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MODEL FOR GIS LANDSLIDE DATABASE ESTABLISHMENT AND OPERATION IN REPUBLIC OF MACEDONIA

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A b s t r a c t: Landslides are one of the most damaging and most significant geo-hazards in the Republic of Macedonia. Due to many reasons landslide data collection in the past have been generally unsystematic. Knowing that new occurrences are to be expected in future, brief overview on landslide databases in Europe is given and model for establishing and operation of national GIS landslide database is proposed in the paper. Model for assignment of governmental body on landslides, along with structure and way of operation of the envisaged database is presented. Formation of this landslide database is the basic step towards better understanding of the landslide hazard in future. This database will enable conditions for selection of most endangered regions and selection of appropriate models for landslide hazard and risk zonation. As a result, land use planning will become more efficient, and vulnerability of people and goods will be decreased. In this context, some results from recent landslide susceptibility assessment studies are also presented.

Key words: GIS landslide database; model; structure; operation

INTRODUCTION

Landslide databases, or digital landslide inventories, constitute a detailed register of the distribution and characteristics of past landslides (Hervás J., 2013). The landslide database gives information for landslide location, type, dates, state of activity, failure mechanisms etc. (Fell et al., 2008). Collecting data on landslides essentially enables zonation of areas which are prone to landslides and creates possibilities for more efficient land use planning. Experiences from around the world and especially European countries show that existence of national landslide database is one of the most important elements in management of this type of geohazard. Analyses of landslide databases & inventory maps are performed by Malamud et al. (2004); Guzzetti F. et al. (2012); Eeckhaut M. V. D. and Hervás J. (2012).

LANDSLIDE DATABASES IN EUROPE

In the frames of the EU-FP7 project SafeLand: Living with landslide risk in Europe – Assessment, effects of global change, and risk management strategies, a study focused on landslide databases in Europe by sending a questionnaire to all EU member states, official candidate and potential candidate countries was performed. Detailed results are presented in M. V. D. Eckhaut and J. Hervás 2012. This study showed that 22 European countries have or are preparing national landslide database, while 6 more (BE, CRO, ES, D, R, SRB) have stated to have regional databases. Italy has eight different databases and Spain two. Some countries register only larger landslides. Number of landslides in each database is presented on Figure 1. The total number of landslides in all landslide databases from European countries counts around 633,700 landslides (Hervás J., 2013). It is suggested that the number of landslides is only half of the real number, and the statement is supported by issues in the collection of data, possibilities for special mapping as well as irregular archiving of past events. European Landslide databases are operated by the Geological surveys, Offices for geology, River basin authorities, Universities etc.

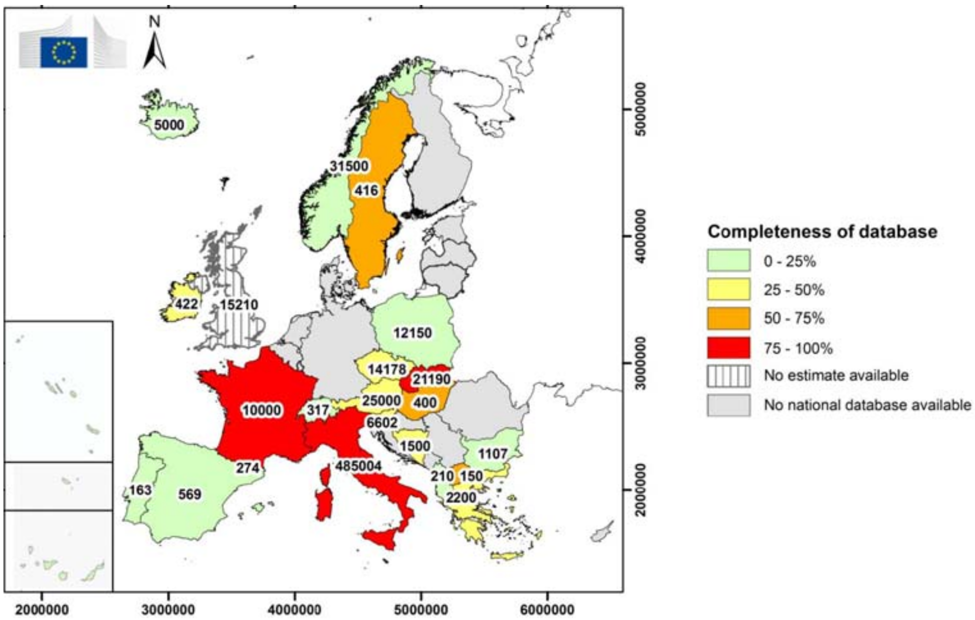

Fig. 1. Number of landslides and percentage of completeness of landslide databases for European countries (Taken from Miet Van Den Eechaut and Javier Hervas 2012), JRC, Report EUR 25666 EN

PROPOSITION FOR ESTABLISHMENT OF LANDSLIDE DATABASE IN R. MACEDONIA

In the frames of the above commented FP7 project, R. Macedonia has stated to own landslide database with around 150 landslides, but which was prepared in 1970. These landslides were mapped during preparation of the Basic Geological Map in scale of 1:100 000. In years to come, collection of landslide data in Macedonia is generally neglected. This is a result of unsystematic and interrupted work of numerous institutions due to problems from different nature. Therefore, in 2012 Peševski et al. proposed model for formation / assignment of governmental body which will create and operate digital GIS landslide database in the Republic of Macedonia (Figure 2).

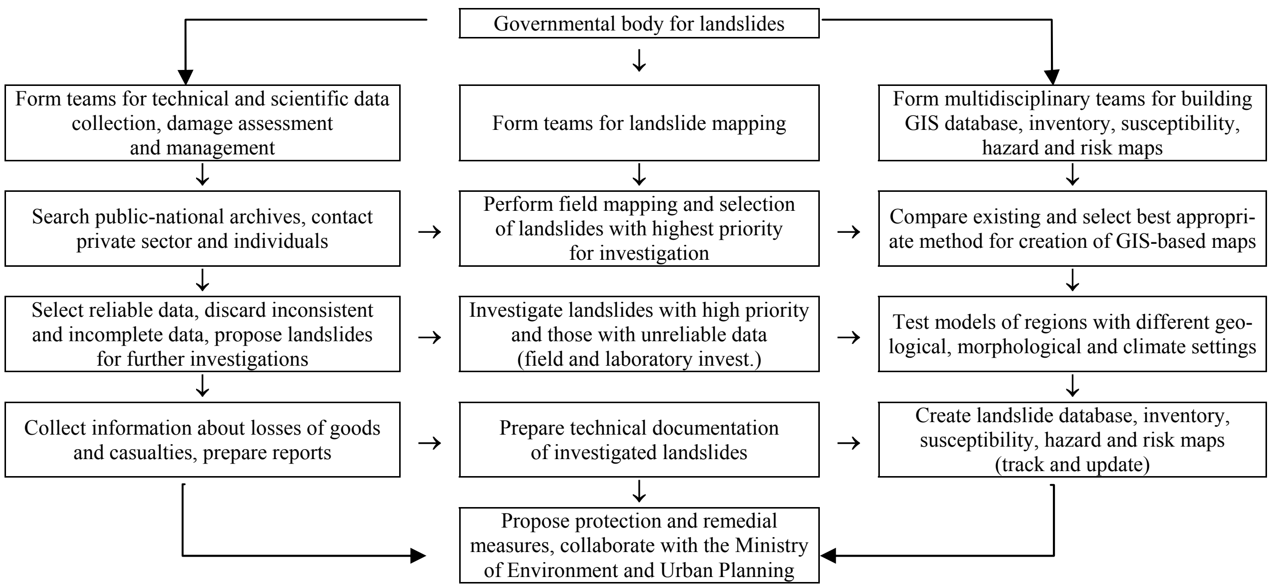

Fig. 2. Model for creation and operation of National GIS landslide database for R. Macedonia

The quality of data which will be entered in the database is of essential importance for future landslide hazard and risk assessment. Incomplete and false data will lead to preparation of maps which will give wrong picture for the landslide hazard and risk distribution. On the other hand, high quality data will enable preparation of precise models of hazard and risk, which is a foundation for taking of right decisions in regards to land-use planning and infrastructure development of the country. Therefore, with the model such type of structure was proposed where special teams will work on different aspects related to landslides, including teams for gathering of technical documentation, field mapping and exploring, preparation and support of database, preparation of thematic landslide maps. Final goal of all activities of this body (institution) will be proposing of appropriate methods for construction/foundation depending on the landslide hazard/susceptibility of given region/areas, proposition of protection and remediation measures in endangered areas, or even disenable construction in such areas, of course in cooperation with Ministry of Environment and Urban Planning. All these aspects are towards better development of the infrastructure, on regional and/or local level. In order to present better the idea, the envisaged operation of the GIS landslide database of R. Macedonia is briefly explained in the following section.

OPERATION OF THE GIS BASED LANSLIDE DATABASE

In order to select most appropriate and as practical as possible operation of the landslide database, research and analysis of existing European databases was performed. General conclusion is that some models differ in many parameters, while others are very compatible between each other. However, the structure of the database is dependent on many different factors, and above all, availability of founding resources, which in turn is a result of the degree of development of the country.

Having this in mind, regarding actual conditions in R. Macedonia, and with the basic principles for creation of possibilities for simplified communication and usage of information from the landslide database (between the institutions and sharing with the public), it is proposed to structure the database in several levels of users which will have different authorizations for entering, processing, suggestion, and modification of data on landslides. The following levels for operation of the landslide database are proposed (Figure 3):

Level 1 – Administrator (governmental body for landslides).

Level 2 – Governmental institutions.

Level 3 – Companies from the field of geotechnics and geology.

Level 4 – Subjects and institutions which perform field activities.

Level 5 – Other subjects and the population.

Interactivity between different levels of user of the database is shown on Figure 3. All activities, connections, obligations and benefits between different levels of users are explained further in the following part of the paper.

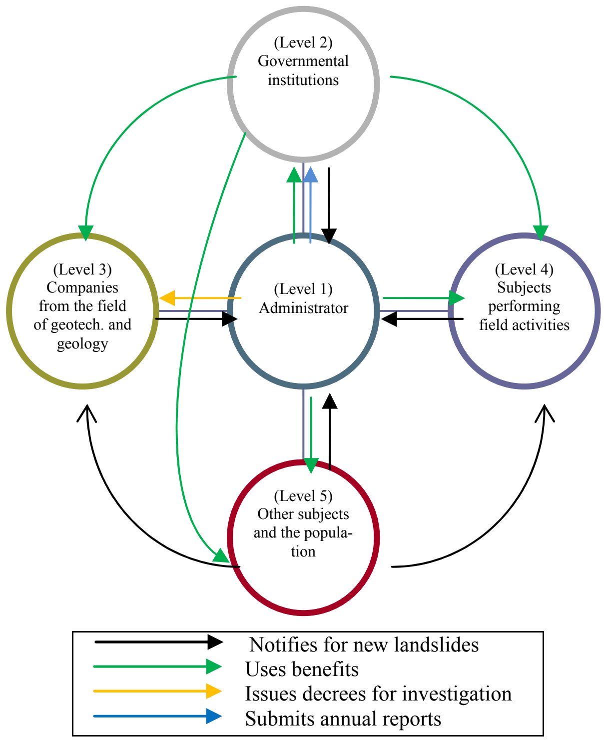

Fig. 3. Interaction between different levels of users of the proposed landslide database for R. Macedonia

Level 1 – Represents the highest level of user (governmental body on landslides) which has complete access to the landslide database with the following possibilities and obligations:

– Establish, change or supplement of the structure of the database.

– Enable access to users from lower levels.

– Prepare strategy for systematic mapping, exploring and analysis of landslides.

– Give tasks to the 3rd level of users for performing of detailed geotechnical and geological investigations.

– Collect, control, process and enter of data declared from lower level of users.

– Preparation of landslide inventory, susceptibility, hazard and risk maps.

– Recommendations for undertaking of remediation measures and minimizing of the effects for landslides.

– Recommendations to the Ministry of Environment and Urban Planning, Ministry of Transport and Communications, etc.

– Issuing of annual reports for suffered damage and undertaken remediation measures and their costs to the appropriate institutions (Ministry of Finance).

– Cooperation with similar institutions from other countries, exchange of experiences with goal improvement of the structure and functioning of the landslide database.

– Organizing workshops, symposiums and other events with presentation of results from investigation, mapping modeling etc.

Level 2 – Governmental institutions, Ministry of Environment and Urban Planning, Agency for Spatial Planning, Ministry of Agriculture, Forestry and Water Economy, Agency for Real Estate Cadastre, Public Enterprise for State Roads, Crisis Management Center, Territorial Firefighting Units, Ministry of Internal Affairs etc., with the following possibilities and obligations:

– Using of benefits from landslide database and maps.

– Notification for landslides and condition of endangered infrastructure (settlements, roads, railways, bridges, dams) to the Administrator level (Level 1).

– Analysis of results from annual reports issued by Level 1, adjusting and adopting strategies for management of landslides.

– Brief the eventual danger to the population and undertake measurements predicted with remediation programs.

– Informing of the population for lowering of vulnerability of their property and goods.

– Monitoring of active and remediated landslides.

– Issuing alerts/alarms, prohibitions and restrictions in case of foreseeable danger.

Level 3 – Companies from the field of geotechnics and geology:

– Notification for landslides to the Administrator level (Level 1).

– Performing of geological and geotechnical investigations according adopted strategies from higher levels.

– Preparation of technical documentation (subject of revision) and entering data in the database.

– Monitoring of active and remediated landslides.

– Suggestions to the higher levels from different aspects.

Level 4 – Subjects performing field activities (companies from civil engineering, road construction, water supply and sewage systems, electrodistribution and telecommunications, etc.).

– Notification of landslides to all higher levels, to Level 1 as priority, including rock falls on roads, instabilities on agricultural surfaces, deformations of housing units, damages of water supply systems, telecommunication cables, deformed sewage pipes and others as result of landslide.

– Notification of landslides during civil engineering activities.

– Following issued recommendations and restrictions for construction.

– Respecting issued orders for prohibition of construction in areas defined as with high landslide hazard.

– Communicating landslide information with companies in the same field of work.

Level 5 – Other subjects and the population:

– Notification of landslides to Levels 1 (as priority), 3 and 4, including rock falls on roads, instabilities on agricultural surfaces, deformations of houses etc.

– Following recommendations and restrictions issued by higher levels.

– Following recommendations for lowering of vulnerability of property and goods.

– Respecting issued orders for prohibition of construction in areas defined as with high landslide hazard.

– Respecting issues, alerts/alarms and orders in time of foreseeable danger.

PROPOSITION FOR ADMINISTRATOR OF THE LANDSLIDE DATABASE (LEVEL 1)

Following the example of other European countries, as a possible administrator (governmental body on landslides) the Geological Survey of R. Macedonia is suggested. The GIS database which will be prepared and managed by this institution will enable easy access to landslide data from all users, and depending on the authorization that they have (Levels 2, 3, 4, 5). All landslide data will be entered in a special module of the existing Geological GIS Database. This module will be named Landslide database of Macedonia. All relevant data which are transmitted from the lower levels will be checked and entered in the database. Also Levels 2 and 3 will have possibility to enter some data directly into the database, without notification to Level 1.

Other possible administrators can be chosen among the Agency for Spatial Planning, Crisis Management Center, Ministry of Environment and Urban Planning, or other. Also the landslide database can be integral part of some other GIS based geohazard portal.

CADASTRE SHEET FOR LANDSLIDES

All registered landslides, regardless of the level of user that enters the data in the database administrator, are essential to be defined with a number of basic and detailed attributive information and parameters according appropriate landslide classification. In European countries' GIS landslide databases, level of details for landslide occurrences differs in many aspects. Some countries have prepared landslide cadastre sheet for each of the occurrences. Based on performed comparisons between them, the data format presented on the cadastre sheet of the Italian landslide database IFFI is considered as the best structured model for data recording in the GIS database. Having this in mind, based on the form of the IFFI landslide datasheet, a somewhat modified version is proposed for the needs of the Macedonian GIS based landslide database. Data of the landslide cadastre datasheet is divided in five sections (appendix) (Guerrieri, L. et al. 2007):

Section 1: Basic information, Location, Date of last activity, Geometry of landslide, Geological setting, Land use, Exposition, Hydrogeology, Springs and their capacity, Movement rate.

Section 2: Classification according landslide mechanism (Varnes and Cruden 1996), Triggering Factors, Landslide Precursors.

Section 3: Damage to Structures and Natural Terrain, Performed Studies and Investigations, Undertaken Remediation Measures.

Section 4: Graphical Presentation of the landslide (geological/geotechnical maps and profiles), with geotechnical parameters of rock masses.

Section 5: Data for vulnerability of people and goods, calculations of damage and expenses for investigations and remediation works, photo-documentation, etc.

Depending on the expertise, the subject that notifies for registered landslide (from levels 2, 3, 4 and 5) enters via internet all known data for the landslide. When Level 1 see this change, it issues a decree to Level 3, after which expert team goes in the field and collects all available data on the occurrence. All data is then reentered in the database. The team can also suggest further investigations or/and monitoring of the occurrence.

LANDSLIDE CLASSIFICATION

Different scientists have treated the classification of landslides, and there are over 200 different landslide classifications at present. As most important, publications of Savarenski, F. P., (1935); Harpe C. F. S. (1938); Terzaghi K. (1950); Varnes D. J. (1978); Cotecchia (1978); Janić M. (1979); Zolotarev G. S. (1983); Hansen, M. J. (1984); Hutchinson (1988); IAEG (1990); Cruden D. M. (1991); Flageollet J. C. (1994); Cruden D. M. и Varnes D. J. (1996); Dikau R. et al. (1996); Soeters R. and Van Westen C. J. (1996); Hungr O. (2001); WP/WLI (1993a,b) and (1995); Augusto F. (2004) are mentioned. In this context the most widely accepted classification by Cruden and Varnes from 1996 is suggested to be used (Figure 4).

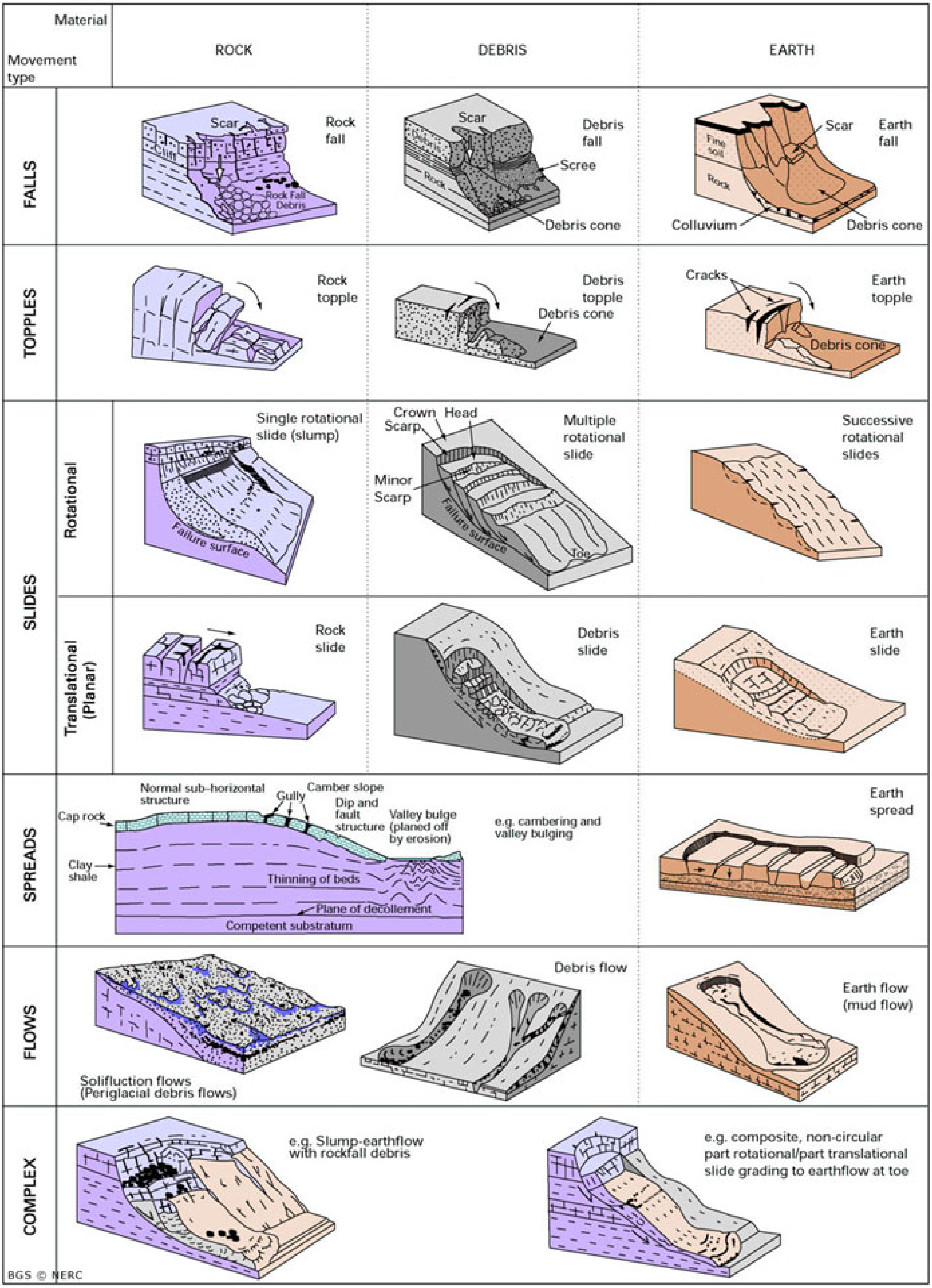

Fig. 4. Landslide classification after Cruden and Varnes, 1996 (Taken from the web page of British Geological Survey)

MAIN BENEFITS FROM LANDSLIDE DATABASE

Landslide databases enable easy analysis and view of all of landslide properties in some region. Later, this information can be used in preparation of methodologies for landslide susceptibility and hazard zonation. In this context, in period 2011–2014, an attempt is made to collect all written existing information on landslides in R. Macedonia when data such as location, geological settings, failure mechanism, depth of landslide, geomorphological conditions, hydrogeological conditions, seismotectonical conditions etc. for over 250 landslides was collected. All data is entered in a GIS system and the resulting GIS Inventory map of the country was prepared (Figure 5).

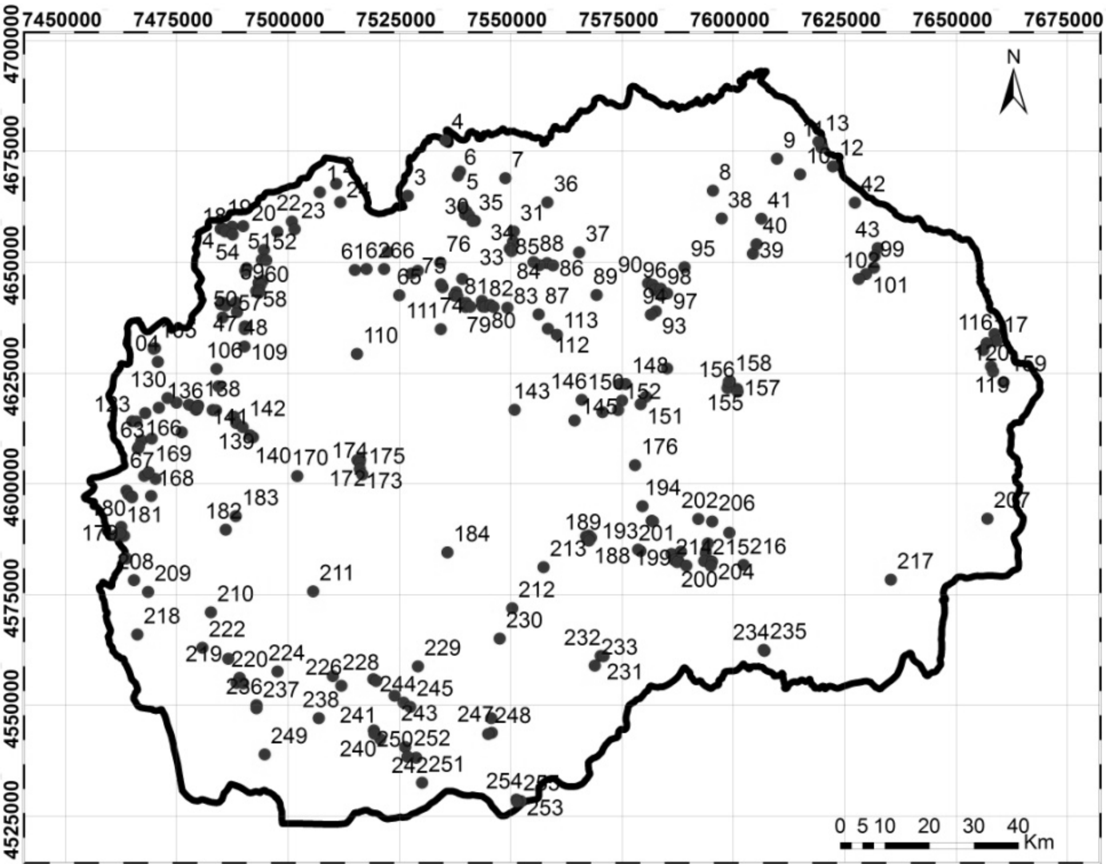

Fig. 5. Landslide inventory map of the Republic of Macedonia, Peševski 2014

If we take a close look on the inventory map, it gives a first clue of where future landslides are to be expected for the given territory. From here, regions of interest (so called landslide prone areas) can be selected for further landslide susceptibility or landslide hazard analysis. This is the main goal and benefit which can be drawn from the existance of landslide database – inventory map.

For example, by application of world accepted mapping techniques, a landslide inventory map for a selected region (Polog–Reka) in R. Macedonia was prepared. The mapping techniques included using of GIS system and remote sensing technics for landslide identification. Orthophoto images (black & white and coloured), topographic maps, geological maps, topographic DEM in scale 1:25 000, the GIS portal of the Agency for Real Estate Cadastre, etc., were used as sources for landslide detection. There total of 1172 landslides were mapped. Resulting inventory map is presented on Figure 6.

Then, by using of a so called arbitrary – polynomial method (Peševski 2015) which takes into account several landslide casual factors: lihological type, slope inclination, precipitation, seismic intensity and land use and their appropriate gradation, landslide susceptibility map of the same region was prepared. Interested readers can find more details for this methodology in Peševski 2015.

With the applied approach and by means of matematical calculations performed by help of the GIS system, the Polog–Reka region is divided in 5 zones of landslide susceptibility: very low, low, medium, high and very high. Knowing the possibilities of the GIS programs, statistical analysis of different character can be performed.

With overlap of the landslide susceptibility map and the prepared inventory map, conclusions can be made for the number of past landslides in each susceptibility zone. Obtained results are given in Figure 7 and Table 1.

It is obvious that even from the most basic landslide database prepared by using of remote sensing for landslide identification, relatively good conclusions can be made when selecting of landslide casual factors. This is important for prediction of future landslide development in region and helps in decision making for application of best suitable methods for landslide susceptibility and hazard assessment.

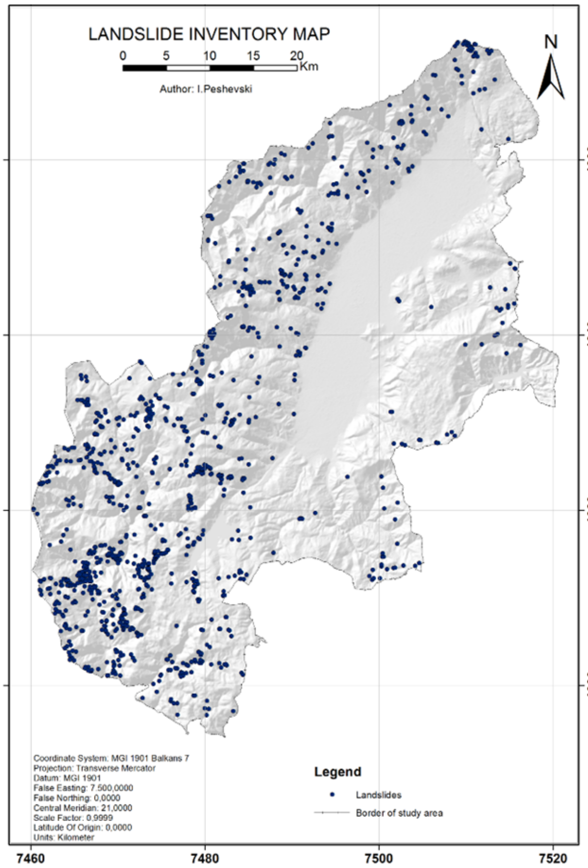

Fig. 6. Landslide inventory map of Polog–Reka region

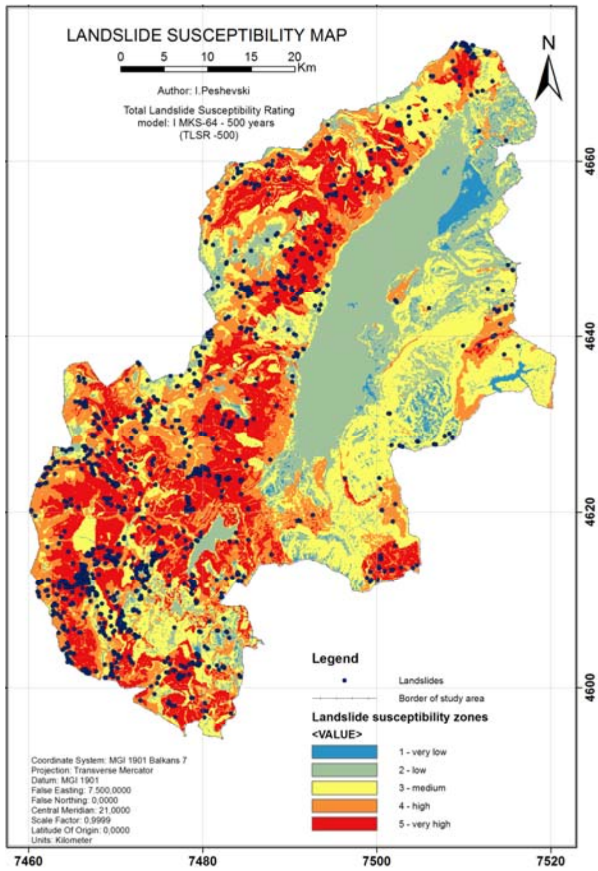

Fig. 7. Landslide susceptibility map of Polog–Reka region

T a b l e 1

Landslide susceptibility classes for Polog– Reka region obtained using arbitrary – polynomial method

Landslide susceptibility	Area (km^2)	Area (%)	Landslides	Landslides (%)
1 – Very low	101.06	4,17	2	0,17
2 – Low	508.87	21,02	24	2,05
3 – Medium	733.49	30,3	244	20,82
4 – High	538.42	22,24	323	27,56
5 – Very high	539.05	22,27	579	49,4
Total:	2420.9	100	1172	100

CONCLUSIONS

Striving towards better management of geohazards, the establishing of GIS landslide database in R. Macedonia is one of the essential steps which should be undertaken in near future. The proposed database will enable preparation of maps for landslide susceptibility, hazard and risk which will help institutions to better cope with this type of geohazard. Conditions for faster reaction and alert issuing to population will be more realistic, with on-time undertaking of remediation measures or prevention of landslide, real-time monitoring of landslides, and precise assessment of the damage on the infrastructure and consequences to the people and their goods. The GIS database will enable updating, elaboration, searching and interactive connection of all landslide data in cartographic, tabular, alphanumerical and photographical form, and it will enable refreshing of data as a result of formerly collected information. The database is envisaged as dynamic, easy to use and available via internet for all governmental institutions and the wide public.

APPENDIX:
LANDSLIDE CADASTRE DATASHEET FOR THE PROPOSED GIS LANDSLIDE DATABASE IN THE REPUBLIC OF MACEDONIA

LANDSLIDE DATABASE OF THE REPUBLIC OF MACEDONIA

Alphanumeric code in the database: _XXXX_	ID number of landslide _XXXX_
Basic data	**Last change** 10.01.2012
Date of first report 06.09.2011	Coordinates X: _XXXXXXX Y: _YYYYYYY
	Region XXXXX / Municipality XXXXXX
Report issuer: Faculty of Civil Engineering-Skopje	
Topographic map: Yes / Scale 1:1000	Locality XXXX

Geometry		**Position on slope** crown		ножица
Crown elevation (m) 341	Azimuth of movement direction α (°) 79	☐	Ridge	☐
Toe elevation (m) 320	Area A (m^2) 24500	☐	Upper	☐
Horizontal length L_0 (m) 70	Width La (m) 350	√	Middle	☐
Height difference H (m) 21	Volume of slide material V_l (m^3) 539000	☐	Low	√
Slope angle β (°) 7- 25	Depth of sliding surface D_l (m) 22	☐	River valey	☐

Geology

Geological unit 1 Soil debris	Geological unit 2 Marlstone		1 2 Lithology ☐ ☐ limestone ☐ ☐ travertine ☐ √ marl ☐ ☐ flysh ☐ ☐ sandstone ☐ ☐ schists ☐ ☐ acid extrusive rock ☐ ☐ basic extrusive rock ☐ ☐ pyroclastic rock ☐ ☐ acid intrusive rock ☐ ☐ basic intrusive rock ☐ ☐ metamorphic rock ☐ ☐ evaporite ☐ ☐ sedimentary Si rock ☐ ☐ conglom. or breccia √ ☐ debris ☐ ☐ gravel ☐ ☐ sand ☐ ☐ silt ☐ ☐ clay ☐ ☐ mixed soil ☐ ☐ artificial fill ☐ ☐ other
Description 1 Silt clay with presence of sand fraction, low plasticity	Description 2 Light brown marlstone, fractured with closed fractures in depth		
Discontinuity 1:	Discontinuity 2: Azimuth / dip angle 79/ 22	1 2 Type of bedding ☐ ☐ horizontal ☐ ☐ dipping in slope ☐ √ obliquely to slope ☐ ☐ dipping downslope ☐ ☐ with dipp larger than slope ☐ ☐ parallel with slope	
1 2 Structure of rock mass ☐ ☐ massive ☐ √ stratified ☐ ☐ low fractured ☐ ☐ fractured ☐ ☐ very fractured ☐ ☐ schistose ☐ ☐ vacuolar √ ☐ chaotic ☐ ☐ caverns	1 2 Geotechnical classification ☐ ☐ rock ☐ ☐ rock material ☐ √ weak rock ☐ ☐ degraded rock ☐ ☐ well bonded soil ☐ ☐ bonded soil ☐ ☐ weakly bonded soil ☐ ☐ coarse grained soil ☐ ☐ dense grained soil √ ☐ loose grained soil ☐ ☐ organic sediments ☐ ☐ mixed soil ☐ ☐ alternating beds ☐ ☐ melange	1 2 Weathering ☐ ☐ fresh rock ☐ ☐ slightly weathered ☐ √ medium weathered ☐ ☐ strongly weathered √ ☐ completely degraded	
1 2 Distance between joints ☐ ☐ very large (>2m) ☐ ☐ large (60cm-2m) ☐ √ medium (20cm-60cm) ☐ ☐ low (6cm-20cm) ☐ ☐ very low (<6cm)			

Land use	**Exposition**			
☐ urban areas ☐ annual crops ☐ forested area √ no vegetation ☐ mining areas ☐ permanent crops ☐ woodland ☐ bush ☐ arable land ☐ riparian vegetation ☐ forest trees ☐ pastures	☐ N ☐ NE	☐ E √ SE	☐ S ☐ SW	☐ W ☐ NW

Hydrogeology		**Classification**		
Surface waters ☐ absent ☐ stagnant √ diffuse runoff ☐ concentrated runoff		☐	1 2 Type of landslide ☐ ☐ fall ☐ ☐ topple	1 2 Speed of movement ☐ ☐ extremely slow (<5*10^{-10} m/s) √ √ very slow (<5*10^{-8} m/s) ☐ ☐ slow (<5*10^{-6} m/s) ☐ ☐ moderate (<5*10^{-4} m/s) ☐ ☐ rapid (<5*10^{-2} m/s) ☐ ☐ very rapid (<5*10 m/s) ☐ ☐ extremely rapid (>5 m/s)
		☐	☐ ☐ rotational slide √ √ translational slide	
Springs ☐ absent √ diffuse ☐ concent.	GWL ☐ absent √ free water table ☐ artesian	☐	☐ ☐ lateral spread	
		☐	☐ ☐ slow earth flow	
		☐	☐ ☐ rapid earth flow	
		☐	☐ ☐ sinkhole	
springs (4)	depth. (m) 6-12	☐	Complex slide	Note Speed of movement varies in time, inclinometers for monitoring are installed
Note Runoff of is from 0.2 to 1.0 l/sec		☐	Deep seated landslide	
		☐	Area affected by rockfalls	
		☐	Area affected by topples	
		☐	Area with shallow landslideso	

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Activity

State				Distribution		Style
☐ active ☐ reactivated ☐ suspended	√ dormant	☐ stabilized √ supported artificially ☐ abandoned	☐ relict	☐ moving ☐ retrogressive ☐ widening ☐ enlarging	☐ advancing ☐ diminishing √ confined	☐ single ☐ complex ☐ composite √ multiple ☐ succesive

Date of last observation of movement	10.1.2012

Source of information: ☐ newspaper, ☐ publication, √ witnesses, ☐ videos, ☐ archives, √ mapping, ☐ remote sensing, ☐ historical documents, ☐ other

Causes for landslide activation

Terrain-soil-rocks		Geomorphology	
☐ weak plastic material √ sensitive material ☐ weathered material ☐ shared material ☐ fractured material ☐ adversely oriented mass discontinuities, bedding, schistosity	√ adversely oriented structural discontinuities ☐ contrast in permeability ☐ contrast in stiffness	√ tectonical uplift ☐ volcanic uplift ☐ glacial rebound ☐ fluvial erosion of slope toe ☐ wave erosion of slope toe ☐ suffosion	☐ glacial erosion of slope toe ☐ erosion of lateral margins √ loading or unloading of toe or crest ☐ vegetation removal
Physical		**Manmade**	
☐ intense, short rainfall √ prolonged period of rainfalls ☐ rapid deep snowmelt ☐ rapid drawdown ☐ rapid GWL rise	☐ weathering due to freeze and thaw ☐ thermoclastism ☐ decomposing due to swell or shrink ☐ physical-mechanical weathering √ earthquake ☐ dam breaking	√ excavation in any zone of a natural slope ☐ loading of slope of crest ☐ drawdown of reservoirs ☐ reservoir level rise ☐ irrigation ☐ crop type and tillage methods ☐ poor maintenance of drainage systems	☐ water leakage from sewage or water supply systems ☐ deforestation ☐ mining (open pit) ☐ mining (underground) ☐ damping of loose material ☐ vibrations ☐ performing cuts in the terrain

Precusory signs

√ fissures, cracks √ local settlement, micro-relief forms ☐ local rockfalls ☐ swelling	☐ slope reversed ☐ subsidence √ new ckracks in structures ☐ creaking of structures	☐ tilting poles or trees ☐ appearance of springs ☐ disappearance of springs ☐ disappearance of water courses	☐ change of water flow averages ☐ sudden change of GWL in wells ☐ pore water pressure in soil ☐ underground noises

Damage n.d. (not determined)

☐ direct ☐ collapse into reservoir ☐ water course blockage ☐ blockage and landslide dam break ☐ artificial dam break

Persons ☐	☐ deaths no	☐ injuries no.	☐ evacuated no.	☐ at risk no.
Structures √	☐ private no. 5	☐ public no.	☐ private at risk	☐ public at risk
Cost (MKD denars)	Assets	Activities	Total	

Investigations		**Remedial measures**		
Technical reports √ reports for location √ geological report	☐ preliminary design ☐ basic design	Earthworks ☐ profiling ☐ reduction of load in crest √ support of toe ☐ restriction	Drainage √ surface drainage √ drainage trenches ☐ drainage wells ☐ sub horizontal drainage ☐ drainage tunnels	√ hydrological modifications ☐ foresting ☐ grass seeding ☐ selective cutting ☐ live fascine, live wattle fences ☐ check dams ☐ river protection ☐ reinforcement ☐ dowels, bolts ☐ ties, anchors ☐ block strapping ☐ grouting ☐ micropiles
Investigation and monitoring √ geological boreholes √ geotechnical lab tests √ hydrogeological investigations √ geoelectrical investigations √ surface seismic investigations ☐ down-hole and cross-hole seismic investigations ☐ penetrometer ☐ pressuremeter ☐ vane test	√ inclinometers √ piezometers √ crack measurements ☐ extensiometers ☐ clinometer ☐ settlement gauge ☐ micro-seismic network √ geodetic monitoring √ hydro-meteorological monitoring ☐ others	Support ☐ gabions ☐ walls ☐ bulkheads ☐ piles ☐ reinforced soil	Protection ☐ mesh ☐ shotcrete ☐ embankment ☐ dithcs ☐ constructions	
		Damage mitigation ☐ consolidation of buildings	☐ demolition ☐ evacuation	

Cost of so far performed investigations (MKD denars) 500 000	Planned fund for performed investigations and remedial measures (MKD denars)	Total cost of performed investigations and remedial measures(MKD denars)

Literature

Author	Year	Title	Report/Book/urnal	Published by	No.	pages

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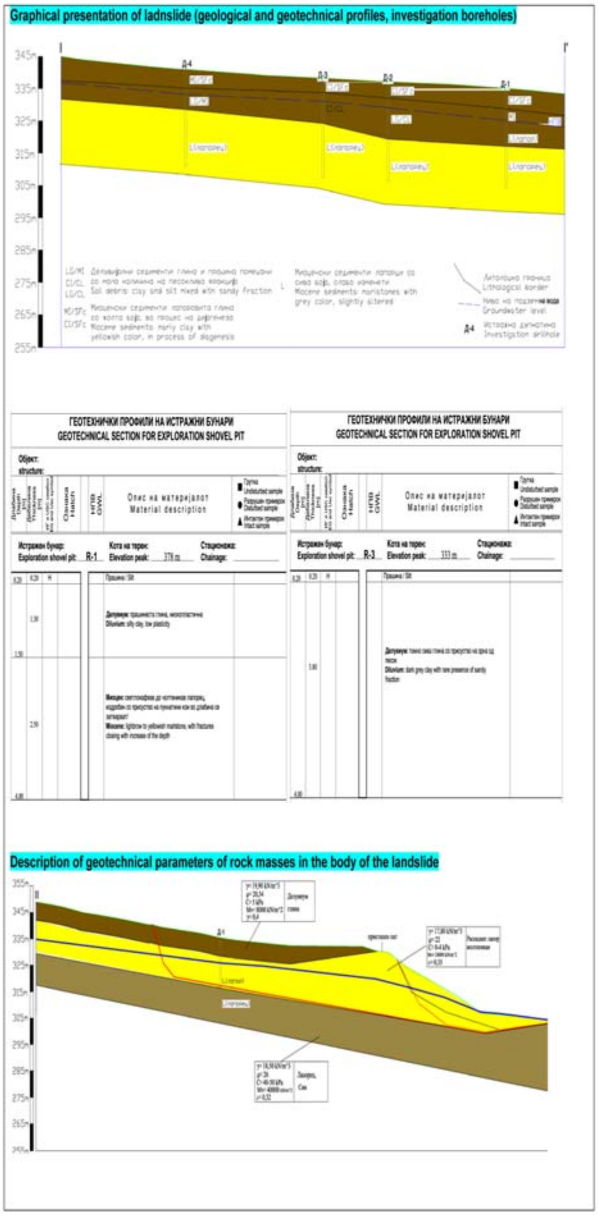

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Detailed information for vulnerability of infrastructure and population

In the locality there are five individual houses with small additional rooms for storing goods (garages). Structures are funded in the diluvia material in which the terrain with more favorable geotechnical properties. Structures are funded on concrete slabs and beams with average height of 50-60cm and percentage of reinforcement of 1-2%. Houses are two stories high, and two of the houses have also basement. An average square of each house is around 300m^2. Additional rooms (garages and shed for storing woods) take in total 100 m^2.
Around 2000 m^2 are covered with vine tries and around 400 m^2 are covered with fodder.
In the area of the landslide, there is a main pipeline for water supply of population of 2000 citizens in near settlement. Four poles for the electrical distributive network are funded in the zone of landslide. This line supplies the aforementioned 2000 citizens with electricity. There are two streets with total length of 140m and average width of 3.5m.
In the individual houses, there are 3 persons occupying the hours 14 hours a day. And additional there are other 5 persons which are in the houses around 2 hours a day. People are present at the houses in the period between 17.00 and 07.00h.

Detailed description of damage and cost of undertaken remedial measures

In the period of registration of the landslide until 10.1.2012 on three of the structures longitudinal cracks are noted on the masonry walls and small deformations of the foundation beams. Significant deformation is noted on one support wall which is long 30m, and rotates in the base. Other damage on the structures isn't noted. In one of the vineyards there is a big fracture which is now closed (filled with local clayey material). After performing of the geotechnical investigations, a design for remediation is prepared. Designed measurements are realized. A drainage "roundabout" channel is performed, a drainage channel in the form of "fish bone" in the lower part of the landslide, and support of the toe with embankment of coarse grained material. Detailed information for performed remediation works, quantities, layout etc. can be found in the appropriate design.

Cost of undertaken geotechnical investigations until 10.1.2012 is 500 000 MKD denars.

Cost of undertaken remedial measures until 10.1.2012 is 10 000 000 MKD denars.

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Р е з и м е

МОДЕЛ ЗА ВОСПОСТАВУВАЊЕ И УПРАВУВАЊЕ НА БАНКА НА ПОДАТОЦИ ЗА СВЛЕЧИШТА ВО РЕПУБЛИКА МАКЕДОНИЈА

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Клучни зборови: GIS банка на податоци; свлечишта; модел; структура; управување

Свлечиштата се еден од најзначајните геохазарди во Република Македонија. Од поголем број причини, прибирањето на податоци за свлечишта во минатото генерално се одвивало несистематски. Знаејќи го фактот дека во иднина ќе се појавуваат нови свлечишта, во трудот е предложен модел за воспоставување и управување на на-

ционална ГИС-банка на податоци за свлечишта. Прикажан е модел за воспоставување/задолжување на државен орган за свлечишта, како и структурата и начинот на функционирање на предложената банка на податоци. За споредба е даден краток осврт на банките на податоци за свлечишта во земјите од Европа. Постоењето на национална банка на податоци е основен чекор кон создавање услови за подобро разбирање на опасноста од свлечување. Со банката на ГИС-податоци ќе се создадат услови за одредување на најзагрозените подрачја и селекција на најсоодветни модели за зонирање на опасноста и ризикот од лизгање на земјиштето. Како резултат, просторното планирање со текот на времето ќе биде сè поефикасно, а повредливоста на луѓето и добрата ќе бидат намалени. Во овој контекст се прикажани и некои резултати од скоро спроведени студии поврзани со процена на подложноста на теренот на свлечување.