landslides; vegetation; exploration of the landslides; data on monitoring; reports (text files) and photos. For each landslide corresponding database has formed and associated with the graphical data, photographs and tables.

The landslide database is an integral part of the geological information system, and it will be developed at the Republic Institute for Geological Researches of the Republic of Srpska.

## **S2-05 – Landslide Inventory Map of the Republic of Macedonia, statistics and description of main historical landslide events**

**I. Peshevski, M. Jovanovski**

*Faculty of Civil Engineering, Ss. Cyril and Methodius University, Skopje, Macedonia*

**B. Markoski**

*Institute of Geography, Ss. Cyril and Methodius University, Skopje, Macedonia*

**S. Petruseva, B. Susinov**

*Faculty of Civil Engineering, Ss. Cyril and Methodius University, Skopje, Macedonia*

**ABSTRACT:** For the first time, landslides in the Republic of Macedonia have been systematically mapped in the past century, during the preparation of the Basic Geological map at a scale of 1:100,000. Additional landslides have been later registered, during the period when the engineering-geological maps of some regions in the country were drawn at scales 1:100,000 and 1:200,000. The total number of landslides on these maps is over 180.

In order to provide a solid base for GIS data, which would serve as a base for preparation of landslide hazard and risk maps later on, collection of all existing data of instabilities in the country is of essential importance. During 2012, in a short period of three months, all companies that work in the field of geology and geotechnics are contacted and consulted; also national archives and internet sites were thoroughly searched for landslide data. Technical documentation in the form of Geotechnical Elaborates and Geological Reports for over 70 (until now unregistered) investigated landslides was collected. The data presented in these documents is relatively comprehensive. For each landslide with sufficient information, separate data sheets have been prepared. A form of datasheet similar to the one of the Italian Landslide Inventory (IFFI project) was used, which was considered as the most advanced one. All the landslides from the Basic Geological map and the newly collected ones were analyzed from several important aspects.

The coordinates of the main scarps of all landslides were placed in GIS environment with the highest possible precision. All the landslides are named by their ID code which consist of symbol for topographic section (1:25,000) and number of the first registered landslide in that section.

The scale of 1:200,000 was used for printing of the Landslide inventory map as a most convenient one. This scale is considered as satisfactory having in mind the total area of Republic of Macedonia of 25,713 square kilometers. Furthermore, the GIS based landslide inventory map will be constantly updated and improved, in parallel with the collection of the other historical data and with the occurrence of the new instabilities in the country.

All the above mentioned steps enabled us to perform statistical analysis and to group the landslides using different criteria. The most important among them are: landslide mechanism, geology, exposure, elevation, area, cause, activity, affected infrastructure, remedial measures, monitoring status, etc.

The most significant landslide events throughout the history are described thoroughly in order to conceive the socio-economic losses that they were brought to the society. Landslides “Gradot”, “Crnik”, “Timjanik”, “Ramina”, “Germa”, “Skudrinje”, “Jelovjane”, “Velebrdo”, are considered as most damaging.

The preparation of the inventory map is considered as a first step in the process of mitigation of landslide consequences in future. In order to prevent further catastrophes in most affected areas, it is essential to prepare regional landslide susceptibility, hazard and risk maps. The recommendations of the world well-known experts and societies in the field of landslide hazard and risk mapping will be respected, certainly.

## **S2-06 – Landslide susceptibility maps of Vlora District**

**E. Plaku, M. Jusufati, M. Lamaj**

*Albanian Geological Survey, Tirana, Albania*

**ABSTRACT:** Landslide susceptibility can be defined as the relative degree of instability of the terrain. This map presents the probability of future landslide occurrences. To build up a landslide susceptibility map we should consider the published methods or we can modify these to get a better-expected result. Most of them only implemented the heuristic method to the area prone to landslide and the problem of this method is in the subjectivity of defining parameters, the weighted and scoring values.

The objectives are building inventory map of the slide and the preparation of Landslide Susceptibility maps of Vlora district. Initially were built up the lithological maps in scale 1:50,000 along with slides, total 87 slides (inventory map).

There are many factors that should be considered to analyze landslide for the preparation of Landslide Susceptibility maps of Vlora district. We divided those factors into 3 groups of factors described as follows:

- Topography factors such as data of digital terrain model, slope direction and length;
- Engineering factors such as data of lithology, structure of geology;
- Land Use factors such as data of land use map.

The slope gradient is the most important factor to build up the landslide susceptibility mapping. This factor is generated from digital elevation model on Albania, the classes of the slope gradient are extracted in grades classified into 9 classes: 0-5°, 5-10°, 10-15°, 15-20°, 20-25°, 25-30°, 30-35°, 35-40° and higher than 45°.

Lithology data were extracted from geological map. Lithology is one of the main factors influencing the type and the intensity of the morph-dynamic processes, including landslides. We involved lithology as a factor for susceptibility mapping, based on geological maps scale 1: 50.000, various formations in the study area have been grouped into 11 classes to prepare the lithology data layer. The 11 classes correspond to 1 strong sedimentary rocks, 2 stratified rocks, 3 sandy rocks, 4

average clay rocks, 5 soft clay rocks, 6 soft rocks the chaotic, 7 evaporate rocks, 8 soils with cohesion, 9 soils without cohesion, 10 soil layers with and without cohesion.

Land Use is one of the key factors responsible for the occurrence of landslides. The classes of land use are categorized into reservoir, forest, mixed garden, mixed forests, urban areas, pasturage, and agricultural lands.

For the preparation of landslide susceptibility maps of district Vlora is used heuristic analysis and bivariate statistical analysis.

Heuristic approach is based on opinion of engineer-geologist experts. Landslide inventory map is accompanied with environmental factors to be main input for determining landslide hazard zonation, and then the experts define the weighting value for each factor. Heuristic approach takes into account a hierarchical heuristic model becomes a part of decision support system (DSS) which aims for spatial decisions.

Bivariate analysis is based in using raster Data. All the factors taken into consideration converted to raster, than made analysis using Van Westen's formula for calculating the weight of each class "i" parameter "j".

In conclusion we can say:

- Gentle slopes are predicted to give the low value for shallow landslide based on commonly lower shear stresses correlated with low gradient. At slope from 10 to 30°, landslides may have high probability. The remained slope angle more than 30° will give a low probability relatively because the existing of resistant lithologic units.
- Larger slides have occurred in the cliffs of soft clay, soft rocks chaotic, stratified rocks and the rest in other lithological formations.
- According land-use larger slides have occurred in coniferous forests, fir, agricultural lands, urban areas and the rest in other classification.

## S2-07 – Landslides hazard maps for Mures County central area, Romania

**E. Milutinovici, S. Corlateanu, D. Mihailescu, R. Iacobescu**

*Field Studies Department, Search Corporation, Bucharest, Romania*

**ABSTRACT:** The main aims of this study are: a) identify all landslides affecting the territory of the central region of Mures county, b) estimate the influence coefficients according to the possibility of landslides formation, c) calculate the hazard average coefficient, based on the values estimated for the influence coefficients, d) preparation of the landslides hazard map.

Mureş County is located in the central-northern part of Romania and stretches between the Căliman and Gurghiu mountains up to Târnavelor Plateau and Transylvania Plain. The physical - geographic axis of the county is given by the Mureş River which crosses the county from north-east to south-west along 140 km. The central area of the county includes 50 administrative territorial units and is divided into three sub- areas: Sarmasu, Targu Mures si Sovata.

Geologically, in Sarmasu sub-area, located in the central-western region of the county, beyond the right bank of Mures River, the predominant deposits are Sarmatian: Volchinian - inferior Bessarabian; in the Targu Mures sub-area located in the center of the county and in the region

beyond the left bank of Mures River, the predominant deposits date since the Pannonian age and in the Sovata sub-zone, located in the central-eastern part of the county, the most deposits date since the Pannonian age, except in a series of regions from the western region where volcanogenic-sedimentary formations can be found, represented by Neozoic migmatites.

A number of 3472 observation points were covered, and a series of vulnerable elements were identified on site. Landslides were identified and consequently 176 landslides identification sheets were prepared.

The value of the influence factors was estimated in all points of observation; each influence factor was estimated at values ranging from 0 to 1. The estimated influencing factors are: the lithology, the geomorphology, the structure, the hydrology and the climate, the hydrogeology, the seismicity, the forests covering and the anthropic factor.

The influence factors values estimated in situ were used to calculate the average hazard coefficient. Based on the average values of the hazard coefficient, a 1:25,000 distribution map was drawn, the interpolation of the existing values being made using the "natural neighbor" method, and the distribution map was drafted by marking the isolines. The equidistance of the isolines was of 0.02.

Following the preparation of this work, a list of the existing landslides was prepared, identifying their sizes, the goods or utilities affected. As a result of the geotechnical investigations, geotechnical patterns of the area landslides were prepared. The support maps were drafted for each influencing coefficient, acknowledging thus the lithological, geomorphological, structural, hydrological, climatic, hydrogeological, seismic, forest covering and anthropic variations in the studied area. The distribution of the landslide hazard was determined for the entire central area of Mures County, establishing thus the areas in which the landslide hazard is average or high.

The landslide hazard maps have multiples uses, depending on the purpose aimed: The map addresses to the local authorities, helping to raise the awareness regarding the development directions of the inside built-up area or of other objectives of interest (industrial, agricultural, social, touristic growth); By using the GIS working system, the maps can be overlapped with the inside built-up area of the localities (GUPs), with the maps presenting the infrastructure or utilities routes, with the touristic objectives or with the objectives of local or national interest, the single condition being that the overlapping maps should be performed in the same coordinates system as the landslide hazard map; The acknowledgment of the "sensitive" area and the road and utilities routes leads to a more precise evaluation of the necessary costs for the construction of new roads or for the rehabilitation of the existing ones, for the maintenance of the utilities that have already been introduced or for the performance of new utilities systems; The map addresses to natural and legal persons, the acknowledgement of a land or of a real estate position according to a landslide hazard map being able to influence its selling / purchase price, as well as the price of a construction insurance.

## **S2-08 – Landslide hazard forecast in Slovenia – MASPREM**

**M. Komac, J. Šinigoj, M. Jemec Auplič, M. Čarman, M. Krivic**

*Geological Survey of Slovenia, Ljubljana, Slovenia*

**ABSTRACT:** In the past 20 years, intense short and long duration rainfall has triggered numerous shallow landslides worldwide and caused extensive material damage to buildings, infrastructure,

roads, and unfortunately also causing deaths. Slovenia was no exception in this regard. But these landslide related problems could be identified and minimized if the knowledge of the landslide occurrence would be upgraded with the more in-depth knowledge of the relation between the triggering factors (rainfalls) and landslides. In the frame of the national project Masprem we aim to develop an automated, online tool for predicting landslide hazard forecast at the national level. The paper presented a design for the system for the modeling a landslide probability through time in Slovenia. The importance of their inclusion in the system will be highlighted.

The system of modeling a landslide hazard probability through time (landslide hazard forecast) will be designed as an integration of static and dynamic input data. In this regard dynamic input data are represented by a real-time rainfall data that will be provided from the ALADIN model, acquired automatically from the server of Environmental Agency of Republic of Slovenia, transferred to local server, and transformed from ordinary text format into GIS raster format to be prepared for the spatial calculations and modeling part of the system. Static input data are represented by a landslide susceptibility map and by the threshold information related to each location, both will be implemented through separate modules. Special attention was paid also on the preliminary testing of 24-hour rainfall forecast as this information still bases on approximations and is the input data that we could manage in terms of enhancing its quality. A validation of different 24-hour rainfall forecast values on the test area revealed that landslides occur in different rainfall periods with different intensities. Landsliding is seen to be generally related to the daily 24-hour rainfall and the amount of the rainfall in a certain period over which accumulated rainfall initiates a slope failure. Based on proposed 24-hour rainfall levels it was found that landslides significantly occurred when the daily rainfall exceeded antecedent rainfall and when the duration of rainfall exceeded certain levels of intensity for a specific duration. For a good landslide hazard forecast antecedent rainfall for up to 30 days has to be calculated regularly on daily basis for every cell to get the real-time information on soil moisture/saturation conditions that could in combination with the daily precipitation trigger slope failures.

Spatial calculations and modeling will be performed on a GIS platform included within the GIS dynamic forecasting modeling module. A landslide hazard forecast model will predict hazards at the level of detail of 4.4 square km as this is the resolution of the rainfall forecast model ALADIN. Updating itself each day (ideally several times per day), the tool will indicate the potential for landslide hazards over the proceeding 24-hour window in a form of five descriptive (instead of numerical representation that is confusing for non-experts) classes: "very low," "low," "moderate," "high," and "very high."

The development of a real-time early warning system landslide hazards that follows for will certainly be beneficial to various stake-holders including the local authorities, relevant government agencies and the public in most exposed and highlighted areas. The developed early warning system, is hoped to achieve its purpose in providing early warning and alerting the authorities as well as the public in general of the potential high landslide hazard areas within the affected areas once there are incidences of heavy rainfall.

# S2-09 – On perspectives of semi-automated landslide assessment

**M. Marjanović, S. Zečević, I. Basarić**

*Faculty of Mining and Geology, University of Belgrade, Belgrade, Serbia*

**ABSTRACT:** Landslide assessment has been in a momentum in the past decade. Numerous methodological approaches have been at stake, ranging from heuristic to statistic and deterministic methods. Particular attention has been driven to a group of machine learning techniques which produce spatially predictive models in a semi-automated fashion, i.e. with limited intervention of the field expert. The concept of machine learning turns out to be very applicable in various spatial prediction scenarios, where landslide assessment is no exception.

Machine learning is a sub-discipline of Computer Science which involves a host of techniques. These can solve various classification or regression problems through the learning process, assisted by the field expert (supervised learning). In the landslide assessment framework, a supervised classification problem (task) is of relevance. It first implies the stage of training in which a machine learning algorithm is being introduced with an expert's interpretation of landslide classes over a specified portion (training area) of an area, supervised by the testing stage in which the trained algorithm automatically extrapolates the interpretation of the landslide classes to the rest of the area (testing area). The machine learning algorithm thus spatially predicts landslide classes in two adjacent terrains, which are necessarily similar enough in engineering-geological terms, and which have a suffice of landslides within (in order to have appropriately sized statistical sample to make a prediction after).

Several machine learning techniques have been proven successful in landslide assessment framework, including Logistic Regression, Decision Trees and Support Vector Machines. Based on the results of numerous researchers, predictable power of such family of algorithms can be speculated. Although the testing area usually has a landslide reference overlay (map or inventory), just like the training area, the predictability of the algorithm is indisputable, and thus its applicability for predicting the landslides is argued. In current practice of landslide assessment via machine learning algorithms it has been shown that plausible predictions with the accuracy of over 80% sometimes even 90% are achievable. It opens possibilities for applications over terrains which hypothetically do not have a landslide map/inventory overlay for the testing area or at least not in a suitable scale.

To support and contribute to the above statements and speculations, the authors have been experimenting on several case studies in last couple of years including: NW Fruška Gora Mountain in Serbia, Starča Basin in Croatia and Halenkovice area in Czech Republic. All three mentioned algorithms (Logistic Regression, Decision Trees and Support Vector Machines) have been implemented in each case study and according to the results, the Support Vector Machines can be singled out as the most preferable technique, since it performs best in all three case studies. The accuracy has been reaching over 90%, while other performance indicators, such as Kappa index and Area Under ROC curve also reached very high values in all case studies (nearly 0.8 and 0.9, respectively). However, the evaluation remains an unsolved problem despite the numerous available statistical measures, because the nature of these models is predictive and it does not necessarily reflects the present state of the landslide distribution, but overall potential of their occurrence in time.

In conclusion, the semi-automatic prediction of spatial distribution of landslides for an area with no landslide inventory is viable, and shows good potential for applications in the future. It heavily depends on the quality of the expert's interpretation and also the quality of used data. Evaluation of such prediction is although problematic, but some guidelines for preference of one type of their errors over the others (false alarms over the false negatives) are a promising approach.

## **S2-10 – Exposure of inhabitants, constructions and infrastructures to landslide susceptibility in case of selected municipalities in Slovenia**

**T. Peternel, M. Jemec Auflič**

*Geological Survey of Slovenia, Ljubljana, Slovenia*

**ABSTRACT:** In the frame of project Masprem exposure maps of inhabitants, constructions and infrastructures to landslide susceptibility in case of five selected municipalities in Slovenia were made. Maps were elaborated based on synthesis of analysis of event-based landslide inventory and field investigations and were developed for five selected municipalities: Bovec, Laško, Slovenj Gradec, Trbovlje and Železniki.

The term exposure can be understood as term hazard without including economical losses. Thus, the exposure is the probability that one is located in the hazardous zone. Due to lack of data (incomplete landslide database e.g. frequency of occurrence and magnitude of landslides) the information about exposure of inhabitants, constructions and infrastructures are referred only to probability of landslide occurrences in a certain area. Exposure of inhabitants, construction and infrastructures to landslide susceptibility were analyzed and made based on landslide susceptibility map at scale of 1:25,000 with raster format 5 x 5 m pixel resolution. All the analyses were conducted in the GIS system with software tools ArcMap, based on statistical method of overlapping.

Exposure maps, based on landslide susceptibility, were divided by range from 1 to 6, where class 1 represents areas with negligible exposure to landslide susceptibility and class 6 areas with very high exposure to landslide susceptibility. Exposure maps of selected municipalities represent areas where inhabitants, constructions and infrastructures are more or less exposed to landslide susceptibility and may provide a very good basis for further determination of risk assessments and risk management.

Results of exposure analysis of inhabitants, construction and infrastructures to landslide susceptibility show that the most exposed inhabitants are at municipality Laško and Železniki. Constructions (e.g. different buildings) are the most exposed at municipalities Laško, Trbovlje and Železniki. From exposure analysis it can be seen that infrastructures elements (e.g. railway, roads, electric system, sewage system, pipelines, thermal system and water supply system) most exposed to landslide susceptibility are at the municipalities Trbovlje and Železniki.

# S2-11 – The preliminary damage assessment of properties based on massive appraisal maps

**B. Bajat, M. Kilibarda, M. Pejović, M. Samardžić Petrović**

*Faculty of Civil Engineering, University of Belgrade, Belgrade, Serbia*

**ABSTRACT:** This paper deals with feasible solution for the preliminary assessment of potential damages costs of dwellings based on different spatial layers as input parameters. The research concentrates on implementation of different spatial data bases that are already available as a public data, like land-use suitability (LUS), building height typology (BHT) databases and massive appraisal maps, that are particularly developed for real estate market.

Massive appraisal maps were produced based on the spatial-econometric hedonic dwelling price model that has been developed for the Belgrade metropolitan area using cross-sectional and georeferenced transaction data. Given that a cross-sectional analysis of house prices involves georeferenced information, Geographical Information System (GIS) and spatial statistics are suitable tools for hedonic modeling. The spatial predictors, given as raster maps, were used as auxiliary inputs necessary for hedonic regression modeling. In addition to standard environmental predictors, some socio-economic data, such as distribution, ages and income of inhabitants, were prepared in the same manner enabling their use in GIS support environment, in order to achieve reliable spatial assessment of dwellings prices per square meter.

The results of spatial prediction are given as digital maps in raster format. The obtained map could be of interest for appraisers, real-estate companies and bureaus, while as long as they provide an overall insight of location prices.

Combined with the data which constitute mandatory contents of town planning documentation concerning information on land-use suitability and height of residential buildings, those maps could be used potential damages costs assessment. Land-use suitability data layer (given in vector format) prepared for the recent Master Plan of city Belgrade was used to delineate regions of hazard-prone areas concerning potential landslides risks. The other sort of input data concerns residential blocks. They are an integral part of planning documents which have already been made for the Master Plan of Belgrade from the year 2000 in digital form in GIS environment, so that they are presented in vector format (shp. files). Obviously, a building block is designated as a residential area clearly delimited by roads. In our case, only purely residential blocks were considered, while mixed blocks were not used in the experiment. An attribute associated to each block is its building height typology (BHT) class. Based on the average number of square meters and structure of housing units which correspond to each class, the total building areas were calculated.

Based on simple map algebra of those three layers and overlaying GIS function, one could easily calculate potential damages costs of residential buildings due to potential landslide risk over the whole case study area

To get better insight in the final results obtained as thematic map and to make easier communication throughout many web map-based services, we used recently developed package in R language environment, plotGoogleMaps, based on Asynchronous JavaScript and XML (AJAX) and Google Maps Application Programming Interface (API) service that produces HyperText Markup Language (HTML) file map mashups (web maps), with high-resolution Google Map as a base map.



Preparing and processing of input data were performed in GIS environment by ArcGIS and open-source R software packages.

## **S2-12 - ICL Summer School on Rockslides and related phenomena: Field training course on morphology and internal structure of large-scale catastrophic bedrock landslides**

**A. Strom**

*Geodynamics Research Centre – branch of JSC “Hydroproject Institute”, Moscow, Russia*

**K. Abdrakhmatov**

*Institute of Seismology of National Academy of Sciences of Kyrgyz Republic, Bishkek, Kyrgyzstan*

**ABSTRACT:** Rockslides (bedrock landslides) are among the most hazardous natural phenomena in mountainous regions. Though relatively rare, as compared with landslides in non-lithified soils, they pose a threat to the vast areas due to enormous amount of material involved (sometimes up to billions of cubic meters), high mobility of debris and ability to create large natural dams, which cause inundation of the valleys upstream and catastrophic outburst floods downstream. Similar rock slope failures occur sometimes in large open cast mines. The aim of the International Summer School is to demonstrate rockslides of different types – long runout rock avalanches, intact and eroded rockslide dams, along with various methods of their study (identification, mapping, dating, detail analysis of rockslide internal structure and grain-size composition) to students and young landslide researchers.

Numerous rockslides and rock avalanches of different morphological types ranging from few millions to more than 1 billion cubic meters in volume are concentrated in the Kokomeren River valley (Central Tien Shan) within a limited area of about 30×60 km at one-day trip distance from the Bishkek city – capital of Kyrgyzstan. Due to arid climate and lack of vegetation rockslides' morphology is well preserved and clearly visible (Strom, Abdrakhmatov, 2009) allowing identification of several morphological types of catastrophic bedrock landslides listed hereafter.

“Primary rock avalanches” are characterized by debris accumulation at a distal part of the transition zone. They can form either really long runout rock avalanches or (when occurring in narrow valleys) relatively compact landslide dams with distinct proximal lowering.

“Secondary rock avalanches” have bipartite morphology with compact body at the headscarp foot and long runout mobile part. Rock slope failures of this type can be divided into two subtypes – the “classical” one with distinct concave secondary scarp that marks the boundary between the compact and mobile parts, which occur when rapidly moving debris collides with valley bottom or its opposite slope, and the “bottleneck” subtype that originate when moving debris passes through sharp narrowing on its path.

“Jumping rock avalanches” are also characterized by the bipartite deposits’ morphology, though differing from the “Secondary” type. Its characteristic feature is the convex shape of the compact part slope rising above the avalanche-like part. Jumping rock avalanche could be formed when rockslide mass really jumps from a slope like a ski jumper and collides with valley bottom almost at a right angle.

Some of rockslide deposits in the study area up to 400 m thick have been deeply dissected by erosion forming excellent outcrops where the internal structure of these bodies could be observed

and studied in detail. At some sites one can see may be world-best evidence of rockslide debris “stratification” when debris originated from different lithologies presenting in the source zone do not mix but form successive “layers” that can be traced for hundreds meters and kilometers. Besides one can observe and sample intensively crushed debris of the lower/internal parts of rockslide bodies to study its grain-size composition and to compare it with composition of coarse upper/external carapace. In-situ permeability tests can be carried out at some outcrops.

Evidence of inundation caused by rockslide damming and of associated outburst floods could be found in the Kokomeren River valley as well (Strom, 2012). Besides the bedrock slope failures several very large landslides in non-lithified Neogene and Quaternary deposits in the adjacent neotectonic depressions are demonstrated.

Besides rockslides and landslides, the study area provides expressive manifestations of neotectonics and Quaternary tectonics. There are numerous active faults, one of which was ruptured during the 1992 M7.3 Suusamyр earthquake, and impressive examples of tilted and folded pre-Neogene planation surface.

Various paleoseismic features such as surface ruptures and liquefaction are demonstrated to the Summer School attendees with special emphasis to paleoseismological interpretation of rockslides.

The annual International Summer School supported by ICL has been organized since 2006. Previous field training courses were attended by participants from Argentina, Austria, Belgium, China, Czech Republic, France, Germany, Great Britain, Hong Kong, Italy, Kyrgyzstan, New Zealand, Russia, Spain, Switzerland, Tajikistan and USA. We hope that the 2013 training course that will be carried out on August 15-31 will be attended by landslide researchers from the Adriatic-Balkan countries too.

## Session 3: Flash Floods and Debris Flows

Friday, 8 March 2013, 16:50-17:30, The Aula, University of Zagreb

CHAIRS: YOSUKE YAMASHIKI (KYOTO UNIVERSITY) AND NEVENKA OŽANIĆ (UNIVERSITY OF RIJEKA)

### S3-01 – Hydrological model of karstic Blue Lake near Imotski (Croatia)

**O. Bonacci, I. Andrić**

*Faculty of Civil Engineering, Architecture and Geodesy, University of Split, Split, Croatia*

**Y. Yamashiki**

*Disaster Prevention Research Institute, Kyoto University, Kyoto, Japan*

**ABSTRACT:** The work analyzes the continuous monitoring of an intermittent karst lake in south east Croatia. Modro Jezero (Blue Lake) is a collapsed doline with ongoing side slope degradation and collapsing processes. The water in the lake is mostly a reflection of the ground water oscillations in the study area, yet the significant contribution of the surface and subsurface flow of the lake's catchment can be registered. Flooding of the nearby karst field is strongly correlated to the hydrological regime of the Blue Lake. The measured data present the first systemized and continuous monitoring of the hydrological parameters of this lake. The hydrological analysis also involved the daily rainfall data and daily average air temperatures recorded at the nearby Imotski meteorological station. Geodetic survey and photogrammetry models were used to determine the geometry of the lake. The intensities of the water level rising and falling, as well as daily average inflow and outflow into and from the lake, were calculated using the obtained data. For the purposes of the water budgeting, the effective rainfall available for the groundwater recharge was calculated according to fluid-mass balance method introduced by Palmer. Furthermore, the hydrological model was created with the attempt to simulate the inflow and outflow processes of the lake.

### S3-02 – Analysis of flood flows at profile of Modrac Dam and its impact on downstream area

**N. Suljić**

*Faculty Mining, Geology and Civil Engineering, University of Tuzla, Tuzla, Bosnia and Herzegovina*

**O. Kovčić**

*Public Enterprise for Water Recourses Management "Spreča" d.d., Tuzla, Bosnia and Herzegovina*

**N. Kikanović**

*Bureau of Urbanism of the Municipality of Tuzla, Tuzla, Bosnia and Herzegovina*

**R. Muminović**

*Mining Institute Tuzla, Tuzla, Bosnia and Herzegovina*

**S. Kadrić**

*Technograd inžinjerin Ltd., Tuzla, Bosnia and Herzegovina*

**ABSTRACT:** After construction of dam on profile „Modrac“ which is built in 1964, it was formed reservoir with basic aim of ensuring the process water for industry Tuzla region. In the present

conditions the storage lake of "Modrac" is a source of drinking water for the municipality of Tuzla. However, this reservoir, in addition to the basic purpose, has a multipurpose character, including flood mitigation downstream of the dam profile. Flood flows typically occur in May / July, when the reservoir, according to the dam and reservoir "Modrac" operation plan, because of the dry flood must be full. Regardless of this statement, reservoir in terms of "preserved volume" softens-cuts peaks of the flood waves due to the large retention effect.

The occurrence of high water (100 yrs., 500 yrs., 1000 yrs.) are the extreme hydrological phenomena defined by unusually high water level, flow or volume of water at a certain place at a certain time. Causes and consequences of flooding are often not predictable, but it can be mitigated. Consequences of floods threatened human lives and material goods, huge damage, inclusion of a large number of people and resources in the field, social insecurity of the population, etc.

The analysis in this paper will include of the two largest flood flows that have occurred in the last 30 years, based on daily stream flow levels and flow at the dam Modrac.

The analysis will be carried out with the help of a software package HEC-RAS (Hydrologic Engineering Centers River Analysis System) which is an integrated system of software, designed for interactive use in a multi-tasking, multi-user network environment. The system is comprised of a graphical user interface (GUI), separate hydraulic analysis components, data storage and management capabilities, graphics and reporting facilities.

HEC-RAS is designed to perform one-dimensional hydraulic calculations for a full network of natural and constructed channels. The following is a description of the major hydraulic capabilities of HEC-RAS.

The HEC-RAS system contains four one-dimensional river analysis components for: (1) steady flow water surface profile computations; (2) unsteady flow simulation; (3) movable boundary sediment transport computations; and (4) water quality analysis. A key element is that all four components use a common geometric data representation and common geometric and hydraulic computation routines. In addition to the four river analysis components, the system contains several hydraulic design features that can be invoked once the basic water surface profiles are computed.

The analysis will be carried out for the calculation of evacuation of high water and flood flow (wave) propagation downstream of the dam and reservoir Modrac as unsteady flow routing.

Hydraulic length of downstream area which will be processed by this analysis is about 670.00 meters.

Unsteady Flow Simulation in HEC-RAS modeling system is capable of simulating one-dimensional unsteady flow through a full network of open channels.

This paper will also envisage the ability of the reservoir "Modrac" to reduce the flow downstream of the dam but also impact of flood flows on downstream area.

## S3-03 – Torrential check-dams as debris-flow sources

**J. Sodnik**

*Water Management Company Kranj, Kranj, Slovenia*

**A. Kryžanowski**

*Faculty of Civil and Geodetic Engineering, University of Ljubljana, Ljubljana, Slovenia*

**M. Martinčič, M. Mikoš**

*Faculty of Civil and Geodetic Engineering, University of Ljubljana, Ljubljana, Slovenia*

**ABSTRACT:** In the past years and in order to mitigate different torrential hazards, numerous structures were built in headwaters and especially in torrential channels in the Alps and elsewhere in mountainous regions of the world. Channelized debris flows are one type of such hazards, and torrential check dams are typical type of torrential structures. The paper is oriented towards a question whether torrential check dams should be considered as sediment sources when estimating channelized debris-flow scenarios and assessing debris-flow magnitudes. One can assume that large amounts of coarse torrential sediment deposits behind torrential check dams can under circumstances importantly change the debris-flow magnitude and/or debris-flow event scenario. Therefore, plausible estimation of debris-flow magnitudes and debris-flow hydrographs is crucial for reliable hazard assessment along torrential streams and on torrential fans.

In Slovenia, a central European country with high hydropower potential and intense torrential processes in mountainous and hilly headwaters, state legislation concerning large dams and spatial consequences of their failure exists, but it does not cover torrential check dams as one of the structure type under consideration. When developing a new approach to estimate risk due to failure of torrential check dams, the before-mentioned existing legislation was taken as the starting point. The newly proposed qualitative evaluation of risk rate due to failure of torrential check dams was tested for a chain of torrential check dams in a selected torrent. The evaluation was developed considering the following parameters: basic parameters of a check dam (constructional height, volume of sediment deposits, design flood/discharge), availability of technical documentation (design documentation, operation instructions, emergency plans in the case of failure, alarming plans), operation parameters (purpose of the structure, monitoring, alarming systems), risks (collapse, supervision, design system, managing) and state of the structures and hydraulic equipment (construction, sediment deposits, hydraulic equipment).

Each before-mentioned parameter was ranked according to a three-level (large, medium, and small) scale of impact on failure risk, based on a professional judgment (skills, experiences, field expertise). To ensure selectivity of the final failure risk evaluation, the rank values of single parameters were scored with increasing steps, and then the ranks were summed up. The final failure risk evaluation is based on a 5 level risk scale (small, medium, large and two intermediate levels). For ranking purposes, also known facts and circumstances were taken into account, gained during previously conducted field inventory of torrential structures and their documentation. The applied rankings of parameters are valid only for the considered structures, and should be further applied on a larger sample of torrential check dams. Obtained values of risk parameters were used for the final classification of torrential check dams with regard to the risk of their failure.

For failure of check dams, two scenarios were considered: a) Partial failure of a check dam during a torrential flood which results in a hyper-concentrated flow in the downstream channel, and b) Complete failure of a check dam. A complete failure results in a channelized debris flow with much greater peak discharge in the downstream channel. These two different scenarios were also taken

as input parameters (inflow hydrograph) for mathematical modeling of debris flows in order to assess debris-flow hazard.

## **S3-04 – Hydraulics of stratified two-layer flow in Rječina Estuary**

**N. Krvavica, V. Travaš, N. Ravlić, N. Ožanić**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**ABSTRACT:** The salinity distributions in the micro-tidal channel of Rječina estuary, in Croatia, are thoroughly studied through intensive sampling campaigns. The salt wedge is developed at the downstream river part, and its length is found to be directly related to Rječina River discharges. The length of the wedge is also dependent, but in smaller intense, to tidal phases. Strong vertical stratification was observed throughout the tidal cycle, proving the limited vertical mixing between salt and freshwater layer. Bottom topography also plays a major role in wedge propagation, especially during small river discharges.

A one-dimensional model for two-layer stratified flow, based on Schijf-Schoenfeld model, was developed and used. Results of literature review were confirmed – the interfacial friction factor cannot be satisfactorily correlated neither with Reynolds, Froude nor Keulegan number. The average interfacial factor was found to be best correlated with the number  $ReRi^3$ , in which  $Re$  and  $Ri$  are Reynolds and overall Richardson number respectively. Comparison of the modeled and measured shapes of the density interface lines suggests that the interfacial friction factor varies along the wedge and that the use of the length averaged interfacial friction factor is not sufficiently accurate.

## Poster Session: Landslides in the Adriatic-Balkan Region

Friday, 8 March 2013, 17:30-18:30, Hall in Front of the Aula, University of Zagreb

### PS-01 – Landslide investigation of earthquake induced landslide during rainfall in Tandikat, West Sumatra, Indonesia

F. Faris, F. Wang

*Research Center on Natural Disaster Reduction, Shimane University, Matsue, Japan*

**ABSTRACT:** Indonesia is an archipelagic country which extends on one of the most active seismicity area in the world. In geological perspective, the west and south coast of the archipelago takes apart into Pacific Ring of Fire makes it numerously contains active volcanic mountains which extensively supplies loose volcanic material. The tropical climate brings consequence of high precipitation of the most area. These facts make Indonesia has high vulnerability against geodaster which induced by combination of earthquake and rainfall on volcanic areas.

One of the most devastating earthquakes in Indonesia struck West Sumatra Province on September 30, 2009, at 5:16 p.m. with M-W 7.6 magnitudes, caused about more than 1,000 deaths. The earthquake excited number of landslides which took more than 60% of total earthquake death toll. The most extensive landslides which occurred in Tandikat, Padang Pariaman Regency, buried hundreds of people and flattened some villages. These landslides occurred on loose pumice layered mountain during rainfall. The combination of intensive rainfall and strong earthquake is considered to decreases the slope stability dramatically. This study attempts to reveal contributory factors which involved on the event.

The study of failure of the landslides has been conducted from previous research using the un-drained shear ring apparatus to confirm the grain crushing mechanism of long displaced pumice material. However, it needs more study about the landslide and its initiation mechanism during rainfall.

Integrated study of the landslide elaborating field investigation, laboratory work and numerical modeling were conducted. Geological investigation on the landslide area and laboratory investigation had been performed to examine geological features and mechanical properties of sliding material. The field investigation consisted of soil sampling, Standard Penetration Test (SPT), geological logging, in-situ permeability and density test. Further examination about mechanical properties of landslide deposit samples subsequently performed in laboratory. Several static and dynamic tests using cyclic triaxial apparatus had been conducted to study about stress-strain history of the soil under dynamic condition. The mechanical parameters of the material were then derived from both geological investigation and laboratory test by correlating SPT values and taking laboratory tests result. These parameters were then used into numerical model using finite element method software ABAQUS to analyze earthquake effect by considering time-historical acceleration from actual earthquake record.

Field investigation revealed that, particularly in the area, impermeable clay stratum is overlain by porous pumice layer. The difference of permeability may cause the saturation of lower part of the pumice layer when rainfall percolates. Both static and stress-controlled dynamic triaxial test showed the contractive behavior of pumice deposit. This behavior brought the consequence of excess pore water pressure increase at small strains. Immediate liquefaction occurred when

specimen was conditioned as fully saturated and initial pore water pressure was given as to simulate ground water table after rainfall.

Finite element modeling using ABAQUS software indicated amplification phenomena of earthquake acceleration in the landslide area. The contributing factor of the amplification was the thick clay stratum and weathered andesitic sandstone layer below the pumice material deposit that was considered have low stiffness. Another possibility causing of amplification was the topographical aspect involving sloping surface. The numerical model and laboratory tests clarified that the amplification effect on the area caused the collapse of the pumice material. Immediate liquefaction was considered as the mechanism of the landslide due to the combination of earthquake amplification effect and soil saturation by rainfall during earthquake.

## **PS-02 – Terramesh system application in landslide remediations**

**N. Suljić, S. Zekan**

*Faculty Mining, Geology and Civil Engineering, University of Tuzla, Tuzla, Bosnia and Herzegovina*

**ABSTRACT:** Landslides are common on the roads, especially on those ones that were built in the embankment. Due to inadequate drainage of surface water or rainfall, a poor sewage system that runs through the axis of road or because of the instability of embankment slopes or cuttings, often leads to the occurrence of sliding of one part of the road. Landslides on the roads endanger the flow of traffic and it is necessary, beside the temporary remedial measures, to make appropriate permanent measures for landslide remediation.

Besides technically correct drainage of surface water and groundwater, it is often necessary to apply an appropriate supporting structure in road landslide remediation. Reinforced concrete and concrete retaining walls are often applied, and this study shows successfully performed landslide remediation on one part of the road in the city of Tuzla, using Terramesh system or gabion structure with an extension for the reinforcement of soil behind the retaining wall.

The main cause of landslide on the part of the road from the mosque Djindic to the University Clinical Centre Tuzla is the appearance of a very soft material in the embankment of a road. Due to infiltration of surface water through quartz sand on the slopes, the material in the embankment body becomes wet.

Also, the cross slope of the road is carried out in the opposite direction so that the rain water does not flow into the drain but it infiltrates into the cracks that are on the road. Rainfall sewage waters pass the road axis so after the occurrence of landslide, deformation of storm sewer manholes and the piping itself occur as well, which further wet the road embankment body.

The embankment has a negative slope and drop down the slope of the natural terrain and the embankment is not placed on quality and good supportive natural soil. The height of embankment, which is made of quartz sand toward the slope of the road, cannot receive significant dynamic loads on this very busy traffic road. After the observed deformations on the road the additional works have been carried out, namely leveling the road alignment and design of the new layer of asphalt. These works were carried out without the design documentation. Shortly after that a new and larger road deformation appeared, in length of approximately 60 m, and there was an almost complete suspension of traffic.



After carrying out geomechanical site investigations, landslide remediation of the part of this road was done by removing the wet sand and poorly supporting natural soil and then forming the embankment of crushed stone by tamping to the compaction compressibility modulus of  $M_s = 40$  MPa.

Beside the new road body, technically correct cross slope of the road, then remediation of damaged rainfall sewage system, the retaining wall of gabions with an extension for the reinforcement of the part of road body was also built (Terramesh system), which aims to prevent the occurrence of a new road landslide in the embankment. Designed and constructed retaining wall length is 60 m.

Reinforcement of part of the embankment body by the extensions of gabion baskets in upper two rows of supporting structures enables taking over of tensile stress. Gabion supporting structure of Terramesh system is made of galvanized and plastic coated steel wire which achieved good resistance to corrosion and temperature changes. After the construction works carried out 5 years ago, today, in this part of the road there are no any deformations or the landslide of part of the road in the embankment.

## **PS-03 – Instability phenomena and mitigation measures in the area of the Cluj Ethnographic Museum**

**G.C. Silvaş**

*University of Bucharest, Faculty of Geology and Geophysics*

**ABSTRACT:** The complexity of the problems and the negative consequences that concern the slope instability phenomena led some researchers to compare it with „a demon who laughs at the human competence”.

A slope must be analyzed as a breathing organism with a health state – stability that is a result of the relation between the actions that provoke the landslide – to weaken it and the actions that gives it the stability –health.

For the risk management of landslides it is required a systematic application of some measures such as:

- 1) the warning of landslides;
- 2) the reduction of the effects of landslides.

Considering the negative impact of landslides, it is essential to give a maximum importance to the warning and reduction measures of the risk. These measures are highly motivated considering the recovery costs of the effects of landslides.

From a geographical point of view the Hoia Hill is situated in the Transylvanian Basin. From my previous work in the area of the basin I was able to observe that the instability phenomena are heavily affected by landslides. The main factors that trigger the instability problems in this area are the geological and the hydrogeological ones. These factors trigger landslides in all the areas of the basin. But when these factors are corroborated with the human activity there are generated situations such as the one in discussion.

The Ethnographic museum is situated on the northern side of the Hoia Hill and consists of very old houses that are part of the historical heritage of Romania. These houses carry the proof of the way

of living of the Romanian people between the 16th and the 18th centuries. The integrity of the existing constructions is endangered by the effects of landslide movements is the northern slope of the Hoia Hill from Cluj. The slopes cliffs have a S-N orientation, with steep cliffs towards south and a gentle cliff towards north. On the surface of the slope there are numerous rotational landslides, debris flow and creep that affect the stability of the slope. The landslides are recent, with a medium depth of 4-5 m of the surface of rupture.

The instability problem is old in the area and is generated by the geological and hydrogeological factors. Despite of the influence of these factors there was another factor that in 2008 triggered some slope activity that lead to some landslides affecting the museum, such as human activity. At the base of the slope a big industrial park in construction needed some cuts to be executed. As there will be pointed in the following the underground water table was at low depth and with a big discharge.

The geologic factor is represented by a lithology with poor mechanical geotechnical parameters. From the drillings performed in 2010 the lithology consists in (from the top to the base of the drilling):

- clays with gravel and cobbles (deluvium);
- clays and silts (loess);
- clays with sandy layers (sandy layers with a big discharge of underground water);
- in some areas altered sandstone.

So the presence of loess and the sandy layers with a big discharge of underground water raise some questions about the stability of the slope with or without the human activity at the base of the slope.

As measures of mitigation of the northern slope of the Hoia Hill there were proposed retaining walls at the bottom of the slope and the lowering of the underground water table by drainage systems at a depth that does not affect the general stability of the area.

The slope drainage system consist of draining wells executed properly so that they can allow a high outflow of underground water. The use of the method is necessary for the urban slopes exposed to landslide movements.

## **PS-04 – Remediation of the unstable location Plavča Draga on the Zagreb-Split railway line**

**P. Šiša, Ž. Sokolić**

*Geotehnički studio Ltd., Zagreb, Croatia*

**ABSTRACT:** Characteristic of a railway as a linear structure is that it's built on soils of different geotechnical properties. Morphology of a terrain, geological stratification, physical-mechanical characteristics of soil layers, hydrogeological and tectonic characteristics of the soil are changing along the railway line. In its natural state, terrains were the railways have been built upon, due to the aforementioned characteristics, are of different bearing capacities and stabilities. During railway construction and its exploitation period, certain changes of bearing capacities and slope stability at some locations occurred caused by changes of soil stress states and groundwater regime due to railway construction.

Negative effects of aforementioned changes on the stability of geotechnical railroad structures will be shown with examples of the embankment on the railway line Ogulin-Split at Plavča Draga. Railway construction at this location is laid on clay, while before and after the instability, it is laid on dolomite rock mass. Through a longer time period, occurring instability was manifested through a constant continuous rail track settling process. Tracks' maintenance department maintained the railway alignment level and position by continuous filling and caulking of the new material under the rail track sleepers. After an extremely unfavorable hydrological period (fast snow melting) that happened at the beginning of March 2001, tracks displacements rate increased, vector displacement reaching 15 cm/day, leading to the collapse of tracks and complete stoppage of traffic. Instability process encompassed the slope of 20 m in width, 150 m in length, while the maximum sliding depth was 4 m. Considering exceptionally inaccessible railway line locations where instability occurred and the importance of the traffic line in matter, it was necessary to immediately start identifying the causes and mechanisms of instability and to provide appropriate technical solutions in order to re-establish traffic within a short period of time.

Apart from geological formation of the locations, hydrogeological conditions and mechanical properties of the soil layers, causes of instability should also be sought within the processes related to the negative impact of traffic load on the reduction of the foundation soil shear strength. This process is known under the term of ballast pockets and occurs as a result of impression of ballast material (due to dynamic traffic loads) into the clayey bedding material. In the embankments, such impressed materials from ballast bed being extremely permeable, absorb and retain water softening the base. Further, ballast bed materials are impressed deeper into the embankment core, leading to decrease of clay strength parameters to their residual values, loss in soil bearing capacity and inability of soil to undertake further dynamic traffic loads without consequences.

With the investigation activities carried out (drilling and trial pits, geophysical survey and engineering geology mapping) the mechanism of instability was determined and a decision was made to carry out the remediation works in two phases (temporary and permanent solution). In the first phase a provisional steel bridge was set up with a span of 21 m resting on foundations on 20 small diameter piles ( $\phi$  15 cm, length of 3-7 m). Field investigations in the first phase lasted for 4 days after which the railway traffic was re-established. In the second phase, a permanent remediation solution of the instability was prepared. Permanent technical solution was selected taking into account requirement that the railway bearing structure foundation is to be built on rock within the narrow zone of the current tracks (in relation to the axis) and the requirement to ensure transportation of materials using rail vehicles. Remediation of landslide was executed by constructing reinforced soil embankment and drainage systems for collection and drainage of precipitation and seepage water. The constructed embankment is 9.5 m high, 3 m wide at the embankment toe level and 6.5 m wide at the crown level. Execution of these works lasted for 2 months.

As the above example shows, processes of destabilization as well as larger soil deformations and geotechnical railway structures deformations, most often are not events occurring instantly. By categorizing railways in a qualitative way regarding the bearing capacity and stability, within the ordinary or extraordinary maintenance works it is possible to undertake certain measures to improve or remediate the railway conditions in order to avoid traffic interruption and major damages.

# PS-05 – Instabilities of open pit cuts, case studies from Croatia

**M. Grošić**

*Geotech Ltd., Rijeka, Croatia*

**Ž. Arbanas**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Croatia*

**S. Bernat**

*Associate Researcher, Zagreb, Croatia*

**I. Matjašić**

*Calx Ltd., Zagreb, Croatia*

**D. Vidović**

*Geotech Ltd., Rijeka, Croatia*

**ABSTRACT:** The environment of rock slopes in which open pits and other types of cuts are excavated is positioned near a surface in area of low stress, and the global stability of slopes is controlled by geological elements such as faults, discontinuities, alteration of different geological units and position of weathering zones. The presence of these elements those cannot be controlled and changed, but during the design process the presence of these factors should be considered and taken into account as part of slope design and stability evaluation. Among these major factors, some minor scale geological elements such as joints and fissures may have an influence on slope stability, commonly on a local scale.

In most cases, once the slope stability analyses are completed and mine management accepts results and designs, the geotechnical consulting is outsourced. This methodology often results to local or global instabilities such these presented in paper. This paper presents two case studies of global instabilities at open pit slopes in Croatia.

In the first case study, the instability in the Fukinac open pit near the city of Okučani is described where the large plane failure occurred in November 2007. The Fukinac open pit is made from amphibolite metamorphic rock mass. About 50 m high rock slope slide was formed along fault with dip of 75° and encompassed cut with several benches. Remedial works included removing of sliding material and shaping-up and cleaning of bedding plane. Exploitation in open pit has been continued.

The Torine open pit is situated near the city of Gradac Našički. Exploitation area is made of basalt rock mass layer in the contact with flysch rock mass bedrock. The basalt plate is about 40 m thick and it is positioned on completely weathered to highly-weathered marl layer. Contact of these geological units has dip of 15° toward the exploitation area. Sliding of basalt rock mass with the sliding surface trough the contact zone was occurred and three different landslides were determinate with total volumes of 500,000 m<sup>3</sup>, 2,500,000 m<sup>3</sup> and 75,000 m<sup>3</sup> respectively. The remediation of instability was never started but the exploitation wasn't abandoned.

# PS-06 – Rockfall hazard management on traffic facilities in Croatia

**D. Udovič**

*Monterra Ltd., Rijeka, Croatia*

**Ž. Arbanas**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**S. Mihalić Arbanas**

*Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Zagreb, Croatia*

**M. Grošić**

*Geotech Ltd., Rijeka, Croatia*

**ABSTRACT:** Along the Croatian side of the Adriatic Coast some large rockfall occurred on the steep limestone slopes and caused serious damage on buildings and traffic facilities with injured persons. The main reasons for occurring rockfalls in limestone slopes near railways and roads are unfavorable rock mass characteristics, rock mass weathering in combination with heavy rainfalls so as men influence during the facility constructions.. The applied technologies the slopes construction were very conservative and attained safety factors are very low. The technologies of rockfall protections during construction of the new roads in the last decades are significantly improved. The rockfall protection started with using of netting techniques with very low quality of the wire material. After some time, the double twisted netting with galvanic protection occurred as the most common type of the rockfall slope protection. On the more demanding slopes the shotcrete was used and still is regarding the quality of the rock mass in the slope that is needed to be protected. The new technologies are applied throughout construction of the support system including high load bearing meshes with reinforced geotechnical self drilled anchors in combination with high performance rockfall barriers. After rockfall phenomena occurring on some particular locations, the projects of rockfall protection were conducted to ensure human lives and facilities from further rockfall occurrences. The process of rockfall protection started with rockfall hazard analyses to identify potential of rockfall occurrence so as possible accidental consequences, i.e., rockfall risk. On locations where hazard with related risk was determined the detailed field investigations were provided. Based on identified characteristics of possible unstable rock mass blocks analyses of motion and resulting paths were conducted. Trajectories, impact energy and height of bouncing are depending of slope geometry, slope surface roughness and rockfall block characteristics. Depending on these analyses rock fall protection measures were designed. Two design approaches were adopted, prevention of rockfall by removing of potentially unstable rock mass or by rock mass support system installation and by suspending of running rock fall mass with rockfall protection barriers. In this paper we will present experiences on rock fall hazard determination and rockfall protection design so as installation of rock fall system protection on some location on limestone slopes near the traffic facilities along the Adriatic coast in Croatia.

## **PS-07 – Landslide and debris flow barriers at A83 Rest and be Thankful in Scotland**

**D. Gibson**

*BAM Ritchies, Bristol, England*

**C. Wendeler**

*Geobrugg AG, Romanshorn, Switzerland*

**V. Budimir**

*Geobrugg AG, Osijek, Croatia*

**ABSTRACT:** Rest and be Thankful on the A83 in northern Scotland has a history of landslides. In 2007 the site was closed for several weeks after debris flow, a form of shallow landslides, deposited 400 t of material on the road. In early September 2009 a further event resulted in 1.070 t of material slipping onto the road at the same place, forcing its closure for 48 hours. No one was hurt in either incident, but these debris flows pose a serious threat to the country's main rural routes.

This site has been the subject of study and is included in the recent Scottish Roads Network Landslides Study produced by Transport Scotland. The study identified the A83 at Rest and be Thankful as one of the most risk sites for debris flow and/or landslide – a fact confirmed by the events that have occurred.

Swiss company Geobrugg AG who specialize in natural hazard mitigation systems including slope stabilization, avalanche barriers, rock fall catch fences and debris flow barriers are well advanced in the research, development and testing of landslide barriers. While rock falls tend to have discrete blocks falling at high velocities and debris flows tend to be high volumes of materials mobilized by significant water flows, landslides are large volumes under gravity initiated by lower volumes of water, ground movement or changed circumstances. Understanding the differences is the key to the provision of suitable tailored catch fences or barriers that work to deal with the type of hazard effectively and in a cost effective manner.

Geobrugg has been developing and testing flexible rock catch fences for many years. The development of flexible debris flow barriers is more recent but has reached a point where they may be designed, specified and installed with confidence. Indeed, installations are now quite common in European alpine areas, California, Japan and Korea in particular.

## **PS-08 – Anthropogenic influence on the stability of slopes in Bosnia and Herzegovina**

**T. Nikolić**

*Federal Bureau of Geology, Sarajevo, BIH*

**ABSTRACT:** Changes of landslide hazard level are strongly influenced by human activities which are mostly triggering factors of slope instabilities. The territory of Bosnia and Herzegovina is susceptible to landsliding caused by natural conditions and high impact of anthropogenic activities. The most often activities which would cause activation of landslides are: changes in land cover such as deforestation; agriculture (i.e. terracing); construction of cuts and fills along

highways; building construction; mining; uncontrolled waste disposal; rapid drawdown of dammed lakes; change in irrigation systems or uncontrolled surface runoff. This paper presents main characteristics of the typical landslides in Bosnia and Herzegovina which are caused by human activities. The Maglaj landslide is one of typical example of elongated landslides, caused by construction activities. Main preparatory man-made factors which caused the Maglaj landslide were the following: the loading of the relatively stable slope by illegal building construction and the inadequate drainage of surface and ground waters. The Maglaj landslide was triggered by intense rainfall. Dimensions of the Maglaj landslide are: total landslide length is 1,000 m; depth of the displaced mass is 10 m and the volume of the displaced mass of approximately 70,000 m<sup>3</sup>. Landslide along the highway near the City of Kakanj is caused by slope excavation during the of road cut construction. It was triggered in time period from 3 to 5 years after construction and it was caused by heavy rainfalls. This is rock slide with total landslide volume of 150.000 m<sup>3</sup> and depth of the displaced mass from 5 to 10 m. The area of the City of Tuzla is highly susceptible to landsliding due to changes in ground morphology in the form of subsidence. These instabilities are caused by consolidation of the superficial soil layers as a consequence of continuous groundwater level decreasing. Negative effects of human activities can be decreased by using of preliminary information about landslide susceptibility in the phases of land-use planning and construction. Prevention of landslide hazard requires development of landslide inventory and landslide susceptibility maps for the territory of Bosnia and Herzegovina. Priorities for landslide mapping should have areas highly susceptible to landsliding encompassed by urban development and transportation routes construction.

## PS-09 – Characteristic landslide risk zones in the Federation of Bosnia and Herzegovina

**H. Begić**

*Federal Bureau of Geology, Sarajevo, BIH*

**ABSTRACT:** In this abstract an analysis of the characteristic zones of high risk of landslides in the Federation of Bosnia and Herzegovina will be presented. The Cadaster of landslides in the immediate and wider area under analysis is of primary importance for assessing the level of risk and hazard to the environment.

From unofficial sources, it is assumed that there are about 6,000 landslides in Bosnia and Herzegovina, of which about 4,000 landslides are in the Federation of Bosnia and Herzegovina, and about 2,000 in Republic Srpska. On the aspect of size they can be categorized from very small to large, from the standpoint of the degree of risk, from high to very low risk.

Regular natural processes, geological structure of the soil, engineering geological conditions, as well as anthropogenic activities, are essential factors for their stabilization, and, the degree of risk to the environment. Based on research, collection and processing of data for characteristic areas of the Federation, it is essential to emphasize the landslide zone areas; Canton Sarajevo, the Tuzla Canton, the Zenica-Dobož Canton and the Bosnian Podrinje Canton.

A common occurrence is uncontrolled construction for the individual needs of the population, and without furnished infrastructure, which in perspective can lead to disastrous consequences for human lives and material goods. Therefore, in the future it is necessary to invest significant funds for the preparation of project documentation and requirements for the construction of objects.

One of the major reasons for the increasing negative development of landslides is the fact that in the past 25-30 years no appropriate care and treatment has been given to this problem, neither on the state and entity levels, nor cantonal, regional and local levels.

## **PS-10 – Landslide inventory map of the Vlora Region at scale 1:50,000**

**M. Jusufati, M. Lamaj, M. Dardha, O. Jaupaj, E. Plaku**

*Albanian Geological Survey, Tirana, Albania*

**ABSTRACT:** Albania is characterized by a variety of geological formations from the Paleozoic to the Quaternary age (sedimentary and magmatic, types together with rather less frequent metamorphic). The Vlora region is located in the south-west part of Albania and belongs to the external tectonic zone (Sazani and Ionian Zone). It covers about 2740 km<sup>2</sup>.

The Landslide Inventory map of the Vlora Region is carried out during the 2012 year by the Albanian Geological Survey (Department of Engineering - Geology and GIS Department). The Landslides Inventory map of the Vlora Region at scale 1:50,000 and the landslide database, provide all the necessary information to the decision-makers to take right measures for decreasing landslide risks in their communities, and to the local authorities for a safe land use planning. The methodology applied to build up the Vlora landslide inventory map is based on the archive's data and field surveys.

Archive data: Get together all the information from the Central Archive of Albanian Geological Survey, Ministry of Public Works and the Roads Administration Authority archives. They are the institutions with rich and well organized geotechnical archives.

Field surveys: Necessary to evaluate the landslide evolution, their current state and activity. For each landslide evaluated by field surveys, is filled out a data sheet.

The landslide inventory (database) is organized in five information levels: 1. General information (region, municipality and geographical coordinates); 2. Data about geology of the sliding body, the map of landslide and surround terrain without movements; 3. Morphology data (lithology, land-use, erosion, cause of activation); 4. Hydrogeology data (ground water, underground water level, springs); 5. Engineering geological data (type of movement, state activity, humidity).

The data collected from archive and field survey are entered as inputs in a database that serves to build the landslides map in the GIS format. Based on the archive data and field surveys, 87 landslides in Vlora Region are already identified.

On the basis the Geological map of the Vlora Region at scale 1:50,000 and engineering - geological field surveys, the lithological map was compiled. Nine groups of lithological/engineering geological unit were defined: 1-Hard limestone rocks; 2- Stratified rocks; 3-Sandy rocks; 4-Clay rocks; 5-Soft clay rocks; 6. Evaporate rocks; 7-Soils with cohesion; 8-Soils without cohesion; 9-Soils stratification with and without cohesions.

Slope mass movements in the Vlora Region are grouped: landslides, debris flow and rockfalls. The landslide inventories are prepared using lithological field mapping and interpretation of landslide occurrence with field verification. The landslides inventory currently holds 87 landslides. The soft clay rocks were found as the most susceptibly lithological complex (about 36 %). The sliding



phenomena occur, in most cases, in slopes with inclination from 10° to 20°. Based on the field work and archive data, a landslide inventory map was created, defining a total of 87 landslides covering an area of 2.2 km<sup>2</sup>. Slide inventory map was constructed using a combination of two layers; lithological and polygon-shaped slide layer. Some landslides are active nowadays and periodically cause serious damage to urban areas, water supply and infrastructure.

The triggering factors in the activation of sliding phenomena in Vlora Region are the intense rainfalls, lithological conditions and human factor.

Based on this map and the analyses of landslide spatial occurrences, it would be possible to derive the Landslides Susceptibility map of the Vlora Region at scale 1:50,000.

## **PS-11 – The instability phenomena along the coasts of the Kvarner area (NE Adriatic Sea)**

**Č. Benac, P. Đomlija, M. Vivoda**

*Faculty of Civil Engineering, University of Rijeka, Rijeka, Croatia*

**R. Buljan, D. Navratil**

*Croatian Geological Survey, Zagreb, Croatia*

**ABSTRACT:** The Kvarner area is a semienclosed part of the Adriatic Sea located between the Istrian Peninsula and the Vinodol–Velebit coast. The island chains Cres–Lošinj and Krk–Rab–Pag divide it into the Rijeka Bay, the Kvarner, Kvarnerić and the Velebit–Vinodol Channel. The wave heights in the channel part of the northern Adriatic Sea are smaller than in the western open zone due to relatively short wind fetch. Hence the strongest northeastern wind Bura (or Bora) does not generate the highest waves. On the other hand, on the western open coast of Cres and Lošinj islands, the stormy southeastern wind Jugo (or Scirocco) can generate waves higher than 6 m.

In the terrestrial part of the Kvarner area Cretaceous carbonate sedimentary rocks (limestone, dolomites and carbonate breccia), Paleogene limestone (foraminiferal limestone) and Paleogene siliciclastic rocks (marls and flysch) are present. Carbonate rocks prevail, whereas siliciclastic outcrops are restricted. Pleistocene and Holocene deposits partly cover this bedrock substrate.

Intensive morphogenetic processes caused by tectonical movements and rapid sea-level changes, as well as climatic changes, caused the present shape of the Kvarner area. Slow sea-level rise during the last 6,000 years created conditions for more intensive marine erosion.

Marine abrasion caused by wave impact is not very pronounced due to its sheltered position and coastal geological settings in the Kvarner area. In places where the rock mass is tectonically crushed or/and karstified, wave notches and cliffs evolve. The destructive impact of waves is more pronounced in coasts formed in siliciclastic rocks, even in sheltered zones, where wave energy is low. There, a different effect of wave erosion is observed. Cliffs are formed in more resistant sandstones, whereas mass movements, earth flows and rockfalls are common in less resistant marls.

Gentle inclined carbonate rocky coasts are generally stable, without visible mass movements. Against that, different types of mass movements are common on very steep and subvertical coastal parts. These morphodynamic processes are clearly visible along the north and northeastern coasts of the Cres Island, southeastern coast of the Plavnik Island and north and southwestern coast of the Krk Island. Similar types of instabilities have been found near very steep

northeastern coasts of the Rab, Prvić, St Grgur and Goli islands. These phenomena are also visible along the western coast of the Rijeka Bay: between the Plomin Bay and the Mošćenička Draga valley, in the northeastern part of the Bakar Bay and sporadically along other steep coasts. Active scree and rockfall prevail on rocky scarps. Somewhere, the traces of planar or wedge failures are visible. The rests of dormant debris flows are situated in several dry karstic valleys. Remarkable phenomenon is a combination of tectonic subsidence and huge rocky slide on the eastern coast of the Rijeka Bay.

The destructive impact of waves is more pronounced in the coasts formed in siliciclastic rocks. Slope and marine erosion prevail, but somewhere different types of landslide are found. Active or dormant slide are visible in the southeastern coast of the St. Marko Island, near the Jadranovo settlement (northeastern coast of the Vinodol-Velebit channel) in the Murvenica cove (northeastern coast of the Krk Island) and near Stara Baška settlement (southwestern coast of the Krk Island). Instability phenomena along the coasts of The Kvarner area are a part of very complex morphodynamic processes which include sea level change and seismotectonic activity.

## **PS-12 – Availability of data about landslides in Croatia and their implementation in proposed formats of EU landslides data bases**

**Ž. Miklin, L. Podolszki, J. Martinčević**

*Croatian Geological Survey, Zagreb, Croatia*

**ABSTRACT:** The importance of landslide inventory or geotechnical inventory has been recognized on the European level. As Croatia should become a member of the European Union in July it would be preferable that the data about existing landslides are in accordance with European Union data. In that sense a questionnaire form was submitted in 2010 to all the European countries. The aim of this questionnaire was a review of the landslide data and their state within the SafeLand project – Living with landslide risk in Europe: assessment, effects of global change and risk management strategies. The main activities of SafeLand project are: to improve assessment of landslide hazard (triggering mechanisms and runout), to assess quantitatively the landslide risk in selected areas of Europe, to assess the changing pattern of landslide risk as effects of climate change and other factors, to verify the estimated hazards through monitoring and remote sensing and to design and test the possibilities of early warning systems as well as to risk management with the development of toolbox for landslide risk mitigation (measures and choosing the appropriate risk mitigation strategy). The project team consists of 25 institutions from 13 countries with the leadership of the Norwegian Geotechnical Institute (NGI). Some European countries have already developed advanced data collection about the landslides but in the majority of the countries this process is still in development. Many European countries work on their national or at least regional data basis (Landslide data basis – LDBs). There are still some difficulties in unifying these data such as their exact content, the data updating methods, the form and structure, the language and availability which differ in wide range. In Croatia the registration of landslides is an ongoing process within production of engineering geological maps. The engineering geological map in the scale of 1:300,000 has been finished but the sheets of the basic engineering geological maps in the scale of 1:100,000 not. It would be preferable to have data even in some more detailed scales but that kind of data exists only for some urbanized areas (for example: The detailed engineering

geological maps in the scale of 1:5,000 for the area of Zagreb). Eventually some detailed data can be found for some specific locations within the different types of reports and investigations, but this type of data has not been organized. For the needs of SafeLand project the existing accessible data about landslides were reviewed and some interesting patterns about landslide number, distribution and type can be seen, on national (regional) level. The main geological division in Croatia is on two regions: Pannonian region and karst region. Pannonian region stretches from the eastern part of Croatia (Slavonia) to the middle part of Croatia (to the city of Karlovac). The karst region stretches from the middle part of Croatia (south from the city of Karlovac) to the coastal part (Istria from west and Dalmatia on east). Geological differentiation is mainly in accordance with the climate differentiation: continental and maritime one. In these main regions some micro regions can be distinguished. For every micro region the main type of mass movement is different and the characteristic model can be developed. Based on the available data, these characteristic models will be presented and explained for every micro region. The emphasis is on incorporating these models into one national model up to the date landslide data base in accordance with the goals of SafeLand project.

## PS-13 – INspired GEOdata CLOUD Services

**M. Podboj, J. Šinigoj**

*Geological Survey of Slovenia, Ljubljana, Slovenia*

**ABSTRACT:** The INspired GEOdata CLOUD Services (INGEOCLOUDS) project aims at demonstrating the feasibility of employing a cloud-based infrastructure coupled with the necessary services to provide seamless access to geospatial public sector information, especially targeting the geological, geophysical and other geoscientific information. This kind of information possesses interesting characteristics like the size of the available data, the existing metadata descriptions (mostly according to the European Directive INSPIRE) and the current availability of related services that can be moved to the cloud. Among the project partners there are many with such data and services available under more traditional infrastructures that can be easily deployed to the cloud. One of the project challenges would be the linking of the partners' data among themselves and with relevant external datasets. On top of the basic cloud services the project plans to demonstrate the ability to build more intelligent services by using and combining data seamlessly integrated through the cloud. Based on the gained experience, the project will provide guidelines in order to support the partners and other stakeholders of public information in their efforts to move more of their services and data to the cloud in order to decide the best possible roadmap, the requirements of the underlying infrastructure that will be chosen as a host, the requirements for the services and the possible pros and cons of these choices. In summary we plan to provide the necessary documentation, the related analysis, the roadmap and a set of working services to support organizations that need to move large amounts of public sector information to the cloud. The service-based infrastructure created by the project can survive the pilot and demonstration phases since the partners plan to integrate it in their infrastructure and various charge-on-demand financial models can be employed to support it.



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